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A Capture & Access technology to support documentation and tracking of qualitative research applied to HCI

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Thesis presented to the Programa de Pós-Graduação em Informática of the Departamento de Informática, PUC-Rio as partial fulfillment of the requirements for the degree of Doutor em Informática.

Advisor: Prof. Clarisse Sieckenius de Souza

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Abstract

Brandão, Rafael Rossi de Mello; de Souza, Clarisse Sieckenius (Advisor). **A Capture & Access technology to support documentation and tracking of qualitative research applied to HCI.** Rio de Janeiro, 2015. 153p. Doctoral Thesis – Departamento de Informática, Pontifícia Universidade Católica do Rio de Janeiro.

Tracking and exposure of qualitative methodology procedures is a problem observed in the scientific community. The traditional form of research publication makes it impractical to provide in detail all the decisions and evidences considered in the course of a qualitative research. To overcome this problem we propose an approach to structure all the procedures undertaken into hypermedia documents with analyses and validations, allowing its representation in a theoretical Capture & Access (C&A) model. This model enables the outlining of the research inquiry, providing semantics to allow relationship between key elements in a qualitative methodology. We discuss about five qualitative studies that guided the reasoning about the proposed model, pondering on how to register adequately the activities performed in HCI evaluations consolidating the collected data in documents used in posterior analysis sessions. Additionally, we present a proof of concept through an implementation using the C&A software infrastructure offered by the CAS Project. This infrastructure supports the recording of empirical data (text, images, audio, video, and slides), data post-processing and the generation of multimedia documents. It is possible to use tags for temporal annotation, create contexts to link data and retrieve other relevant information from the captured investigation processes.

Keywords

Capture & Access; Hypermedia documents; Qualitative methodology; Scientific inquiry

Resumo

Brandão, Rafael Rossi de Mello; de Souza, Clarisse Sieckenius. **Uma tecnologia de Captura & Acesso para suportar documentação e rastreamento de pesquisa qualitativa aplicada a IHC.** Rio de Janeiro, 2015. 153p. Tese de Doutorado - Departamento de Informática, Pontifícia Universidade Católica do Rio de Janeiro.

O rastreamento e exposição de procedimentos metodológicos qualitativos é um problema observado na comunidade científica. A forma tradicional de publicação de pesquisa torna impraticável fornecer em detalhes todas as decisões e evidências consideradas no curso de uma pesquisa qualitativa. Para superar este problema propomos uma abordagem visando estruturar todos os procedimentos realizados em documentos hipermídia, com análises e validações, permitindo a sua representação em um modelo teórico de Captura & Acesso (C&A). Este modelo permite o delineamento da investigação científica, fornecendo semântica para relacionar elementos-chave de uma metodologia qualitativa. Abordamos cinco estudos de casos que nortearam o raciocínio sobre o modelo proposto, ponderando sobre como registrar adequadamente as atividades realizadas em avaliações de IHC, consolidando os dados coletados em documentos que foram posteriormente utilizados em sessões de análise. Adicionalmente, apresentamos uma prova de conceito através de uma implementação sobre a infraestrutura de C&A oferecida pelo Projeto CAS. Esta infraestrutura suporta a gravação de dados empíricos (texto, imagens, áudio, vídeo e apresentação de slides), pós-processamento de dados e a geração de documentos multimídia. É possível utilizar *tags* para anotação temporal, criar contextos para relacionar dados e recuperar informações relevantes de processos investigativos capturados.

Palavras-chave

Captura & Acesso; Documentos hipermídia; Metodologia qualitativa; Investigação científica

Contents

List of figures

List of tables

"The more elaborate our means of communication, the less we communicate."

Joseph Priestley (1733 – 1804)

1
Introduction

Scientific research conducted through qualitative methodology comprises cognitive-intense activities, such as interpretation, association and correlation, over empirical data that describes moments, routines and problematic meanings in individuals' lives (Denzin & Lincoln, 2005). There is an inherent subjectivity in this approach, as well as in any knowledge construed by human interpretation. Moreover, qualitative researchers often cannot publicize in detail all the procedures they undertake due to space constraints in the published material. This has led to historical debates over the years with post-positivist advocates arguing against qualitative methodology characteristics, while supporters tried to convince the public about its legitimacy (Creswell, 2014). Today, there is some agreement over this approach's trustworthiness, but the traceability of qualitative inquiry still poses a challenge. Peers and general stakeholders want to acquaint and trace down the scientific development, from research questions, through analyses, validation procedures, and results achieved. This is a complex task, given that the amount of empirical data can be massive, and the decisions made during the project always convey the researcher's bias. Several authors in the literature (including Creswell (2014), Anfara et al. (2002), Yin (2009) and Blandford (2014)), argue that a detailed registration, structuring and publication of the qualitative process is essential to promote such traceability, which is needed to assess trustworthiness and scientific reputation on this form of research.

Conversely, researchers relying on quantitative methodology emphasize the collection of numerical data. They test hypotheses through statistics and data trends in search for patterns that allow prediction of phenomena occurrence and behavior. Automated analysis tools and scientific workflow systems can aid part of the research process, facilitating the researcher's inferencing. Generally, stakeholders and peers can validate the results obtained by quantitative methods replicating the elaborated scenario and reanalyzing the statistical data obtained. Qualitative researchers, however, sometimes struggle with the acceptance of their research since their results come from personal and systematic interpretation based on observations. They usually analyze empirical data collected or generated by themselves in the field, so that they are instruments of their own research. The analysis encompasses multiple forms of data, ranging from discrete media (time independent information), e.g., text notes with comments and observations, single images and binary documents, to continuous media (data with temporal relationships as an integral property), such as audio and video from observations, slide presentations, annotation tags with timestamps, and so forth. Technology able to capture, classify, and structure the activities performed in a qualitative methodology can help researchers and stakeholders interested in the research process. Potentially, this technology could support both the researcher's analysis, offering facilities to register and review observed scenarios in the field, and the scientific community, over the assessment and validation of the undertaken research procedures, as well as the exposure of the methodology employed.

The problems addressed through qualitative methodology are particularly multifaceted, since researchers explore different human perceptions that emerge from the case studied. Typically, they construct a complex representation of the problem at stake. This includes reporting multiple perspectives, identifying the diverse factors involved in a situation, and usually, the sketch of a broader picture that emerges. A visual multifaceted model of this process can help in establishing a holistic framework to facilitate the understanding of the applied approach (Creswell, 2014). The thorough registration of such rich approach demands an integrated technology capable of collecting the procedures in details, enabling the specification of relations among them and the collected data. It also should provide a way to access this information later on in an informed manner. By this means, this solution can provide a view of the holistic representation of the conducted research, supporting researchers while pondering on the course their investigation is taking and the next steps they will perform.

The use of software programs to aid the qualitative process is not new, but much of the effort found in literature falls into the analysis support category. Back in 1989, Raymond Lee and Nigel Fielding coined the term Computer-Aided

Qualitative Data Analysis Software (CAQDAS[1]), following that year's Research Methods Conference at the University of Surrey in the United Kingdom. Today, this class of tools encompasses a wide range of software solutions, with a varied set of features that support qualitative analysis over qualitative data. Common functionalities include, but are not restricted to, content searching, *coding*[2] tools (term used for categorization using *codes* or tags), querying, writing and annotation, data linking and data mapping. However, these solutions generally do not take into account data acquisition features and tracking of the applied methodology. Some may offer an audit trail, as a history of the researcher's interaction. However, the researcher has to deal with specifics of the tool throughout his investigation, and in the end, the software interface will directly shape this evidence.

Concerning the methodology registration in the quantitative studies, researchers are able to specify a complete workflow to define data collection, simulations, statistical procedures, hypothesis definition, result confrontation, and other research activities they can operate and parameterize. In fact, scientific workflow models and systems are quite disseminated at present, many solutions provide tools and script languages for quantitative researchers to be able to specify their experiment and execute automated steps, typically in a distributed infrastructure, also called grid, or cloud. However, in qualitative studies the researcher cannot foresee all the investigation process' details beforehand, given the emerging nature of such studies. When collecting data in the field, unanticipated perspectives often emerge. Thus, it is not possible to prescribe a systematic methodology to drive a qualitative study autonomously. Rather, one can only register it during or after its accomplishment, leaving a trail of evidence at the end of the process. For a comprehensive registration of these processes based on such a particularized and "volatile" methodology, comprising data collection in the field

[1] As stated by Silver & Lewins (2014), some prefer the term Qualitative Data Analysis Software (QDAS). For simplicity's sake, this work will employ the QDAS acronym (or just QDA tools) as well. Nevertheless, we recognize the original version (CAQDAS) for its roots and acceptance in various fields.

[2] The term *coding* can be misleading in the context of Computer Science because it is overloaded with multiple connotations in this field. People that perform this categorization process are also referred to as *coders*.

(i.e. outside any specific instrumented venue), we propose the use of a ubiquitous technology adequate for the recording, structuring and provision of empirical data.

The Ubiquitous Computing (UbiComp) research field aims at providing a transparent use of various computational devices dispersed in the environment (Weiser, 1993). It is a broad area of research and development in Computer Sciences, which encompasses several other areas with common interests, such as Distributed Systems, Software Engineering, Human-Computer Interaction (HCI), and Mobile Computing. This approach offers a distinctive paradigm in the use of computing devices. A particular research subtopic inside this paradigm is Capture & Access (C&A), which supports the registration and publication of a broad range of social events, backed on the use of multiple devices, including procedures carried in scientific investigations.

C&A research involves preserving (in a ubiquitous manner) the recording of a live experience (capture stage) and offering tools for processing the collected data. Usually held in controlled environments equipped with media recording devices and different sensors, it uses these devices to capture the content and characteristics of the location where a particular event occurs. As a result, C&A systems produce a structured multimedia document indexing all the registered media. People interested in the captured event can review it later on (access stage) (Truong, Abowd, & Brotherton, 2001). Thus, C&A systems allow people to keep their focus on the understanding and interpretation of the experience itself, without worrying about the information-recording task (Abowd et al., 1998). Discussions over locations where the applicability of a C&A technology is valuable generally fall into three distinct settings, workplace, personal and educational (Abowd, Mynatt, & Rodden, 2002). In workplace environments, C&A technology essentially assists the registration of meetings and teleconferences. In personal locations, C&A can support continuous registration of daily activities used for entertainment, or in health-care situations supporting patient-chart generation to assist physicians' diagnosis. Educational scenarios range from the conventional recording of classes and seminars, to registering activities in operating rooms and scientific inquiry development. In a way, C&A usage covers almost any social experience where the goal is to record information in the form of digital media.

This work investigates how a C&A technology can support the registering and structuring of scientific inquiry conducted with qualitative methodology, backed by case studies with observations of HCI experts performing qualitative evaluation activities.

Regarding scientific development in the Computer Science context, quantitative methods have had traditionally more application than qualitative methods. In fact, manipulating numbers and statistics is very close to the nature of computers. Nevertheless, in the HCI disciplines this relation changes with qualitative methods playing a key role in its development, since the subjectivity of the notion of "quality" demands the analysis and generation of qualitative data by humans (Barbosa & Silva, 2010).

HCI evaluations are essential to produce high-quality systems in the course of software development process. Evaluation methods guide HCI experts' rationale about the quality of the analyzed artifact, helping them to identify interaction and interface problems that could undermine its use. Quality criteria regarding interaction include usability, user experience, accessibility and communicability (Barbosa & Silva, 2010). One can categorize evaluations as formative or summative, considering the software development lifecycle. They are formative when held throughout the software project to assess whether the product keeps satisfying the users' needs. Evaluations are summative when conducted to verify the success of an already deployed product (Rogers, Sharp, & Preece, 2011).

One can classify HCI evaluation methods into three distinct categories (e.g., Barbosa and Silva (2010)): methods for investigation, methods for observation and methods for inspection. Investigation methods involve the use of questionnaires and interviews, focus groups, field studies, among others, to collect data to support investigating design alternatives, frequent user problems and their expectations. Observation methods aim at capturing interaction data in a real-world setting to identify user experience issues. The evaluator can observe users in the field (the place where they use the system) or in a laboratory (a more controlled environment). Inspection methods support the evaluator in the early identification of problems users are likely to have when interacting with the analyzed artifact. In general, they have a lower implementation cost because there is no user involvement, or meetings to gather opinions, nor any interactivity observations. These three categories share basic activities, such as preparation, data collection, interpretation, consolidation and result reporting. If the evaluation identifies opportunities for improvement, the result can be a redesign in the system.

The scope of this thesis extends over qualitative methodology typically used in HCI research. Specifically, this work takes HCI evaluations as case studies, targeting to explore specificities around the registration and publication of qualitative analyses from the perspective of a C&A technology, targeting to build a conceptual model to support the process. Four of the five case studies presented involve evaluations based on methods from Semiotic Engineering (SemEng).

SemEng (de Souza, 2005) is a theory of HCI, grounded in Semiotics, a discipline that studies what Peirce (Peirce, 1992) has broadly defined as everything that means something to someone (signs). SemEng theory focuses on software communicability, the ability of a system to communicate in an organized and consistent way the software design intent. From its point of view, HCI is a particular case of computer-mediated human interaction, where software interfaces are metacommunication artifacts (de Souza, 2005). The message of this metacommunication expresses the system designer's[3] understanding of who his users are and what they want, how the artifact designed by him will meet users' requirements, and how users can (and should) interact with the artifact to achieve objectives embedded in his vision. This way, the produced artifact acts as the designer's proxy that will transmit the original message to the user who interacts with it.

SemEng proposes epistemic tools associated with its theory. They do not necessarily provide a solution to the problem, but explore the problem's nature and interpretation, as well as conditions for possible solutions. The theory proposes two methods, one for inspection, the Semiotic Inspection Method (SIM), and the other for observation, the Communicability Evaluation Method (CEM). The former evaluates communicability focusing on the metacommunication message emission by the designer, while the latter assesses the metacommunication quality focusing on the metacommunication message reception by the user. Both methods are qualitative data oriented.

This work presents five case studies involving HCI evaluations based on qualitative approaches, showing their methodology characteristics and requirements to the registration of the observed procedures. The first two case

[3] The term "designer" in singular refers to a representant of the team of people who conceived and produced the software artifact the user interacts with.

studies, which we carried as preliminary assessments, comprised studies using single methods from SemEng (CEM and SIM) theory. In the third and fourth studies, the researchers applied combined methods mixing SemEng methods with the Cognitive Dimensions of Notations framework (CDNf) (Green & Blackwell, 1998; Blackwell & Green, 2003), a method that supports usability evaluation of an existing notation in an information artifact. In the fifth case study, the observed researcher carried his study as an action-research with a semi-structured approach. His goal was to investigate the deployment of a wearable assistive technology; he designed a macro-level research plan *a priori* but did not follow a detailed methodological framework to guide his observations and analysis. The first and fifth studies had user participation, the evaluation using the CEM method on a web system interface, where HCI experts observed user interaction with the system; and the investigation carried out by the researcher over the first contact of a motor-impaired user with the assistive technology that he proposed. The other three case studies had an analytical approach, without user involvement. The main goal on the case studies involving SemEng was to inspect issues concerning communicability breakdowns. It also plays a central role in the fifth case study (semi-structured action-research study), although the researcher did not apply specifically SemEng's methods. The goal of this study was to develop a configurable technology from the perspective of a specific user. The technology is meant to be configured by end-users, including caregivers and relatives without technical background. In this context, the analysis of communicability is a valuable resource to achieve an effective configuration process.

1.1. The researcher's bias

In qualitative studies, the exposure of the researcher's bias is one of various validity strategies (Creswell, 2014), since reflectivity plays a major role on this kind of methodology. The researcher's background naturally shapes his interpretations of the findings, and its clarification can help readers to understand better the results achieved and decisions made throughout his work's development. Since a qualitative methodology also guides the development of this thesis, apart from being also its very object of study, I have chosen to picture here my past professional experience in order to help clarifying my bias in this study.

Briefly, most of my professional experience has been influenced by a quantitative perspective, although the qualitative aspect has always been present as well. I currently act on different fields in academia and industry, in a multidisciplinary way, studying and working with both perspectives, from Software Engineering to Semiotic Engineering. Still, I often think that the field that best define my interests within the Computer Science is Multimedia Systems. Audiovisual content has always fascinated me and, in one way or another, this has always been present in my work as a researcher and developer. As a research area Multimedia Systems is very comprehensive, enabling us to explore different aspects, ranging from strictly technical and objective (quantitative) features like, stream encoding and data transmission techniques to distribution, middleware design and development, to cite but a few. However, it is also possible to explore subjective (qualitative) aspects of multimedia systems, such as the perceived quality of audiovisual content, or the user experience when interacting with applications on multiple devices, and so on. The latter is crucial to the success of a multimedia software project, because the best technique is of no use if the end-user experience is not satisfactory. In fact, the success of systems that deal with audiovisual media largely depends on the perception and individual reactions by spectators. How can one automatically check if an output video stream is playing as smoothly and fluidly as desired? Or, if the color perception is adequate for the current ambient lighting? How is it possible to assess audio output and check if it has an appropriate frequency response? Is it pleasing to the listener? This kind of perceived quality is fundamentally subjective. Generally, there is no way to understand how and why people reach certain quality perceptions other than by asking a user about his impressions.

I have graduated in Computer Science from the Federal University of Rio Grande do Norte (in Natal, Brazil) back in 2006. All along my undergraduate years, I was involved with academic Research & Development (R&D), working with Digital TV (DTV) middleware and interactive applications development, among other things. In my final graduation project, I developed a visual tool for building declarative DTV applications in XML (eXtensible Markup Language) through an interactive interface, whose assessment followed a qualitative approach, in a way.

During my master's degree studies at the Federal University of Paraíba (in João Pessoa, Brazil) between 2008 and 2010, I delved into the multimedia world at the Digital Video Applications Lab (LAViD)[4]. There, I have studied and worked with low-level media encoding, programming media-processing native software on embedded systems (DTV set-top-boxes), but at the same time designing high-level APIs to enable interactive application development on top of it. My dissertation was the specification of an API in Lua script language, called LuaTV. This API was targeted at extending application development with the declarative subsystem of the Ginga middleware (the standard specification for the Brazilian Digital Television System), specifying an additional set of procedural functionalities for NCL (Nested Context Language) applications. This work got my attention to an existing complementarity in software development processes. On the one hand, a software engineer must have constantly in mind the technical aspects of a software architecture, while on the other he must also attend to the design of the technology use by others in higher abstraction levels, up to the end-user. As a native code programmer and software architect, I had to interact with low-level data structures and procedures (in C language) to provide a hardware abstraction layer in the form of an API to be used by another programmer (using C/C++). This programmer (often myself) in turn, would provide another API (in Java or Lua language) to be used by an application programmer, who hopefully would create a captivating DTV app to the end user.

Over the last few years (2011-2015), during my doctoral studies at the Pontifical Catholic University of Rio de Janeiro (PUC-Rio), I had the opportunity to join the CAS Project team at the Tecgraf Institute, to work with R&D. However, at this time, I was involved in a mixture of industrial and academic R&D, in a partnership with the Brazilian oil & gas state-owned company, Petrobras. The CAS project's main purpose is to develop a flexible ubiquitous software infrastructure for C&A. This generic infrastructure aims to support the recording of heterogeneous media in different scenarios, from simple slide presentations to the registration of rich events with multiple devices and collaboration among participants. Working in parallel with this project and studying disciplines with a strong methodological basis in my doctoral course, such as the study of SemEng

[4] http://www.lavid.ufpb.br/en

(initially proposed by Professor Clarisse de Souza), sparkled the possibility of proposing a C&A technology for the registration and structuring of scientific development processes. Especially for the qualitative process, that forms the basis of SemEng's methodology, and which the scientific community often does not view as being as well-defined and consensually accepted as the quantitative research process.

I see my role in this initiative almost as an antagonist, exploring qualitative research in case studies trying to draw a better understanding from them into the quantitative atmosphere that sharply surrounds me, given my work as a software developer and the technical background I have.

1.2.
Motivation and goals

The central motivation of this work relies on the absence of adequate technological tools to keep track of the application of complex qualitative research methodologies. There are several works within the C&A community discussing the registration of a wide variety of social events, including the support for scientific inquiry activities, as stated before. However, despite our best efforts we could not find any approach specifically concerned with the registration of the methodology itself, taking into account the traceability and publication of the entire scientific endeavor as its ultimate goal. Existing QDA solutions do not focus on data capturing and methodology tracing either. These applications usually assist data structure and the analysis itself, offering tools specifically for that matter.

Furthermore, qualitative methodology depends primarily on relevant data collection, and on the researcher's expertise to map and interpret relationships among the data. These activities comprise a process that is hard to trace down if not carefully captured and essential for those who want to understand in details the decisions made throughout the whole investigation process.

The main goal of this thesis is then to explore how qualitative research can be broken down into manageable procedures, allowing for its registration and structuring down to all necessary details using C&A as technological support. Ultimately, this would lead to a comprehensible outlining of the applied procedures and the results obtained from them.

1.3. Contributions

This thesis contributes to different areas of Computer Science, in particular to C&A as a subtopic within the Ubiquitous Computing and to Scientific Methods used in technical and theoretical research in HCI and related areas where user studies are called for.

The discussion about issues involved in data collection, data relations and disclosure in qualitative inquiry attempts to shed a little more light over this historical issue, often faced by the Scientific Methodology community. A detailed examination of these intricate issues promotes knowledge creation, an inherent characteristic of qualitative research itself, which relies on multiple views of a single topic to gain a better understanding of the addressed problem and the generation of possible solutions for it.

The primary contribution of this thesis is our proposal of a conceptual model with which to analyze and characterize how existing C&A tools can aid the systematic registration and publication of a scientific process achieved through qualitative methodology. A model of such nature has to consider not only the capture and management of empirical and documentary data but also the indexing of analysis and validation procedures, along with a relational semantic to allow for qualifying the correlation between them.

A reification of the proposed model promotes an overview of the process, enabling practical navigation among relevant aspects in the registered procedures. In addition, it eases the association between the research questions and achieved results. This study presents a proof of concept of this reification through a prototype implementation, using a C&A software infrastructure provided by the CAS (Capture & Access System) Project (Brandão, et al., 2013). A project developed in partnership between the Tecgraf Institute[5]/PUC-Rio and Petrobras. The construction of an integrated solution designed to assist qualitative data capturing, processing, and methodology exposure is a relevant aspect of this prototype.

The proposed C&A model, along with the prototype implementation supporting the structuring and recording of HCI qualitative procedures can also support education in HCI disciplines. The use of qualitative methods is less mature

[5] http://www.tecgraf.puc-rio.br/en/

in HCI, when compared for example, to its use in the social sciences. Thus, there is still controversy and uncertainty when and how to apply such methods, and how to report findings (Blandford, 2014).

To sum up, this work explores the registration of qualitative analyses based on HCI evaluations in a series of case studies, through the perspective of a ubiquitous C&A technology. The main use of such explorations has been to outline a conceptual model, based on activities observed in the studies and over aspects of the qualitative research design literature, to guide the registration of this type of scientific inquiry. We named this model C&A4Q, a Capture & Access for Qualitative research model. In addition to this model, we present a proof of concept implementation through customized software components on top of the CAS infrastructure to support the tracking process. Figure 1 illustrates the context surrounding this study and its main contributions.

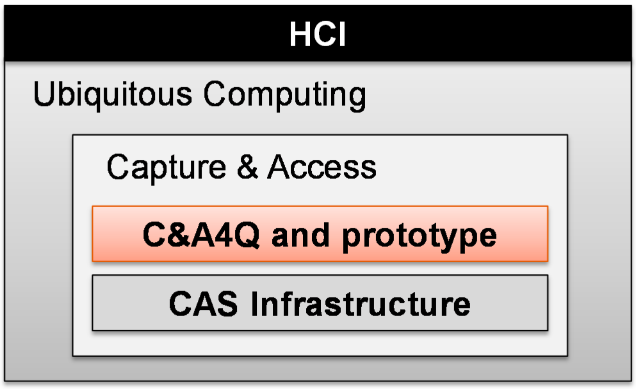

Figure 1 – The context surrounding the work presented in this thesis.

1.4. Methodology

The qualitative approach has a dual role in this work. Besides being its object of study, this methodology has also guided our own research process. We conducted a series of case studies, including preliminary and further consolidation studies, in order to identify relevant elements in the qualitative process applied to HCI that may be also suitable to other fields. These studies enabled us to ponder on different aspects to achieve a well-informed inquiry process. This research experiments with the registration and structuring of methodological aspects supported by digital media in hypermedia documents. The choice for this approach as this study's methodology is natural, given its innovative and exploratory nature.

We defined an iterative methodology for this work, with activity cycles for each of the case studies. These studies involved the observation of qualitative HCI evaluations by experts of the Semiotic Engineering Research Group (SERG), from PUC-Rio. Preliminary studies served as a proof of concept to assess the feasibility of the infrastructure provided by the CAS Project in the registration of qualitative scientific events. Such activity cycles were intended to identify common procedures in the qualitative approach and requirements for a C&A software implementation to support the documentation of these procedures. The identification of relevant procedures to conduct and expose this type of research promoted the development of a conceptual model for registration and publication of qualitative studies. Conversely, the identification of software requirements led to the development of software components that contributed to broaden our knowledge about aspects necessary for the development of C&A tools in this context.

The activities in the applied methodology followed a sequential flow, starting with the definition of the investigated scenario. In each cycle, we defined the configuration of the case study, including the characterization of the participants involved, the location and the qualitative method we wanted to observe and register. For each of the observed methods the investigation yielded different configurations.

In these studies, data collection consists of a detailed registering of the observed qualitative evaluation activities. The registered information includes user interaction with software artifacts, verbal protocols, externalized attitudes, files, annotations, among other information captured in digital media. During this data collection, a preliminary analysis took place in parallel, since the interaction of experts with the tool used for media recording (CAS control panel) is of particular interest for this study.

After a detailed registration of the evaluation activities by HCI experts, the next step is the generation of hypermedia documents comprising all the captured media. These documents must reflect accurately the captured procedures, so experts can interact with it and carry out their analyses. All the media is structured and indexed in a way that enables a temporally consistent navigation.

The creation of such hypermedia documents is a key aspect of this study's methodology, since the interaction between specialists and documents is a relevant part of the analysis of this study. Registering this interaction in a further document (a new document depicting their interaction with the previous document), allows for an analysis of the document's layout elements. That is, firstly, we provide a document with the captured media of the expert's evaluation. Afterwards, we create another document reflecting the experts' interaction with the evaluation document (initial document). This study then benefits from observations and analysis of the experts' interaction with the tool used for capturing their evaluation, as well with the generated document. During the case studies cycles, we tested different layout elements based on identified requirements. The creation of such layouts evolved through experimentation. Later on, we integrated some of these layout features into a component for document generation in the CAS Project.

A risk associated with this study comes from the author's bias that has a strong background in software development, since this study demands a multidisciplinary approach involving aspects of both qualitative research design and software implementation. We have defined validation strategies so that the development perspective does not dominate this study. In other words, several procedures are targeted to minimize the possibility of excessive focus on the implementation at the expense of fundamental aspects of the qualitative research foundations and practice.

Furthermore, these strategies enhance the internal validity of the study. We performed comparison between the different cases (triangulation), the confirmation of findings with participants of the studies (member-checking) and with external peers through advising meetings (peer review) and various presentations in SERG weekly seminars (result presentations) for feedback.

As a result, this study provides a thick description hoping to communicate a holistic picture of the experiences about the registration of qualitative procedures. To this end, this work offers a textual report with the challenges we encountered, along with a sampling of the hypermedia documents we generated during the research activities. Hence, we hope to provide a lens through which interested parties can get acquainted with the details of this study. Figure 2 shows an overview of the iterative methodology defined for this study, along with the defined validation strategies to ensure internal validity and minimization of associated risks.

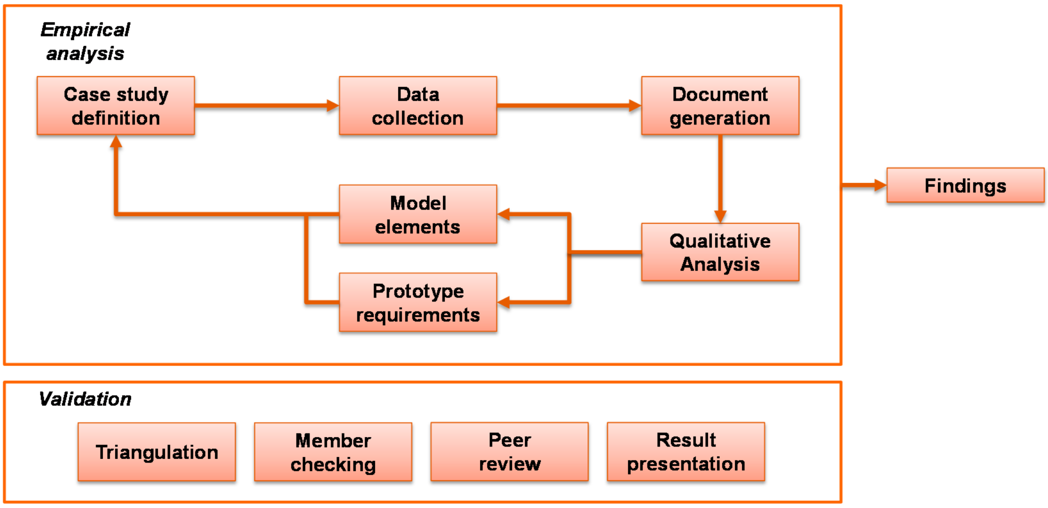

Figure 2 – Overview of the iterative methodology applied in this study along with validation procedures.

1.5. Thesis organization

This thesis is organized as follows, Chapter 2 discusses the general characteristics of qualitative research and how it is distinct from the quantitative approach. It presents an overview of the types of data typically collected, the theoretical perspectives and analysis process conduction, and validation procedures to ensure the quality of the scientific inquiry.

Chapter 3 presents the current dominating technological approach to support qualitative research, the provision of QDA tools. This chapter brings an overview and the general features of some of the key tools found in the literature. In addition, it presents works in the research design literature aiming at the structuring and conduction of qualitative studies. This chapter also touches on scientific workflow models in the e-Science context, which are analogous works targeting to support scientific development structuring within the quantitative approach.

Chapter 4 outlines the C&A research topic inside the UbiComp, presenting a brief discussion on its basic concepts, its applicability, and how such concepts can support activities carried out on qualitative research studies. Additionally, this chapter presents the CAS project, an initiative aimed at providing a distributed C&A software infrastructure for the registration of various types of media and events across different settings. This infrastructure served as a test-bed and based the development of a proof of concept implementation to support and register qualitative research, in the HCI evaluation context.

Chapter 5 covers five case studies conducted during the development of this thesis, from which we observed specificities and requirements for an adequate structuring of the analyses, enabling a subsequent access in an organized and well-informed manner. Qualitative approaches guided the registered evaluations, four of them based on explicit methods, and one of them with a more flexible and constructive structure, not following a specific methodology. In addition, this chapter presents details of the proof of concept implementation that supported the case studies and evolved with requirements identified in them.

Chapter 6 presents the main result of this thesis, the C&A4Q model: a conceptual C&A model to support documentation and traceability of qualitative research (with evidences from case studies' findings and from Scientific Methodology literature supporting its design). The model highlights relevant aspects in the registration of qualitative procedures, the sequentiality involved in them, the access to the data and how researchers can used it to support an abductive reasoning process.

Chapter 7 concludes this thesis presenting a brief wrap up of our vision about the potential of the proposed technology. In addition, this chapter brings future work on both the proposed model and proof of concept implementation, with a draft of features that could further extend this work.

2
Qualitative research

This chapter outlines key concepts and elements of qualitative research and the main theoretical perspectives used in this approach. Additionally, it covers some of the strategies applied for validation and quality assessment in this type of methodology, along with the possibility of generalizing its results. Finally, this section discusses features that distinguish qualitative approach to quantitative approach and briefly examines how they can be combined into a mixed methodology.

Qualitative research involves collecting and analyzing a myriad of empirical materials registered in different media such as, audio, video, images, texts, diagrams, interactive and visual materials, software artifacts and so forth. This data may represent different moments and situations including, observations, interviews, interaction with artifacts, case studies, personal experiences, introspections, descriptive narratives, history and other. According to Denzin and Lincoln, these materials often describe "routine and problematic moments and meaning in individuals' lives" (2005, p. 3). Through this variety of empirical materials, qualitative methods explore behaviors and processes targeting to develop an interpretive framework to aid the understanding of new phenomena (Leitão, 2009). Such methods involve cognitive intense activities such as, interpretation, association and correlation of data by researchers, which must assign meaning and categories to these data iteratively in a process sometimes called segmented analysis. Frequently, qualitative analysis is said to be a bottom-up approach, where researchers go from data (from particular cases or instances) trying to develop a theory or broad explanation (a general case), which can be further evaluated with qualitative or quantitative methods. In addition, qualitative research allows for other uses of the theory, as discussed in next section. In such a subjective approach, software tools generally can only assist on data manipulation, leaving the researcher in charge of all data collection and analysis process. Since the researcher collects data by himself, he becomes an instrument of his own research.

Reflexivity plays a central role in qualitative inquiry. Researchers are an important part of the process because they directly shape the study. Their bias and backgrounds may influence research design and analysis, to a greater or lesser extent depending on their awareness and purposes in the study. In part, this may also be the case with quantitative studies or any other scientific procedure. However, qualitative research specifically encompasses an interpretive process by researchers. Throughout the qualitative analysis, they have to examine all collected data, trying to make sense from the evidence. They categorize parts of data by classifying them in themes (or categories), creating a coding scheme. In other words, subjectivity from researcher's interpretative activities permeates through the entire qualitative process. Given this building on subjective concepts in addition to the process' emerging trait, qualitative researchers can benefit from the definition of a research protocol to guide the inquiry process. Usually, this protocol is an outline to structure data collection and analysis procedures, but it may also encompass a presentation of the researcher's profile, to clarify readers about his expertise and biases.

The establishment of this protocol (for a step of the study or as an umbrella covering the whole process) may benefit the researcher, since he may verify this protocol at any time, clarifying any questions regarding the current purpose of the study. Additionally, researchers can create an evidence chain defining a protocol for each step of the process. Stakeholders may assess this evidence chain to understand how it has evolved throughout the research process. Still, this protocol's definition is only a framework of the conducted process. Qualitative researchers usually cannot define a systematic and detailed plan beforehand, since research steps can change significantly after they get into field to collect data. Qualitative research focus is on understanding meaning that participants bring to the observed problem, not the meaning the researcher brings to the study.

2.1.
Theoretical perspectives

Qualitative methodology allows for different uses of theory. Creswell (2014, pp. 64–66) discusses this variation of theoretical perspectives observing four different approaches: theory as the endpoint of a inductive methodology where a broad explanation or theory is expected as a result, such as grounded theory (Glaser & Strauss, 1967); as a starting point, supporting the generation of hypotheses, similarly to the quantitative approach; as a theoretical lens that provides concepts and methods to address specific problems; and, qualitative studies that do not employ an explicit theory, such as phenomenology that attempts to construct a rich and detailed description of a central phenomenon without any theoretical influence. This last approach is debated, since some researchers argue that no study begins without (implicit or explicit) influence of theories, concepts and methods.

The use of theories in qualitative research may come both at the beginning and at the end of the studies. Similarly to the quantitative approach, researchers can make use of previously developed theories and hypotheses ready for testing from the literature. Sometimes, researchers do not term them specifically as theories, but they work as broad explanations for the study. This is a common approach in qualitative health science, in which theoretical models may be available beforehand for researchers.

The use of previously established theories also occurs when investigators apply it as a perspective or a "theoretical lens". In this case, the theory does not provide ready hypotheses, however, it influences in research questions and methodology, defining how researchers should collect and analyze data. For instance, Semiotic Engineering (de Souza, 2005) theory provides a specific worldview (framed by communicative aspects), established concepts, known issues and epistemic tools to deal with them.

In contrast, the use of the theory may appear as the endpoint of qualitative studies, commonly based on an inductive reasoning. These qualitative studies comprise a reasoning process in which patterns and categories emerge based on characteristics of collected evidence. Researchers try to develop a theory or broad explanation from abstract conceptions and categories from data. The creation of a theory or explanation as a result is observed in different qualitative studies. For instance, researchers supported by case studies may establish theories that should be compared to results from different case studies. Yin (2009, p. 40) argues that use of theory helps defining research design and adequate data collection procedures in case studies. It is also the main vehicle for generalizing results. Another example is grounded theory, which is based on the construction of a theory grounded on an iterative process of data categorization. The researcher continuously adjusts designed models and theories comparing it with collected data, until it reaches a certain saturation point where new data no longer lead to new adaptations on the theory.

Table 1 — Overview of common theoretical perspectives observed in qualitative research.

Theory usage	Placement	Goal	Example
Final goal	Endpoint	To build a theory or broad explanation as a result of the research process	Case studies, Grounded theory
Broad explanations and ready hypotheses	Beforehand	Use established theories and hypotheses in literature	Qualitative health science
Theoretical lenses	Beforehand	Use broad explanations, worldviews and methodology for a specific context or problem space	Semiotic Engineering
No explicit theory	Not applicable	Exploratory and other studies where researchers may build the essence of experiences and participants' perspectives	Phenomenology, exploratory case studies

There are also qualitative studies that do not explicitly employ a theory. Creswell (2014, p. 66) mentions phenomenology methodology that builds the essence from participants' perspective without theoretical influences. Another example is the use of exploratory case studies to investigate new phenomenon that has no references and theories in literature. In any case, this approach is a debated subject by researchers who claim that every study is influenced directly or indirectly by previous theories and conceptions.

Table 1 summarizes the main uses of theory observed in qualitative studies. It correlates the use of theory with its positioning in the research process, the purpose of their use and examples of disciplines and methodologies applying it.

2.2.
Research quality and validation

Qualitative research is rooted in interpretative aspects. Not surprisingly, validation and quality assessment of this approach comprises a particularly challenging issue. As stated by Flick "the problem of how to assess qualitative research has not yet been solved" (2009, p. 384). This is a rather recurrent topic in scientific community.

Generally, validation of qualitative research involves three interested parties: researchers themselves interested in confirming their results; research consumers, for example, funding agencies and other external stakeholders interested in assessing the research process; and peer researchers interested in reviewing the inquiry, for example, for acceptance in journals or by reviewing committees.

Different authors have proposed terms attempting to create a parallel of the *rigor* criteria from quantitative research under a qualitative perspective. For example, Yin (2009) adheres to four common tests for validation of empiric research based on common quantitative terms: *construct validity*, *internal validity*, *external validity* and *reliability*. Based on these criteria, he suggests procedures that may be useful for clarifying aspects concerning these tests in the context of case studies.

Construct validity deals with the subjectivity factor, identifying operational measures for the concepts studied. In this regard, Yin suggests procedures such as, use of multiple sources of evidence (triangulation), creating an evidence chain of the research and study reports so participants can review the research findings (member-checking).

In explanatory studies, aimed at identifying causal relationship of events and concepts, researchers can promote *internal validity* through analytical tactics. Yin suggests procedures such as use of logic models, creating pattern-matching schemes, explanation building and addressing contrary explanations.

External validity deals with the possibility of generalizing results and applying them to other cases. Yin characterizes this process as an "analytical generalization", in which the researcher tries to generalize a particular set of results to some broader theory. In contrast, quantitative researchers deal with statistical generalizations with numerical trends and statistics from data. He suggests showing detailed use of theory in single-case studies, along with a replication logic for multiple case studies.

Reliability criterion tests whether a study demonstrates how its relevant operations can be replicated yielding the same results. For example, if the study details data collection procedures and other methodological details.

Previously, Lincoln and Guba (1985) suggested terms such as *trustworthiness*, *credibility*, *transferability*, *dependability* and *confirmability* as alternative criteria for validating qualitative research. They define trustworthiness (equivalent to rigor of the quantitative approach) as general criterion and most important for the evaluation all together, encompassing the other four criteria.

They define *credibility* criterion as the "truth" of the results and propose seven procedures for promoting it: prolonged engagement, persistent observation, triangulation, peer debriefing, negative case analysis, referential adequacy and member-checking.

Prolonged engagement assumes that the researcher had enough time (usually in the field) to understand the phenomenon of interest, along with the culture and contextual factors involved. That is, it targets at amplifying the researcher's perception of the possible multiple influences that may exist. **Persistent observation** is related to prolonged engagement; it tries to deepen understanding of these contextual factors in situations considered relevant to the study. **Triangulation** provides correlation of multiple data sources and methodologies to promote a better understanding of the problem. This assumes that a weakness in one method may be compensated by another method. However, different methods may have different weakness and biases. Qualitative researchers usually apply triangulation in order to produce robust and rich results, rather than as a guaranteed verification procedure. This procedure may elucidate complementary aspects of the same object of study or phenomenon. **Peer debriefing** involves participation of a peer researcher in an attempt to reveal aspects that otherwise could remain implicit in the researcher's mind. This may support discovering research features taken for granted, as well as being an opportunity to verify that emerging hypotheses seem plausible for other researchers. **Negative cases analysis** involves discrepant cases in data that may contradict patterns (categories) or explanations that emerged from previous analysis. This contrasts with the quantitative approach that usually eliminates discrepant cases to avoid "noise" or inconsistent results. Qualitative researchers may benefit from negative cases creating valuable knowledge from them. **Referential adequacy** aims at separating a portion of collected data so researchers can compare analysis results to it. It enables researchers to validate and test the patterns they created with fragments of data they did not use in analysis. Finally, **member-checking** involves the return of reports and results for validation by the participants of the study. It gives participants an opportunity to correct misunderstands or misinterpretations in their perspective.

Transferability is the criterion to show that the results are applicable to other contexts, it relates to "external validity". Lincoln and Guba propose that research results should contain thick descriptions to promote this feature. *Dependability* is the criterion to show that results are consistent and repeatable. They suggest the use of external audits by people not involved in research to promote their validity. The purpose of this criterion is to evaluate accuracy of results and assess if collected data in fact support interpretations and conclusions of findings. *Confirmability* criterion aims at neutrality of the study results. The authors suggest the use of procedures such as external audit, creating audit trails, triangulation and procedures to support reflexivity disclosure such as, researcher's bias exposure and involvement of multiple researchers.

One can find in literature a wide range of definitions and terminologies, with variations and reformulations of the criteria presented here, along with a variety of procedural strategies tackling the issues involved. For example, Gibbs (2007), Maxwell (2009, pp. 126–129) and Creswell (2014, pp. 201–204). Overall, there is a considerable intersection of discussed issues and solutions in these approaches.

2.3. Generalization

Generalization of qualitative methods and findings is also an aspect that raises questions, even though the focus of qualitative research should be less in its generalization and more in its particularity. The implication of the results in a specific context and the applicability of the method itself form the gist of this approach.

Researchers cannot generalize results through any *a priori* procedure. However, they can define a general case by observing a sequence of evidences, supplemented by a systematic process of rebuttal attempts to maintain their assumptions consistent. Yin (2009) believes that it is possible to generalize the results of a qualitative case study to some broader theory or template. The analytical generalization occurs when two or more cases are shown to support the same theory. However, repeating the results of a case study in a new scenario requires good documentation of the qualitative procedures, such as a research protocol to document the process in detail, and the development of a complete database of the case study. Figure 3 illustrates Yin's view about the process of qualitative generalization. He proposes two levels of inference and contrasting the formulated theory with rival theories. Empirical results may be considered potent if two or more cases support the same theory. In addition, results may be even more cohesive if they do not support plausible rival theories.

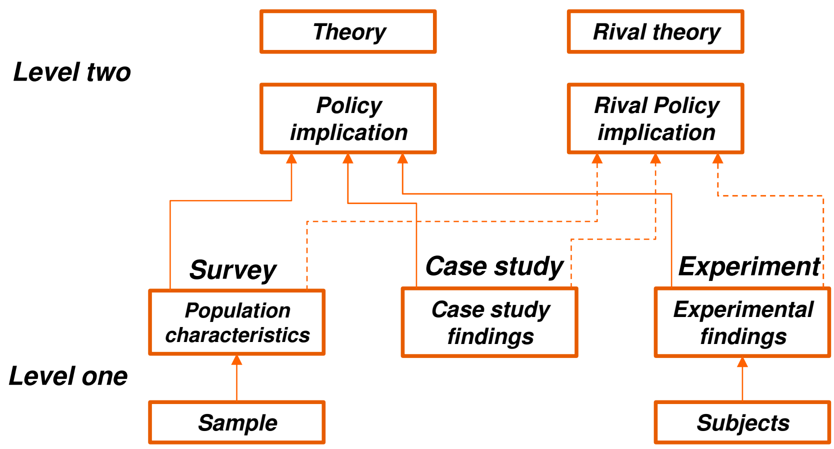

Figure 3 – Qualitative generalization process as a two level inference, adapted from (Yin, 2009, p. 39).

2.4.
Contrast with quantitative approach

The scientific community often perceives qualitative research as being less transparent than the quantitative approach. This can be related to the fact that qualitative researchers deal with meanings and descriptions, while quantitative researchers deal with measurements and numbers. The goal of quantitative research is to develop and employ mathematical models (theories and/or hypotheses) concerning phenomena. The measurement process is central to quantitative research since it provides fundamental connection between empirical observation and mathematical expression of quantitative relationships.

The distinction between quantitative and qualitative research often is described in terms of "direction" of the abstraction level in concepts and constructions in these methodologies. For example, quantitative research is largely associated with a reductionist logic. Researchers applying this methodology start from an established theory (i.e. from a high-level abstraction concept) toward data manipulation and experimentation to test their hypotheses (at a lower abstraction level). This type of analysis is often defined as a top-down approach. Qualitative approach results from a reverse process, it goes from data manipulation towards more abstract constructs. Commonly, qualitative researchers are interested in building a theory or comprehensive explanation on a bottom-up process. They conduct their research from concrete data (involving low-level abstraction concepts) toward increasingly broader and more abstract concepts.

Figure 4 depicts both quantitative and qualitative studies, respectively with a deductive analysis in a top-down approach, from a theory (the general case) to specific data (particular case) and a common inductive analysis as a bottom-up process, from specific data (particular case) towards a general explanation or theory (general case). This figure is an adaptation from Creswell's view of the two approaches from (Creswell, 2014, pp. 59, 66).

In addition, there are clear differences between the two approaches with respect to the form of evidence and media that express this evidence used as analysis object. Quantitative researchers generally observe empirical evidence of natural phenomena and perform their analyses expressed in the form of mathematical "language" (numbers and statistics). Thus, there is a clear separation between evidenced phenomenon and their results, or rather between “evidenced” and “interpreted” discourses, aided by mathematical language. There is no question about what comprises evidence and what comprises researchers’ analysis.

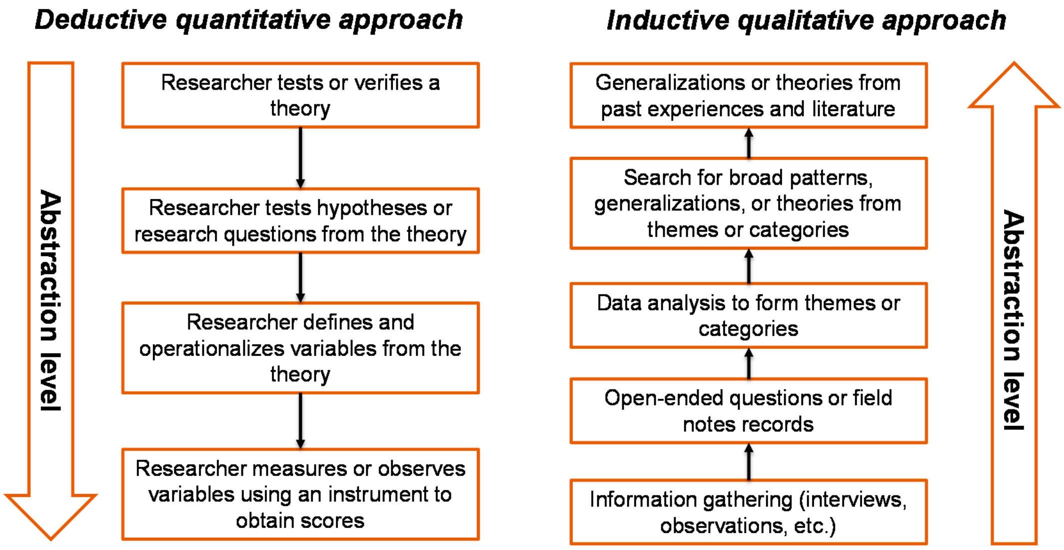

Figure 4 – Common quantitative and qualitative analysis, respectively as top-down and bottom-up approaches, adapted from (Creswell, 2014, pp. 59, 66).

Conversely, in some qualitative studies there may be a continuity of the carrier medium between object of study and the object of analysis, which can create misunderstanding among researchers and people interested in research results. For example, researchers applying a discourse analysis approach often observe textual documents as evidence. In this case, a representation of the object of study (his object of analysis) could be a digital or physical copy of (or even the same) original documents. This representation or sign, although integral, is not the same thing as the evidence. Different contextual factors of the evidence space may not be available at a later analysis or validation time frames. However, evidence, analyses object and results are all expressed in the same language, making it difficult to delineate what actually researchers produced in the study. In other words, this representational continuum does not prevent researchers to cross inadvertently into the evidence space with their interpretation. This representational continuum occurs in HCI evaluations as well, in which researchers often observe evidence in the form of interactive discourse, produced during the interaction between users and software artifacts. In this case, it is possible to transport software artifacts to later time frames, enabling researchers and validators to manipulate them and generate empirical evidence by themselves. Chapter 6 (Section 6.1) discusses further specificities of the qualitative approach in the HCI case that influenced our solution.

One can enumerate several other characteristics that differentiate the quantitative from the qualitative approach, including in their designs, conduction and form of results. The following passages highlight key differences observed in representative cases of both approaches. Later, Table 2 summarizes the distinguishing characteristics discussed about both approaches.

A first clear distinction one can notice about both approaches is their purposes. Quantitative research is essentially confirmatory, based on experimental procedures that allow researchers to confirm or refute hypotheses. Qualitative research has a more flexible feature and therefore supports studies with exploratory purposes, allowing for the creation of new concepts and theories.

Regarding research design, quantitative research allows for a prior definition of a detailed plan for its conduction. This makes no sense in qualitative research, which has an emerging character. Researchers cannot identify exactly what will happen in their investigation, thus a complete representation of the research process is only reasonable to be created during or after its completion.

The use of theory differs in both approaches' design. On one hand, researchers following a quantitative methodology use established theories to define hypotheses that are later confirmed or refuted through experimentation. On the other hand, qualitative researchers may use them as theoretical lens, as an outcome of a study or possibly do not use them explicitly at any moment in the research process. Besides, it is possible to use established theories to define hypotheses as well.

The distinction of theory use in the two methodologies reflects the different logical reasoning applied in quantitative and qualitative studies. In quantitative research, researchers apply deductive reasoning as a logical process to reach a conclusion beginning from one or more premises. That is, researchers start from assumptions and examine the possibilities of reaching a logical conclusion. The basic form of deductive reasoning is known in propositional logic as "affirming the antecedent" or *modus ponens*. It takes the following arguments:

- If A, then B (conditional statement);
- A (hypothesis);
- Therefore, B (conclusion).

The first premise is the conditional statement (if-then), i.e. that A implies B. The second premise is that A (a hypothesis), the antecedent of the conditional statement, is true. From these two premises, one can logically conclude that B, the consequent of the conditional claim, must also be true. A classic example is "all men are mortal. Socrates is a man. Therefore, Socrates is mortal". In this reasoning, the truth of the premises guarantees the truth of the conclusion ("all men are mortal" and "Socrates is mortal" are actually true). If something is true for a class (general case), it is also true for the members of this class (specific case). However, it is also possible to reach logical conclusions even if the premises are not true. For example, "all scientists are programmers. Einstein is a scientist. So, Einstein is a programmer". This is a logically valid argument, but it is false as it assumes an untrue premise (it is not true that all scientists are programmers).

In a way, the inductive reasoning is the opposite of the deductive logic. Researchers using this reasoning attempt to generalize a class or category (general case) from specific instances (particular case). Whereas in deductive logic conclusions are *certain*, in induction logic they are *plausible*, based on observed evidence. Thus, researchers can perform an inductive generalization. In a simplified form, it could be stated as the following logical argument:

- The proportion P of the sample has attribute A; (observed fact)
- Therefore, the proportion Q of the population has attribute A. (concl.)

A classic example of induction logic is, "all of the swans we have seen are white. Therefore, all swans are white". That turns out not to be true (in fact, there are black swans), despite the conclusion is supported by true premises (observed facts). Despite its uncertainty, induction is vital for scientific development since it allows for researchers to make broad generalizations, creating theories and hypotheses.

Another form of logical inference employed in qualitative research is abductive reasoning, which also involves uncertainty in the conclusions. It is based on an informed guess as explanation for an observed phenomenon. Furthermore, it comprises an iterative process of testing hypotheses using the best available information. Often, the literature relates abduction to creative and investigative processes, e.g. diagnosis of a disease by physicians (or discovery of a new one), examination by detective investigators seeking explanations from facts observed at the crime scene, or explanations by scientists seeking explanation for observed facts. Chapter 6 (Section 6.8) further discusses abduction reasoning, presenting how researchers could use our proposed C&A4Q model as a support for registering an abductive process.

The instrument used for data collection is a further distinguishing feature between qualitative and quantitative approaches. Quantitative researchers use technical devices or inanimate mechanisms for data measurement. In contrast, in qualitative studies the researcher himself is the primary instrument in data collection. It is up to him, with his bias and influence, to collect and describe the data he will analyze. Naturally, researchers are increasingly using digital devices for data recording, but generated data still have to be structured and often with descriptive reports. The form of manipulated data and the way researchers present their results differ between the two methodologies as well. Quantitative research is typically associated with manipulation of numbers and statistics. In contrast, qualitative research makes use of empirical materials such as audiovisual content, images and descriptive text.

In qualitative research, the focus is on the participants' perspectives. The research is interested in their experiences and meanings, researchers often observe multiple realities. On the contrary, the focus of quantitative research is on the researcher's perspective and his view over the analyzed data. Generally, qualitative researchers focus on the process that is occurring, as well as in its outcomes or products. Understanding how processes develop is essential in this approach. In contrast, quantitative researchers are interested in the outcomes of practical experiments.

The location where both approaches take place differs too. Usually, quantitative researchers carry out their measurement and experiments in laboratory or other similarly instrumented facility. Qualitative research in turn, is usually associated with field research; researchers explore situations in their natural setting (also called *in situ* or *in loco*).

Finally, validation in a quantitative process refers to ensuring that researchers can actually draw significant meaning from scores measured on instruments used in the study. Quantitative research is commonly associated with positivists, which assume there is an independent reality that other investigators can agree upon. Distinctively, qualitative research is closer to constructivists and interpretivists, which construct a reality through researchers' interpretation. The likelihood of such agreement observed between quantitative researchers to happen in qualitative studies is doubtful, since multiple interpretations of the same phenomena may emerge. To qualitative researchers, agreement and confirmation comes through the exposure of the applied methodology and evidences supporting the interpretative process. This promotes inspection and tracking of scientific development, from research questions to obtained results.

Quantitative validation involves aspects related to consistency of measurement and how reliable and stable are the measured scores. Often, researchers use terms such as, rigor, validity, construct validity and reliability when discuss quantitative validation (Creswell, 2014, p. 160). In qualitative methodology, validity is related to performing strategies or procedures (e.g., peer debriefing, external audit, triangulation of data and methods, etc.), along with the discussion about critical aspects of the research. In this way, qualitative researchers try to promote the accuracy of their results. Commonly, researchers apply terms such as, trustworthiness, authenticity and credibility as an analogous concept to quantitative rigor. Still, this is a contentious and debated topic (Creswell, 2014, p. 201).

Table 2 – Distinguishing features between quantitative and qualitative approaches.

Characteristic	Quantitative approach	Qualitative approach
Goal	Confirmation	Exploration
Design	Previously established plan	Emergent
Common use of theory	Theory and hypothesis established *a priori*	Theory and hypothesis established *a posteriori*, or used *a priori* as a lens
Common logic reasoning	Deductive	Inductive, abductive
Context	General case	Particular case
Instrument in data collection	Technical device or other mechanism	Researcher
Form of results	Data emerge in numbers and statistics	Mostly descriptive material

Perspectives	Researcher’s perspective over analyzed data	Participants’ perceptions, meanings and experiences
Most interested in	Outcomes, products	Processes and outcomes
Location	Laboratory or other instrumented location	Natural setting, field
Validation	Rigor, based on validity and reliability measures	Trustworthiness, based on procedures and discussions of critical aspects

2.5.
Mixed approach

Quantitative and qualitative approaches are not mutually exclusive. In fact, they are complementary. Even though there are researchers that still do not deem that mixed methodology may be valuable, literature shows that this approach have been increasingly applied in the last decade. It is seen as a “third methodological movement” (Teddlie & Tashakkori, 2012), following quantitative (first) and qualitative (second) approaches. Flick sees this approach as an opportunity to “end the paradigm wars of earlier times” (2009, p. 31).

Bryman (1992) discusses several manners of integrating quantitative and qualitative methodologies. To begin with, researchers can triangulate results for verification in both directions, i.e. qualitative results checked against quantitative procedures, and vice versa. One can also combine the two approaches to get a general picture of the problem itself. Quantitative methods can facilitate the analysis of structural features, while qualitative methods can aid processual aspects. Likewise, researchers may opt to explore the addressed problem through their perspectives (using quantitative methods), together with participants’ perspectives (using qualitative methods). Bryman argues that integrating quantitative findings in in qualitative approach can solve the generality issue often discussed in the latter. The opposite, integrating qualitative categorization in quantitative approach, can facilitate the interpretation of relationships between variables of a quantitative data set. In addition, he states that the relationship between micro and macro levels can be clarified by combining the two paradigms in different stages of a scientific process.

Miles and Huberman (1994, p. 41) suggest four research designs mixing quantitative and qualitative methodologies. In the first design, researchers apply both methods in parallel and keep constantly comparing their findings. In the second strategy, there is a continuous qualitative observation in the field with "waves" of quantitative procedures interleaving the process. The third design proposes an integration beginning with a qualitative method, e.g. a semi-structured interview, followed by a quantitative study as an intermediary step to the final result. In the final step, the researcher deepens the previous quantitative results with a second qualitative study. In the fourth proposed design, a field study aims to complement the results of a quantitative survey. Posteriorly, an experiment tests the results of previous steps. Figure 5 illustrates the four mixed designs proposed by Miles and Huberman. Similarly, Creswell (2014, pp. 220–221) proposes basic and advanced mixed designs.

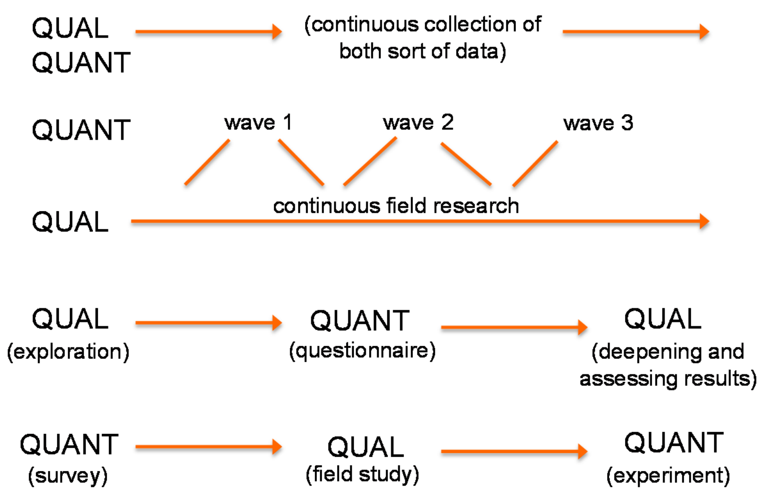

Figure 5 – Four mixed research designs discussed by Miles and Hubberman, adapted from (Miles & Huberman, 1994, p. 41).

3 Current approach

This chapter discusses the current approach for supporting the design and conduction of qualitative research. It discusses methodological issues often addressed in the research design literature presenting different approaches about planning and modeling the qualitative process. Generally, one can see research design as a systematic plan to study a scientific problem. This discussion is usually more associated to quantitative research. In qualitative research, it is more related to planning than to control, although it also plays a role in this sense.

In addition, this chapter outlines the most common software approach associated with qualitative research, namely Computer Assisted Qualitative Data Analysis Software (CAQDAS), or QDA tools for short. These tools support qualitative analysis offering features such as coding, content search, data linking, data mapping (in diagrams), query tools, annotation, and other. The purpose of this section is not to delve into the details and features of such tools, which would be impractical and unnecessary given the amount of published material about it. We briefly discuss the main features present in some of the more established solutions and the support they offer from a methodological perspective. We also discuss key distinctions between these tools and our approach.

To conclude, this chapter briefly goes over the newly established e-Science research field, which promotes structuring and access to quantitative scientific procedures. This is in a way analogous to the solution that we are proposing for the qualitative context. E-Science comprises infrastructures to support computationally intensive procedures that researchers execute in highly distributed network environments. Its use involves grid computing and massive data sets commonly referred as to “big data”. This chapter also discusses about solutions that address the development of these computational procedures and manipulation of data in scientific applications, namely Scientific Workflow Systems.

3.1. Qualitative research design

Several works have discussed planning and modeling of qualitative research process in the qualitative research design literature, particularly by authors within the Social Sciences such as Marshall and Rossman (2006), Creswell (2013; 2014), Flick (2009; 2014), Maxwell (2009; 2013) and Yin (2009). Yin claims that "every type of empirical research has an implicit, if not explicit, research design" (2009, p. 26).

There are two common strategies in the literature aiming at modeling the qualitative research process. One strategy is to offer a variety of basic structures of research methods that are in their own specific way undoubtfully coherent and logical, for instance the five approaches suggested by Creswell (2013) and the discussion over case study methodology by Yin (2009). Commonly, this strategy involves models with a logical (linear or cyclic) sequence of procedures or tasks, from problem formulation to generation of conclusions or theories. Both authors list a number of issues to be decided about the components (procedures) involved in their proposed approaches, presenting difficulties and problems usually faced when performing crucial procedures. This way, researchers may rely on these basic designs for instantiating their own research.

The other observed approach is to present a list with a rundown of the common issues and conflicts the researcher may face when planning and conducting a qualitative research process. This is the case with Maxwell's (2013) interactive model, which makes explicit the implications that each component (design decisions) has with respect to other components. He argues that the traditional approach (typological or linear) provides a prescriptive model for the research. Researchers must use them as a guide, arranging the components and tasks involved in planning and carrying out a study in an order considered optimal by design. In Maxwell's perspective, this research design modeling does not represent properly the qualitative process, which must be reflective and operate through all stages. He proposes an interactive model with five main elements with goals, conceptual framework, validity and methods connected through a central "research questions" element. This model emphasizes the interactive nature of design decisions. Components are interrelated and influence each other along the qualitative research process.

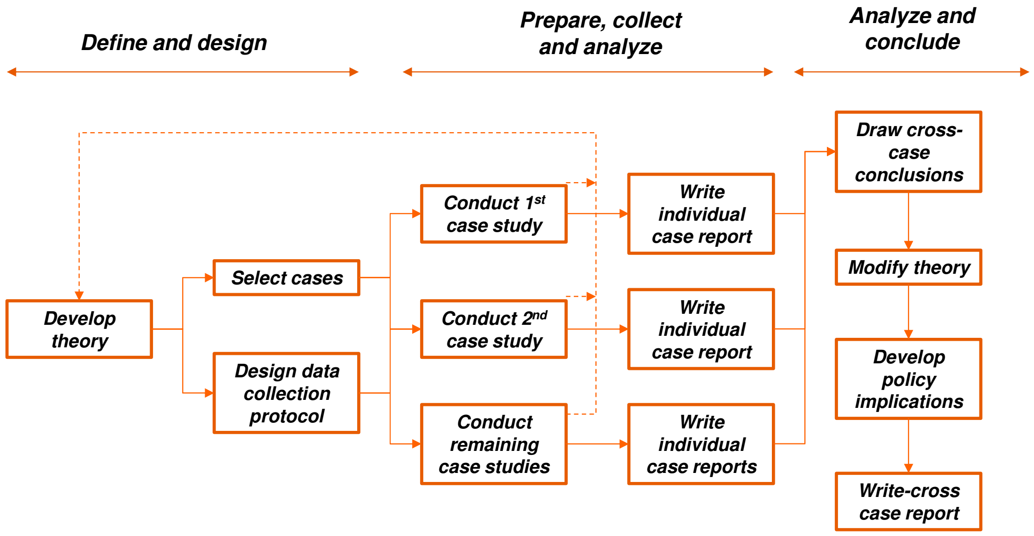

Figure 6 – Overview of the case study method suggested by Yin (2009, p. 57).

Figure 5 shows Yin's modeling for the case study method. He offers a basic strategy to apply this methodology with a clear plan with definition of procedures and their execution order. He discusses issues that researchers may face in each of the model's components. Figure 7 shows a simplified view of the model proposed by Maxwell. He also presents several further factors influencing these components, which may be external to the research.

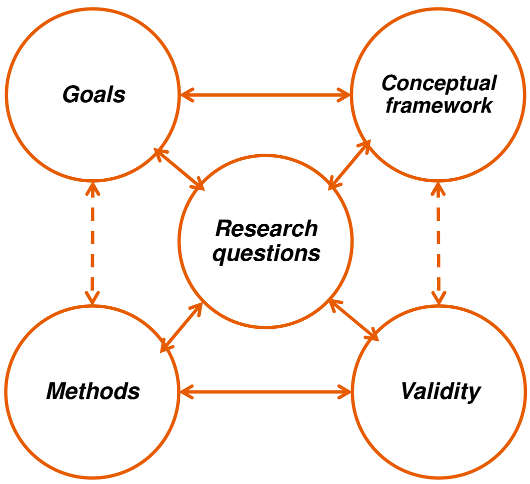

Figure 7 – Simplified view of the interactive model proposed by Maxwell (2013, p. 5).

Flick (2009) goes over these two strategies, comparing various basic designs and discussing components and critical issues involved in planning and conducting qualitative research. He argues that in the end the discussion about "tensional fields" is decisive in the resulting research quality. He raises a discussion over the duality of qualitative research between "rigor x creativity", "consistency x flexibility" and "criteria x strategies". The researcher must be strict and follow a clear methodological approach, but at the same time he must be creative and open to change in the course of his investigation to produce new insights. Research conduction should be consistent to allow contrasting evidences through an established frame. However, it may be valuable to adapt the methodology to cover emerging issues instead of rejecting them in favor of a methodological consistency. Flick also discusses the conflict between defining criteria for distinguishing good quality research, using traditional terms of Social Science (reliability, validity and objectivity, or reformulations of these), as opposed to defining validation strategies to promote research quality (as the procedures discussed in Section 2.2).

Research design can be viewed as the means for achieving the goals of the research. In this perspective, the concept connects different methodological aspects and external factors that may influence the research in some way. This includes the research questions and goals, sampling selection, resources available for conducting the research, methodology specifics and its appropriateness, risks involved, validation strategies, theoretical frameworks and generalization goals (if applicable). Figure 8 presents a visual representation of these components, based on the illustration proposed by Flick (2009, p. 133).

Figure 8 – Main elements discussed in qualitative research design, adapted from (Flick, 2009, p. 133).

Research design models are relevant in planning, but also aid the execution and structuring of the research. Components of these models explicitly identify key issues that the researcher needs to address in his inquiry. Thus, they enable the researcher to deal with these issues in a systematic manner, minimizing the possibility of ignoring them. Furthermore, the manipulation of these models lead to reflections and analysis that may be valuable for the definition of the next steps of the research. By the end of the study (or one of its steps), the process of registering these models' components leaves a trail comprising the design of the qualitative process. This representation is a sign that communicates and justifies the main decisions taken during the research project.

3.2.
QDA tools

Software support for qualitative analysis has a relatively long history in computing. Programs for manipulating textual data were developed as early as the 1960s (Silver & Lewins, 2014, p. 20). These offered basic features such as word listing, word frequency and other standardized metrics associated with content analysis.

The Department of Sociology at the University of Surrey in United Kingdom holds an annual conference on research methods that brings together researchers with interests in the area. Ray Lee and Nigel Fielding coined the term CAQDAS[6] in the first conference held there in 1989. Since 1994, the institution develops a project called CAQDAS Networking, with the goal of disseminating knowledge and guidance on the use of such tools. The project maintains a resourceful collection of material on the topic comprising articles, educational resources, detailed reviews of software packages and QDA utilities, among others.

QDA software solutions aim at supporting a general qualitative analysis, but they are often used and developed for fields of Humanities and Social Sciences, including but not limited to psychology, sociology, ethnography and education. In fact, many of the QDA tools originated in the mid-1980s and share some particular features shaped by their initial context. Some of them were developed by academics

[6] http://www.surrey.ac.uk/sociology/research/researchcentres/caqdas/about/

themselves who needed computational support for analysis. Thus, some of these tools today still reflect the requirements that came from this context.

Some of the most popular QDA tools include ATLAS.ti[7], Dedoose[8], HyperRESEARCH[9], MAXQDA[10], NVivo[11], QDA Miner[12], Transana[13] and Digital Replay System[14] (DRS). These tools support common analytical activities in qualitative research. Generally, they offer features such as, project management for handling analysis continuity and to build an audit trail, data organization, note writing, data annotation, searching for strings, coding (creation, retrieval and recoding of broader categories), hyperlinking between data, data mapping (with diagrams) and exporting reports.

In recent years, advances in the latest versions of these tools and development of QDA solutions as web systems seem promising. However, these solutions still do not seem to figure so prominently among HCI evaluation experts, in spite of recent increasing usage by researchers in this field.

3.2.1. Coding

Coding is a categorization process by which researchers relate data (or segments of data) to a concept or attribute represented by a *code* (string with a word or short phrase). Commonly, researchers combine categories forming broader concepts. The coding process is similar in most QDA tools, but there are distinctions in the form of structuring and presenting this mechanism. The visual representation of the coding structure in a tree (hierarchical) or list (linear) format is often a contentious subject. Some researchers feel constrained by a perceived notion of hierarchy (Silver & Lewins, 2014, p. 53). However, if the researcher's purpose is to carry out a plain coding or simple thematic analysis then, any of the

[7] http://atlasti.com/

[8] http://www.dedoose.com/

[9] http://www.researchware.com/products/hyperresearch/hr-nutshell.html

[10] http://www.maxqda.com/

[11] http://www.qsrinternational.com/products.aspx

[12] http://provalisresearch.com/products/qualitative-data-analysis-software/

[13] http://www.transana.org/

[14] http://thedrs.sourceforge.net/

previously mentioned tools may be useful in supporting this task. The process of managing coding schemes is well assisted by most popular QDA tools. Researchers may choose to use coding for creating relationships in data or just as a reminder tag for future analysis. Regardless of its purpose, software tools are agnostic to it. “Code” is simply a tag associated with a data segment or time interval of audiovisual media.

Coding process is a relevant part of the interpretative analysis. Through this procedure, the researcher classifies or categorizes evidence systematically according to his current conceptual map. Moreover, even if the researcher’s methodology does not comprise an explicit code-based step, he still can use coding tools to organize and index collected data facilitating future access and analysis. For example, if handled as hyperlinks codes can trigger the visualization of a referenced data. In this sense, ATLAS.ti solution stands out offering advanced tools to create relation between segments of data (called quotations in the software).

During the coding process, a significant number of categories may emerge. Commonly, it is expected that the researcher reduce the number of codes by agglutinating or combining them into broader categories. A methodological risk associated with coding is that analysis results comprise an excessive number of very specific categories. That is, the researcher is unable to reduce a large number of categories into a smaller and more representative set. This is a problematic situation called by different terms such as, “coding crisis”, “coding trap”, “fragmentation data” or “decontextualization” (Gibbs, 2014, pp. 285–286). The reverse situation can also be risky, if analysis results in very few and excessively broad categories the researcher may have reduced codes too much. As mentioned above, QDA tools are agnostic to analytic process. They only provide technical support for researchers so that they can structure their reasoning. Typically, these tools offer interactive mechanisms such as, lists and hierarchical tree view for code representation; thereby researchers can represent their conceptual models in a structured way.

3.2.2. Qualitative strategies

Silver and Lewins (2014) discuss about five analysis strategies that can be supported by QDA tools: discourse analysis, narrative inquiry, framework analysis, grounded theory and thematic analysis. They also discuss the use of QDA tools in mixed methods approaches involving quantitative analysis.

Researchers using discourse analysis are often interested in language characteristics. This may include particular types of discourse (e.g., medical, legal, philosophical, digital interaction, etc.), the use of implicit theories to make sense of social action and linguistic mechanisms used to structure discourses and their intentions (Spencer, et al., 2003). QDA tools usually support this type of analysis through text-mining features, such as verifying occurrence of words, phrases and structures. Additionally, these tools may offer coding features in this process.

In contrast, narrative inquiry focuses on the structure of reports as a whole. The researcher is interested in how narratives are constructed, including processes, intentions and meanings involved. Some QDA tools support two-dimensional mapping allowing for creating a graphical representation of relationships between certain passages in a narrative and observed concepts. Narrative analysis is not a uniform and singular approach or method. Silver and Lewins (2014) characterize it by the diversity of its use across different disciplines and theoretical traditions.

Framework analysis was originally developed in the 1980s at the National Centre for Social Research in the UK. Today, it is usually applied in case-based and thematic approaches. It is a method for analyzing empirical dataset using matrices for sorting and summarizing data. This method involves three main steps including the creation of a theoretical framework, indexing through coding and summarizing the data (Ritchie, et al., 2003). This type of analysis has common features with grounded theory and thematic analysis. However, it differs in that its goal is to summarize and present data through matrices, which is not prevalent in the other two strategies. Framework analysis is often associated with the NVivo solution, originally developed by NatCen as “FrameWork” targeting to support this very type of matrix-based analysis. Other tools can also support this analysis through memos and note writing.

Researchers widely use grounded theory in qualitative research and it is well supported by different QDA tools. This is not a simple analysis strategy but a full-fledged methodological approach. Since its original proposal by Glaser and Strauss (1967) different variations have been suggested. Generally, it involves a coding process (also called open coding), typically using the participants’ own terms (called *in vivo* codes). Researchers analyze data segments refining concepts and observing relevant aspects of these categories. The process of collecting, coding and analysis occurs concurrently allowing for a comparison between different groups and settings. Researchers refine the emerged categories and identify relationships among them. Then, these categories are reduced into a smaller set of higher abstraction concepts. This higher abstraction level allows researchers to observe generality that may lead to the construction of formal theories. The continuous collection of information reflects the principle of this theory being grounded on data, allowing new evidence to be analyzed from the perspective of established concepts and modifying it if necessary. When the analysis of new evidence does not lead to further adjustments in the emerged concepts, the categories are said to be theoretically saturated (Mason, 2010). That is, new data and analyses will not contribute with further findings.

Thematic analysis is a very common strategy in qualitative research, but it is debatable whether it should be considered as a method of analysis by itself, since this technique is used by several other approaches. It can be applied in a variety of theoretical contexts and disciplines because of its flexibility and independence of theories (Braun & Clarke, 2006). The analysis activity involves the initial generation of codes, search for themes, revision of themes, theme characterization (over different aspects) and production of a final report.

A recent breakthrough in QDA tools came with the support of quantitative data, allowing researchers to import numerical data and use it in coding process and other activities, promoting a mixed methodology. The approach of mixed methods is recent, having been formally discussed as an independent research field only within the past 15 years (Teddlie & Tashakkori, 2012). Researchers are increasingly using QDA tools to support this approach. For example, they may perform an in-depth investigation (qualitatively) on samples selected from of a large-scale quantitative survey. Alternatively, they may apply the reverse process as well, using qualitative information into quantitative variables in order to sort or to rank them. This concept is known as descriptive variables (Bazeley, 2006). Various QDA solutions provide support for importing spreadsheets and/or files in SPPS[15] format.

[15] www.ibm.com/software/analytics/spss/

3.2.3.
Multimedia support

One can see a sharp influence of textual language and media in QDA tools, a natural trait they carry from their original context and the problem space they tackle. However, the support for importing and carrying analysis over continuous media is becoming more common in QDA tools.

Atlas.ti, NVivo, MAXQDA, HyperResearch, Transana and DRS all can handle video importing. However, support for video, audio is still a barrier, since manufacturers use different codec formats. Often, users need to perform a transcoding process in a third-party tool to make their files compatible with the QDA solution they are using. This is even considered a “fairly normal” issue by Gibbs (2014, p. 282).

In Transana, the multimedia concept plays a fundamental role. Differently from other tools, it uses media such as, audio, video and images as anchors for the analytical task. Users must add media files to the project (creating a concept called Episode), then it is possible to import or create transcriptions that are synchronized with the media through timestamps. One can use these transcriptions entries as indexes to access parts of the audiovisual material. The software associates codes produced by the researcher to data through this transcript.

DRS enables parallel and synchronized display of multimedia files. It combines audiovisual content with annotation, transcripts, coding and other sources of data such as, system logs to offer a differentiated multimodal analysis. Additionally, it provides a mobile application so researchers can generate data tagged with GPS position that may be relevant in fieldwork. This is an academic and open source project, thus it has less activity than the other commercial solutions in terms of updates and new versions. Still, it remains relevant in the multimedia aspect.

NVivo supports the association of an adjacent file to audiovisual files, where transcripts are generated. MAXQDA and ATLAS.ti support transcriptions in a specific format from F4[16] tool. Users can import these transcriptions and have them automatically synchronized with the corresponding media. HyperRESEARCH also supports transcriptions by its own partner solution called HyperTRANSCRIBE.

[16] https://www.audiotranskription.de/english/f4.htm

Generally, these solutions support both concepts of transcription and annotation in audiovisual content.

3.2.4.
Contrast with our proposal

Unlike QDA packages that focus on supporting especially qualitative analysis, our solution aims at supporting research conduction in a broader context. Ultimately, we target to outline the research design of the final process (or a step of it), providing a holistic view of analysis and validation activities. In addition to analysis procedures, we provide support for registering planning procedures such as, activities concerning a research protocol definition, data collection, data publication and validation strategies.

There is also a difference regarding the way that methodology and computational support influences each other. As the following chapters of this volume will show, our proposal is to construct a conceptual model encompassing various methodological aspects that we observed in practice through case studies and in research design literature. Along with this model, we designed software components on top of a generic C&A software infrastructure for documenting details of the investigative process. We are designing software based on processes we observed. Researchers using QDA tools end up with processes shaped by the software design from the tools they select.

C&A solutions produce documents in order to register relevant information. These documents can be webpages with intuitive layouts that facilitate retrieving and visualizing information. Besides, this concept enables publicizing information decoupled from the software tool. In the qualitative research process, this concept can benefit validation strategies where access by external people is relevant. People wanting to inspect research details may not be acquainted to QDA tools or familiar with reports generated by these tools in specific formats. In our solution, external people may participate in the process through the manipulation of hypermedia documents, with interactive elements commonly used in the web.

QDA tools generally do not consider data collection steps of qualitative methodologies in their design. These solutions provide facilities for importing data externally generated, but do not support media capturing directly from available devices. Concerning audiovisual media, this often leads to codec compatibility issues and eventually extra work for researchers. Furthermore, data collection process sometimes comprises a unique moment where valuable information can be registered. Conveniently, C&A tools can generate structured data depending on the registered content, exploiting this possibility. For example, CAS infrastructure enables capturing social events with slide presentations with implicit metadata generation describing user interaction. That is, along with the slide file the infrastructure creates an adjacent metadata file, in NCL (ITU-T, 2014), with slide transition timestamps, text content and other embedded media within slides. These may comprise valuable information only available during the presentation session.

Another example of this rich data capturing is the interaction with software artifacts. It is possible to instrument artifacts to implicitly generate metadata about its use, enriching the registration of a possible interaction. Internal reactions of the system may be incorporated as textual media, e.g. interactive elements the user have manipulated, output of the system, logs and exceptions can be integrated during media capturing. By integrating the collection stage in their design, C&A systems enable creating a more structured information than would be a raw video depicting the user's screen during a presentation or his interaction with other tools.

Finally, synchronization of multimedia files in these tools is generally restricted to videos along with transcripts and annotations. Our prototype solution (presented in Section 5.4) has a strong connection with temporal information, since analyses in HCI evaluation greatly benefit from continuous media. Synchronization plays a key role in our proposal, researchers can record an arbitrary number of parallel audiovisual media and the system performs their synchronization automatically.

3.3. E-Science

John Taylor introduced the term e-Science[17] when he was at the United Kingdom's Office of Science and Technology in 1999 as, “science increasingly done through distributed global collaborations enabled by the Internet, using very large data collections, terascale computing resources and high performance

[17] http://www.nesc.ac.uk/nesc/define.html

visualization". At the time, he used the term to describe a large funding initiative that was starting in the following year. Since then, e-Science has been more broadly interpreted as the application of computer technology to the undertaking of modern quantitative scientific investigation, including the preparation, experimentation, data collection, results dissemination, long-term storage and access of all materials generated through the scientific process. It promotes "innovation in collaborative, computationally- or data-intensive research across disciplines, throughout the research lifecycle", as defined by the e-Science IEEE International Conference[18].

The distinction between qualitative and quantitative approaches results in very different options regarding the technological support offered to researchers. In the quantitative approach, researchers can prepare *a priori* operations commonly in the form of a script, which can be created manually (through text) or supported by graphical interfaces of some front-end.

In e-Science context, researchers define the operations they want to execute in a process known as composition, which involves the abstract modeling and instantiation of a series of procedures and input data. In this phase, researchers can make use of available libraries and previously cataloged data to specify their experiments as a workflow. Generally, this workflow is represented as a graph. Researchers can specify workflows indicating the computational steps and data flows across them. Or alternatively, workflow composition can be done in two stages with a template description in high-level abstraction without specific data that is subsequently instantiated with actual data (Deelman, et al., 2009). Currently, there are various Scientific Workflow Systems available (e.g., VisTrails, Discovery Net, Kepler, Triana and Taverna, to cite a few).

A workflow may include a number of functional units such as, components, tasks, jobs and services, along with the dependencies between them. Researchers may use different models and languages to represent these concepts, e.g. UML (Unified Modeling Language), BPMN (Business Process Modelling Notation) and Petri nets.

Afterwards, a mapping process takes place for associating the defined jobs with computing resources available in the infrastructure. This process can occur in two different ways, researchers can perform this mapping directly by selecting the

[18] http://escience2015.mnm-team.org/

appropriate resources or the infrastructure may perform this mapping process in an automated manner. The system then executes the defined procedures by the researcher, distributing the jobs according to this mapping. Figure 7 illustrates a simplified and general view of the lifecycle of experiments executed through Scientific Workflow Systems.

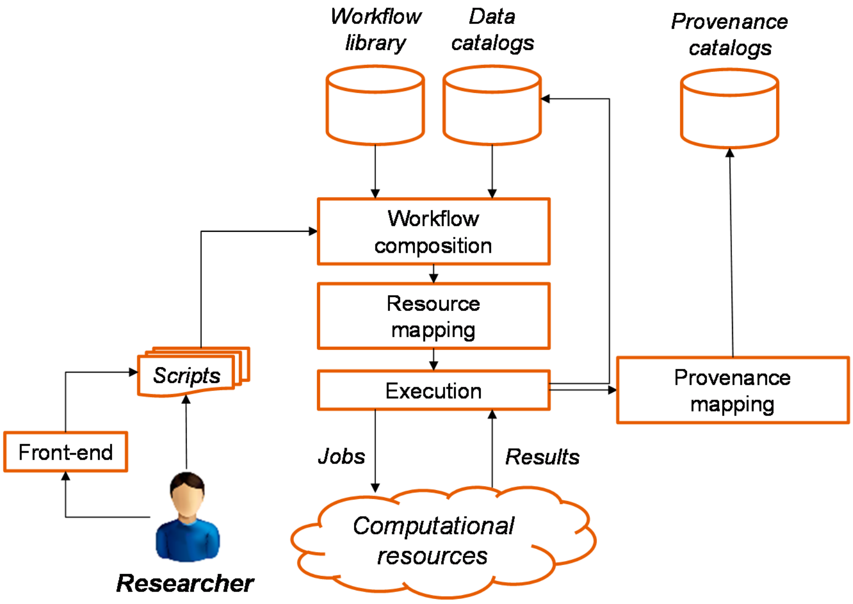

Figure 9 – Overview of a scientific workflow lifecycle used in quantitative research.

Scientific workflow infrastructures must adequately register the generated data resulting from the execution along with relevant metadata including, structures representing the workflow, timestamps, component and service versions, and others. The registration of this history of data creation is commonly called data provenance. It allows for the reproduction of results, which is a critical element in the quantitative methodology.

This approach allows for external validators and general stakeholders to reproduce results deterministically, re-executing procedures (represented as scripts or other type of job-control language) and assessing intermediate results to aid examination and comprehension of the experiment. Besides modelling the provenance of data, it is also necessary to model the provenance of hypotheses and results generated from analyzing the data as well, in order to provide evidence that support new discoveries. Different scientific workflows have been proposed and developed to assist scientists to track the evolution of quantitative data with intermediate and final results, thus documenting the evolution of discoveries within a specific scientific research stage.

Data provenance enables researchers to return to the point when the data was generated, promoting an inspection of the workflow and original data sources involved in certain results. In addition, the reproducibility observed in quantitative experiments has no parallel in the qualitative approach. This valuable resource can promote validation across researchers and may support novice researchers, since experienced peers can share their workflows and data with scientific community.

3.4.
Wrap up

The solution we propose in this thesis tackles some of the issues addressed by the works discussed in this chapter. Efforts in research design literature target to support planning and structuring for the qualitative process. Different models in such context consider qualitative procedures as first-order elements. In practice, by representing and manipulating these models researchers can create an evidence trail that they (and other people interested in the research) can revisit later on to reflect upon decisions made during the project. In addition, these models support the actual conduction of the qualitative process offering visualization of the undertaken procedures and other factors that may influence the decision of the next steps. This approach is in line with the C&A4Q conceptual model (discussed in Chapter 6) for structuring qualitative research through a registration perspective, presented as the main result of this work.

Regarding qualitative analysis, various software solutions aim at supporting a variety of strategies and methodologies. In recent versions, QDA tools have improved in terms of supported features and usability making it easier to perform certain analytical activities common to the interpretative process. Our solution comprises a prototype software (discussed in Section 5.4, after the case studies that inspired some of its features) that supports some activities of the qualitative analysis, similarly to QDA tools. This prototype is based on a C&A infrastructure and supports researchers by offering data capturing and document generation features. Moreover, we hope to support researchers throughout the qualitative process and not just with analysis. Since it is based on a ubiquitous infrastructure, software distribution is a fundamental element of its design. Collaborative processes involving different actors can potentially benefit of its design.

Collaboration in scientific research involves different people playing different roles and should be structured and well defined. We think that the e-Science approach along with Scientific Workflow Systems is a somewhat analogous structuring concept, which may be a direction we can follow with the qualitative research. However, unlike the quantitative approach that allows for *a priori* plans, in qualitative studies it only makes sense to register the process in *a posteriori* manner.

In this context, C&A research field emerges as a suitable candidate technology providing adequate tools for the registration of social and ubiquitous experiences, which involves registration and analysis of empirical content. Furthermore, the use of hypermedia documents may provide similar facilities to the concept of data provenance observed in scientific workflow systems. Thus, we dedicate the next chapter to discussing the C&A research field within Ubiquitous Computing domain, presenting concepts and resources, which qualitative researchers can make use. Following, we present case studies with observation of five qualitative HCI evaluations that inspired the creation of a conceptual model for registering qualitative research process. Additionally, we present the software prototype that supported activities performed in our studies.

4
Capture & Access

This chapter presents the Capture & Access (C&A) research area, a topic discussed within the Ubiquitous Computing (UbiComp) domain. We present its main concepts discussing how C&A can assist the registration of live social events, such as those discussed about qualitative approach in previous chapters. In addition, we present the CAS Project, an initiative aimed at developing a software infrastructure with common features present in C&A systems. In addition, its design promotes agile development and component prototyping. This infrastructure enabled the registration of the case studies in this thesis (presented in the following chapter).

Mark Weiser (1991, 1993) coined the term UbiComp (back in 1988) while he was at Xerox PARC. He envisioned its main concepts and challenges, describing it as a future in which "invisible" computers, embedded in objects, would replace PCs. Since then, UbiComp has become an established computing paradigm targeting at making human-computer interaction transparent. That is, it integrates computational resources in the environment with actions and behaviors of users in their natural settings, which may involve manipulation of everyday objects. Today, people are increasingly surrounded by a wide variety of computational devices at their homes and work, such as desktop and laptop computers, media centers, connected televisions, smartphones, tablets and a multitude of sensors; all of which are capable of registering and delivering information. In this sense, UbiComp as envisioned by Weiser is becoming a reality. Nevertheless, instead of replacing the use of PCs, it integrated them as another device comprising the computational resources available in the environment.

Among the various research topics within UbiComp, the Capture & Access (C&A) subarea has come to particular prominence with the emerging availability of such pervasive computer power. According to Truong, Abowd and Brotherton (2001), C&A can be defined as the "*task of preserving a record of some live experience that is then reviewed at some point in the future. Capture occurs when* *a tool creates artifacts that document the history of what happened*". Where, live experience may comprise any social event or moment whose record can be useful. These artifacts are recorded as streams of information that flow through time and can be accessed later.

Historically, people have had the necessity to record knowledge and information for different reasons. Human memory has its limitations and may be insufficient to capture information and access it with relevant details over time. A variety of devices and tools (analog and digital) were proposed throughout history. Vannevar Bush (1945) perhaps was the first to write about the benefits of a capture and access mechanism (Truong & Hayes, 2009). He described his visionary device, called *memex*, as a system capable of storing everyday artifacts and create relationships between them.

A study by Czerwinski et al. (2006) synthesized four reasons why people capture their experiences: first one, for personal reflection and analysis. To understand and aid personal development, review key situations or past research, find situational patterns that may be correlated to other information, or improve health via medical monitoring; second, memory recall to replay learning and teaching events, revisit experiences, review discussions and meetings, and even to find things (for example, keys and eyeglasses); third, experience sharing to improve communication with family, share everyday events over distance, or relive experiences of people who passed away; fourth, time management to improve productivity, improve coordination with family, friends and co-workers and identify relevant or proximate information provided the current context (including but not limited to location).

C&A systems are often associated with instrumented rooms and the concept of "active spaces", i.e. facilities equipped with specialized devices and sensors enabling a rich registration of events. However, with the advance of technologies in mobile devices and the increasing computing power available in them, applicability of C&A on events outside this context became a possibility. This can directly promote field research, as observed in qualitative research.

As discussed in previous chapters, qualitative research has a volatile nature; one cannot determine in advance all the details of the process, until it actually occurs. Qualitative research comprises investigative processes whose designs emerge based on observations in the field and the perspectives of participants involved in the study. These rather subjective processes are not easy to be expressed clearly, let alone to be expressed systematically and amenable to computational registering. Observation, analysis and validation procedures of qualitative studies often involve different actors playing different roles, providing and consuming different empirical data. Furthermore, the iterative process observed in qualitative analysis demonstrates the researcher's need for continuous access to a database, in his pursuit for data categorization. Research activities may also involve collaboration between peers and participants, requiring orchestration of distributed data collection and multiple access to database.

UbiComp's approach enhances the opportunity of implicit data input, i.e. systems may explore the natural interaction of users with their environment, physical objects and other artifacts to collect significant data without direct user intervention. In this sense, a major issue is the identification of routine and practicalities of people in their setting, in order to allow for developers model them in a ubiquitous software (Abowd, Mynnat & Rodden, 2002). This type of practical observation along with the need to gain a rich understanding of a particular setting is closely related to qualitative research studies.

In this sense, we think that both C&A and qualitative research can benefit from each other. The focus of C&A on capturing live social experiences is appropriate for registering qualitative research procedures. Equally, the qualitative perspective may be valuable to C&A (and other UbiComp topics) in supporting a better understanding of user practices in his environment.

4.1. Process outline

Abowd et. al (1998) identified distinct phases that occurs during a capture and access process: pre-production, capture (or live recording), post-production (or integration) and access. These phases comprise a well-defined workflow where each step takes place sequentially, but asynchronously to the previous steps. Figure 10 illustrates the different phases observed in conventional C&A process.

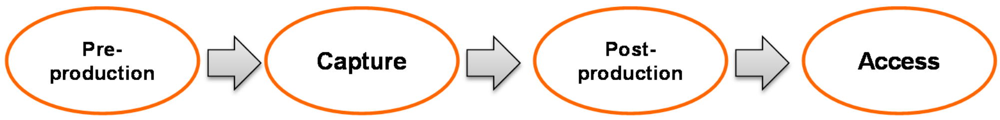

Figure 10 – Distinct phases identified by Abowd et al. (1998) in a common C&A workflow.

Pre-production involves the whole preparation and definitions prior to recording. One must define several aspects such as, users (or participants) of the event, available devices, time and locations involved in the recording, so on. Truong, Abowd and Brotherton (2001) proposed design dimensions in the form of five questions (shown below) to support the design of C&A systems. Likewise, researchers can use these design dimensions to ponder on when planning the registration of certain events.

- *Who* are the users?
- *What* is captured and accessed?
- *When* does capture and access occur?
- *Where* does capture and access occur?
- *How* is capture and access performed?

The authors assert that, the *who* component of a C&A design deals with users and their roles. For different kinds of situations, there may be a different number of users participating in the experience. People involved during the capture of an experience can be different from the people accessing the information. The *what* dimension addresses artifacts in the live experience that should be captured. It also covers the fidelity of the access experience with respect to the live experience. The *when* dimension includes aspects such as the time when capture and access activities occurs, highlighting aspects such as the frequency/periodicity of the capture and access occurrences. The *where* dimension alerts designers to consider features regarding the locations of capture and access, also the mobility of the users, and the diversity of locations. Finally, the *how* dimension addresses aspects about the capturing method, i.e. should it be implicit (fully automated) or explicit (commanded and operationalized by the user)?

The capture phase may occur in an implicitly or explicitly manner, i.e. devices and software artifacts may be instrumented to automatically provide data or applications may support explicit interaction through a visual interface to command the recording process. Explicit recordings demand an effort on the part of users that should operationalize the process. In opposition, implicit recordings are fully transparent to the user, but require further effort by system designers. An implementation supporting fully automated registration needs a considerable degree of intelligence. For example, systems may build on computational vision techniques to detect changes in the captured audiovisual material. Additionally, designers can instrument artifacts and tools to generate implicitly structured media. For instance, browsers can be instrumented to provide metadata about user navigation. Presentation tools can register slide transition times, provide hints about the presented content, etc. Thus, registering interaction with tools that enable an associated “metalanguage” to describe its manipulation may generate structured data with a finer granularity than a raw material representing such interaction, for instance, a video of the user’s screen representing his navigation or presentation. This type of instrumentation is an alternative to the generation of richer media without needing to add much intelligence to the system.

In the post-production or integration phase, C&A systems collect all generated media (across the various devices used in the event or stored in data repositories) merging them in an artifact that will be accessed later. This phase may comprise media post-production or post-processing procedures, including transcoding to different formats, editing captured data to discard unnecessary portions of it or to correct some information, structuring and relationship creation among data. Systems can automate digital media processing to some extent. However, data structuring and correlation depend on user intervention. It relates to the captured content (knowledge) not to their form (or media). This is similar to the categorization processes observed in the qualitative analysis, which involves a subjective and cognitive-intense activity.

The access phase comprises manipulation and reproduction of captured data in the form of a browsable artifact. Usually, a hypermedia document that aggregates and synchronizes the various captured information. There is a trade-off between capture and access phases concerning how much information one should capture from an experience and the feasibility of structuring such data in access artifacts. A detailed capturing promotes a richer registration of the experience, although a massive amount of data can make the visualization experience impractical. Another important factor is the consistency between observed experience and its reproduction in access artifacts. The visualization experience should be as close as possible to the observed experience, particularly with regard to chronological fidelity.

4.2.
The CAS Project

The CAS (Capture & Access System) project[19], developed in partnership between Tecgraf Institute/PUC-Rio and Petrobras, targets to provide a distributed C&A infrastructure for the registration of heterogeneous media in social events across different scenarios (Brandão et al., 2013). The project offers basic and common features present in C&A systems, promoting prototyping and testing of components and systems on top of its infrastructure. Some of the offered features include, capturing audiovisual media directly from devices, textual notes (with timestamps), screen video, slideshows and general document attaching. Additionally, CAS infrastructure provides media processing to different formats (post-processing), data transfer, storage and document generation, among other features.

CAS is based on a space concept for structuring the registration of social events, which allows for simultaneous and independent recordings in a scalable manner. Capture components running in different devices can discover available spaces and contribute with digital media during an event or experience. Users may operate these devices or they can implicitly generate media as well, such as the component for capturing slide presentations. Posteriorly, post-processor components merge all produced media in browsable documents. In order to participants and other interested parties access these documents and inform themselves about the knowledge produced in the recorded event.

Figure 11 shows an overview of the CAS infrastructure with multiple spaces simultaneously registering different social events (research procedure, presentation and meeting) and the automatic generation of documents for later access by external users.

[19] http://cas.tecgraf.puc-rio.br

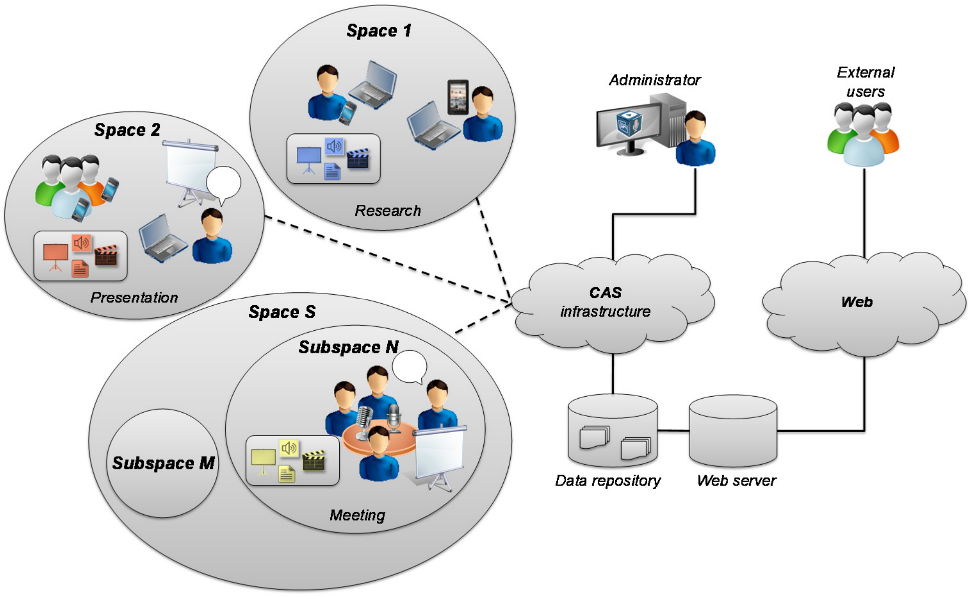

Figure 11 – Overview of CAS infrastructure with simultaneous spaces and subspaces recording different events producing different documents.

4.2.1. Architecture

The CAS infrastructure was conceived with a modular and extensible design. It is a component-oriented architecture, based on SCS[20] (Software Component System) model, a lightweight software component system developed by Tecgraf, inspired by COM (Component Object Model) and CCM (CORBA Component Model). There are three main concepts in the infrastructure: spaces, SpeedCars and services.

Space components can be used to reflect physical settings, structuring the recording environment through a hierarchical approach. They are composite components allowing for recursive nesting, thus creating recording contexts that may reflect the organization of buildings or facilities, for instance, a college with different internal sub-spaces (classrooms). Space components can disseminate method calls on its interface to its internal subspace components and aggregate the results returned by them. This can be achieved by using connector objects to create a mapping between *facets* and *receptacles* (terms used in SCS model to designate respectively provided and required interfaces) (Santos, 2012). For each space

[20] http://www.tecgraf.puc-rio.br/scs

component there is an associated configurator component responsible for handling connection requests and disconnection of internal capture components, namely SpeedCars.

SpeedCars (*SPEcializED CApture driveRS*) components are specialized drivers that control capture devices and software tools to generate digital media. Capture components are independent, in a way that the infrastructure can be extended to support new media capturing without any side effects on other components. Currently, the infrastructure provides components for capturing audio and video directly from devices, temporal annotations, binary file attaching, screen recording and slide presentations with PowerPoint® program.

The infrastructure also provides various services, specific components that run in the background and often perform lengthy tasks. There are services for different purposes, e.g. data transfer service for receiving captured media from SpeedCars, post-processing services for media transformation, data repository service for long-term storage and distributed logging service. Figure 12 shows a detailed view of the component-oriented design of the CAS architecture. At the center, an integration manager handles local and remote components offers. Remote integration is performed through a service bus called Openbus[21], a middleware developed by Tecgraf for integrating enterprise systems through a service-oriented architecture. Users interact with the infrastructure through a control panel tool that enables space configuration, event recording and post-processing.

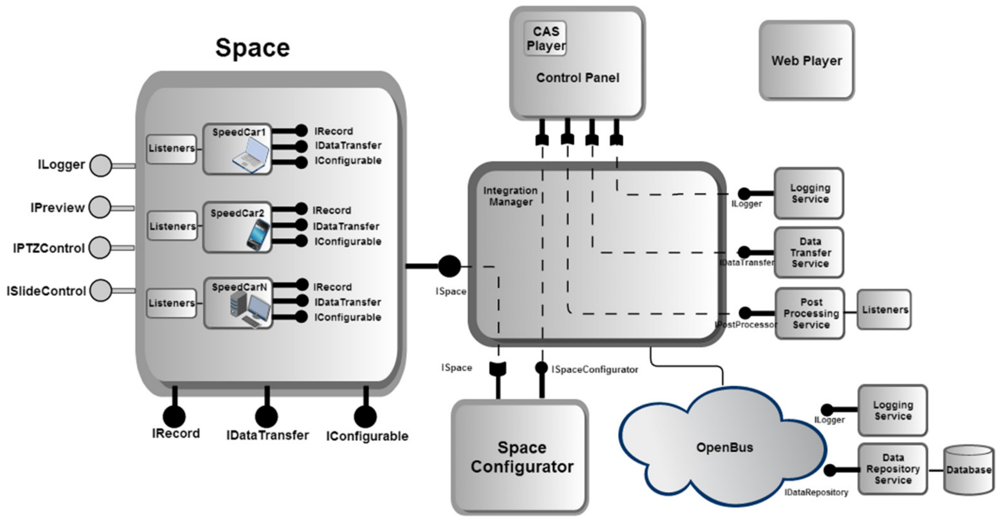

Figure 12 – CAS infrastructure's component-oriented architecture.

[21] http://www.tecgraf.puc-rio.br/openbus

4.2.2.
Document generation workflow

CAS uses NCL (Nested Context Language) (ITU-T, 2014) to describe generated media and for temporal representation of events in the infrastructure. In capture phase, each SpeedCar creates, along with its media, an associated description with information such as start and end time, media format, space contexts and other relevant properties. At post-production phase, a post-processing component for document generation combines all media descriptions previously created by SpeedCars in an intermediary description of the event, which is the basis for the creation of final access documents. This intermediary representation is specified using the NCL's Raw profile (Lima et al., 2010), a subset of the language that has only basic elements for media and context description, without presentation and interactive aspects, nor syntactic sugar of any kind, in order to promote portability to other technologies. Thus, document generation is uncoupled from the event's representation, promoting extensibility for future support of further types of documents, regardless of the employed technology.

NCL is based on NCM (Nested Context Model) (Casanova et al., 1991; Soares, Rodriguez, & Casanova, 1995; Soares & Rodrigues, 2005), which employs a concept of nodes and links, representing hypermedia documents as graphs. Figure 13 shows a hypothetical presentation event represented using NCM's concepts.

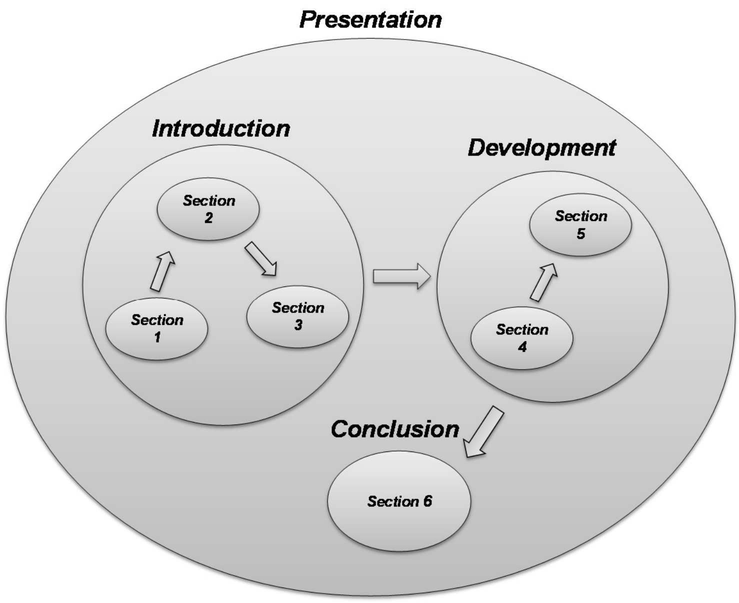

Figure 13 – NCM's approach uses graphs with nodes and links to represent and structure media.

A key concept in NCM is the distinction between two basic classes of nodes, called content nodes and composite nodes. Content nodes are also called media nodes or media objects, they are logical representations of media files (audio, video, text, image, application, etc.). Composite nodes are further divided into five classes (context node, switch node, trail, public hyperbase and private base) that define semantics for specific collection of nodes (Soares & Rodrigues, 2005).

Additionally, NCM offers mechanisms for causal rules definition and constraint semantics, which under certain predefined conditions can trigger an action. A common and simple example of causal rule is “node A should be presented as soon as the presentation of node B finishes”. Another example is the traditional reference relationship observed in hypermedia, i.e. a navigation to a target node when a source node anchor is selected. The NCM model promotes a clear distinction between media content and presentation structure.

In turn, NCL language has no restriction on the content type of media objects described in the document, it works as a “glue” language (Soares, Moreno, & Sant’Anna, 2009). Supported media formats depend on media players available for the so-called NCL *formatter*, the component responsible for presenting the document. Ultimately, NCL allows for relating declarative objects, imperative objects and perceptual media objects (audio, video, image, text, etc.) in time and space.

In CAS infrastructure, NCL is also used to define contexts in recorded events. Supported by a post-processor component, users can create contexts based on event’s times or event’s media through the control panel tool. For example, one can define that any media (or portions of them) falling within 10m00s to 35m00s of an given event will be associated to an “introduction” context, or anything falling within 45m00s to 55m00s will be part of a “conclusion” context. Alternatively, one can define that a set of media comprises a “presenter” context and another set defines an “audience” context. These context definitions may be used by the component in charge of generating the final access document. For example, it may present it as links that trigger their presentation. Figure 14 illustrates the document generation workflow in CAS infrastructure. Currently, HTML5 and NCL document formats are supported.

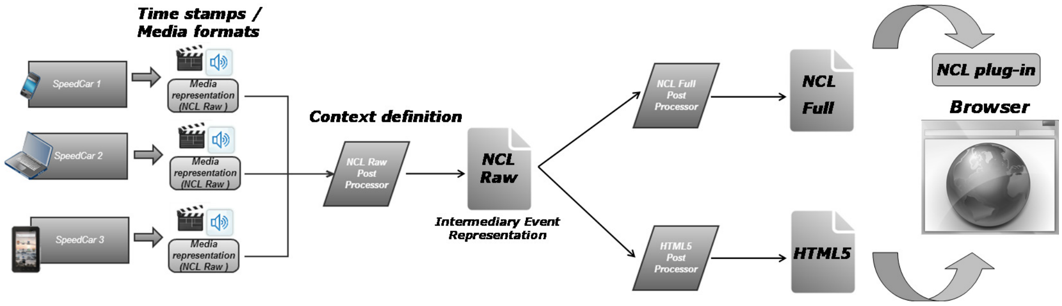

Figure 14 – Document generation workflow in CAS infrastructure.

4.2.3.
Control panel

The CAS project provides a control panel through which users can configure and operate spaces, capture components (SpeedCars) and other components and services, such as post-processors for generating documents. This rich-client tool allows users to interact with the infrastructure, supporting all C&A phases. It is developed in Java and inherits the interoperability of the technology. Its implementation is based on the NetBeans Platform[22] framework that provides several features related to desktop applications such as, a variety of software design patterns, window handling, contexts, menus, modules and other features that allows the developer to focus his efforts in the logic of the application. This framework makes it possible to create and deploy custom builds by personalizing available platform modules, and to perform remote updating of these modules. The control panel employs a *role* concept with different views according to the situation that the user is operating. Currently there are two roles in the control panel, a role for capturing and a role for post-processing (switched through tabs at the top of the window)

Figure 15 shows the capture role (or view) of the tool. At the upper area (item 1), there is a ribbon bar with easy access to functionalities related to capturing. On the left (2), there is a list of available spaces and SpeedCars, which users can choose to view as a tree, list or separated icons. The central region (item 3) comprises a preview area, where users can view streams from SpeedCars. The bottom region (item 4) displays output and other information such as, warnings and errors of the

[22] https://netbeans.org/features/platform/

system. This output area also aggregates output messages from remote components as well. The interface is currently in Portuguese only, but its internationalization is expected at some point.

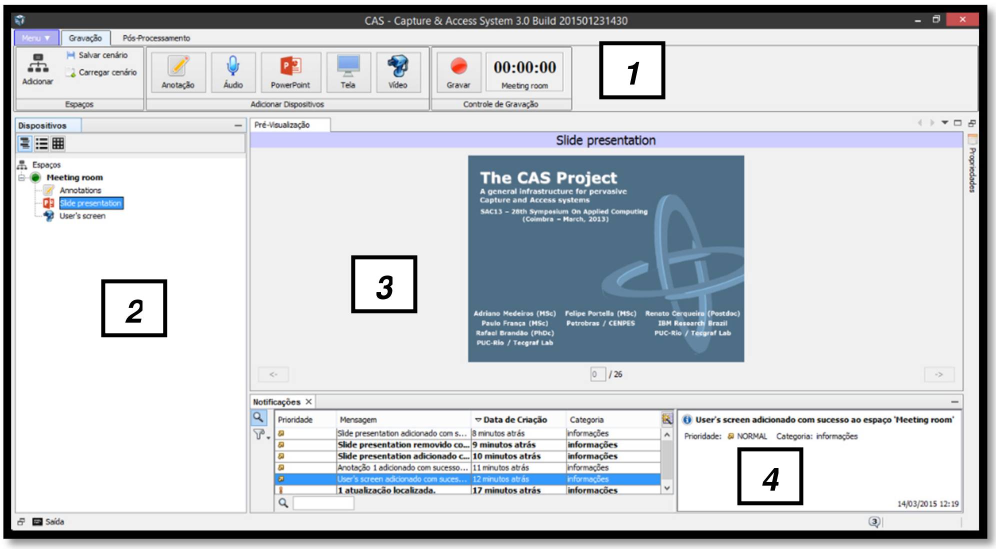

Figure 15 – Capture role (or view) of the control panel tool.

When adding a SpeedCar to a space, the user is prompted with a wizard that helps him to configure devices and general properties of the component. Users can configure SpeedCars for textual annotation for different purposes. They can be used for general annotation along with timestamps that will be synchronized with other media in the generated document. Alternatively, users can configured it to support a tagging or categorization procedure, similar to the coding process observed in qualitative studies, as shown in Figure 16.

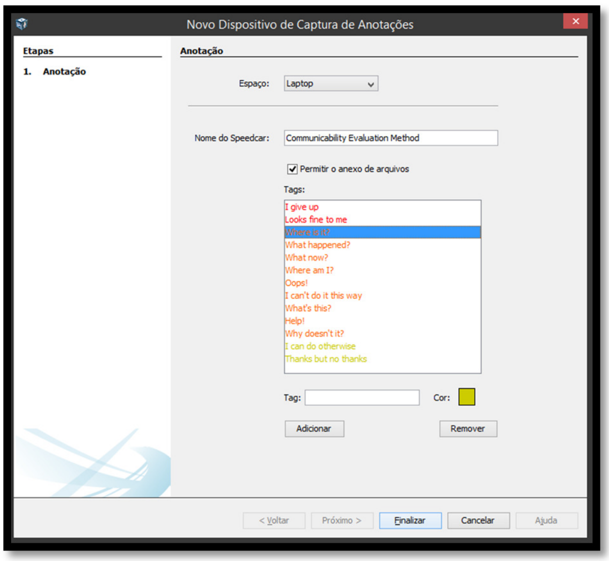

Figure 16 – Configuration dialog for the textual SpeedCar.

Figure 16 exemplifies how the text SpeedCar, used for temporal annotations, could be configured to reflect a categorization (coding or tagging) process. Through this configuration dialog, users can create a color scheme by defining a color for each tag. In this example, thirteen tags from the Communicability Evaluation Method (CEM) (de Souza, 2005), a methodological tool from Semiotic Engineering theory, were defined, with a color scheme reflecting the method's categories. CEM defines tags to label and describe communicability breakdowns in the interaction of the user with the software interface. In this example, red represent tags related to total failures, orange represent partial failures and yellow(ish) represents temporary failures. Figure 17 illustrates the result of this configuration in the text SpeedCar input panel. This panel can be detached from the control panel, so the user can operate it through a separate window, as illustrated in Figure 17.

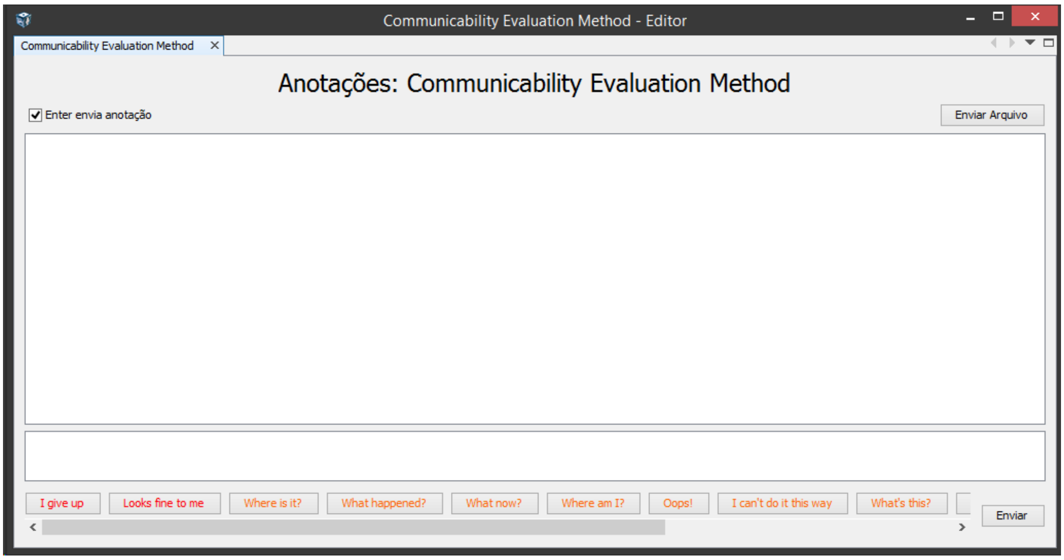

Figure 17 – Input window for temporal annotations (text SpeedCar) configured to reflect CEM tagging system.

The post-processing role enables users to configure and perform transformations on media of recorded events using available post-processors. Currently, there are three post-processor components comprising context generation, access document generation and multiplexed video generation. Wizards guide the user through the configuration of these components.

Users can generate contexts by slicing the timeline of an event, defining terms to identify media (or portions of them) within a given period. Alternatively, they can create contexts by defining media sets. The document generation process has a simple design, requiring the user to perform only two configuration steps. He must select a desired document template and the media formats to be generated. However, currently there is only one document template available in the implementation, which supports an arbitrary number of media. Thus, the template selection step has been omitted from the configuration wizard until other templates are developed. Users may choose to create documents compatible with the most popular browsers currently (Google Chrome, Mozilla Firefox, Safari and Internet Explorer). This is step is necessary since these browsers support different audio and video formats in HTML5 documents. Another option is to generate a single video multiplexing (or condensing) two other videos. A post-processor facilitates this operation, allowing the user to define what video will be in the background and what video will be in a small foreground area. This is similar to a PiP (Picture-in-Picture) scheme.

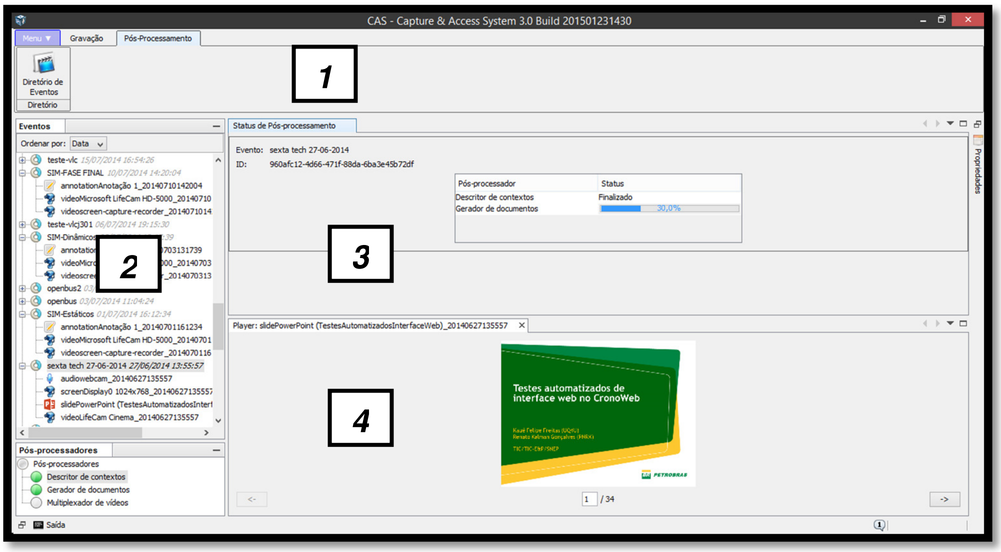

Figure 18 – Post-processing role (or view) of the control panel tool.

Figure 18 shows the post-processing role of the control panel tool. This view, similarly to the capture role, has a ribbon bar on upper region (item 1). A list of captured events and media is displayed in the left area (item 2). The central region (item 3) displays post-processing tasks in progress and queued for execution. The bottom region (item 4) displays media playback if any is selected by the user from the left list. Though a settings menu, users can configure the tool to connect to a remote service bus, enabling space sharing and collaborative capturing. Users can configure devices and media they want to create in a distributed event recording. To maintain a temporal consistency across remote SpeedCars in these recordings, CAS infrastructure employs a clock synchronization mechanism based on NTP (Network Time Protocol).

5
Case studies

This chapter presents five case studies (carried out in a thirteen-month time interval) whereby it was possible to observe characteristic procedures that motivated the proposition of the C&A4Q model. Two of these studies were preliminary investigations to verify the feasibility of registering qualitative procedures in HCI evaluations through the facilities provided by the CAS Project infrastructure. The other three case studies consolidated our research and provided insights for the registration of more sophisticated scenarios, including evaluations with combined methodologies and the use of wearable devices in a ubiquitous setting. In total, we registered fifteen procedures in HTML5 documents, including observations (user interaction), researchers' analysis, presentations and validation procedures. These registrations resulted in more than 16 hours of recordings, with roughly 16GB of processed data. The documents created in the case studies are in Portuguese, both the recorded content (participants' native language) and the textual information in the documents. In addition, access to online documents is restricted, given the necessity to preserve the participants' identity.

We analyzed the case studies from a registration perspective, pondering on the recorded content and generated artifacts for each of the observed procedures. In each one of the studies, we raise questions relating to two main themes: methodological aspects and technical issues observed in the registration process. Afterwards, this chapter presents a cross-analysis of case studies, trying to identify relationships and common difficulties in the observed procedures.

In addition, this chapter goes over key aspects observed during the studies that led to the identification of software requirements for C&A solutions targeting the registration of qualitative research. We prototyped some of these requirements as software components on top of the CAS infrastructure to assist the registration, analysis and access in the procedures conducted across the case studies. Later on, part of these features became official requirements for the CAS Project and the project's team incorporated it to its architecture. They also intend to incorporate further features identified in this work at some point. This discussion aims at contributing to the design and implementation of C&A systems focused on registration of qualitative activities based on interactive events, similar to our approach. This chapter also goes over a specific contribution resulting from the prototype implementation concerning the NCL's Raw Profile (Lima et al., 2010).

5.1. Preliminary studies

The preliminary studies were our first attempt to systematically register HCI evaluations supported by a C&A technology, specifically the infrastructure provided by the CAS Project. We have defined two scenarios comprising the registration of observational and inspectional studies based on SemEng's methods, the Communicability Evaluation Method (CEM) and the Semiotic Inspection Method (SIM) (de Souza & Leitão, 2009). In the first evaluation, researchers used CEM, an observation method, to evaluate PoliFacets'[23] interface. PoliFacets (Mota, Monteiro, Ferreira, Slaviero, & de Souza, 2013; Mota, 2014) is a web system developed by SERG researchers to explore multiple facets (or design dimensions) of software games developed by end-users in AgentSheets, a tool for teaching programming through games (Repenning & Ioannidou, 2004).

The second evaluation consisted of a communicability inspection in SideTalk[24], making use of SIM. SideTalk (Monteiro, de Souza, & Tolmasquim, 2015) is an asynchronous and scripted interpersonal communication resource for navigating on internet sites. It is also developed by SERG, offered as a Firefox browser's extension that works as a macro recorder for the web on top of CoScripter technology (Leshed, Haber, Matthews, & Lau, 2008). SideTalk enables a form of assisted navigation on websites through pre-configured text dialogues to guide third-party navigation.

After each one of the preliminary evaluations was concluded, we carried out an interview with participant experts for feedback, aiming at gathering contributions for our qualitative assessment and learning their feelings about the

[23] http://www.serg.inf.puc-rio.br/polifacets/

[24] http://www.serg.inf.puc-rio.br/sidetalk/

impact of using CAS in analyses and application of the method itself. Listing 1 shows the questions that guided the interviews.

1. How has the registration of interaction in artifacts and their publication through CAS documents affected your activities in the evaluation?
2. How do you compare the use of CAS with other tools you normally use to carry out your activities?
3. Has the use of temporal annotations had any impact on your analysis activities?
4. What do you think of the documents' layout?

Listing 1 – Questions used in the interview with HCI experts after the procedures carried out in preliminary studies.

5.1.1. Observation using CEM

CEM (de Souza & Leitão, 2009) is a method to support evaluators' interpretation about the user experience with respect to the quality of the designer-to-user metacommunication. It has four main steps: application, tagging, interpretation and semiotic profiling. There is also a previous preparation step (common to many HCI evaluation and other qualitative methods). The application consists of recording the user interaction with a software artifact, which should be as rich as possible. Usually researchers make use of separate tools for this matter, including screen recorders, text processors for annotation, cameras and audio devices for recordings, etc.

Then, specialists have to organize and analyze all the collected information and to label moments of the interaction with communicability tags in a *coding* process, with a set of pre-established categories (13 in total). These categories describe communicability breakdowns in the interaction of the user with the software interface. Tags are expressions that evaluators use to describe the user's reaction, e.g. "Where am I?", "Oops", "Thanks, but no, thanks". This tagging activity may begin on the fly during the application step depending on the evaluators' preferences and conditions during the data-capturing phase.

The interpretation step aims to assess all of the meanings that the evaluators assign for tagged sections in the recordings. The absence or a small number of tags is likely to be a sign of success of the artifact's communicability. The final step of semiotic profiling supports the evaluator in the identification, explanation and recommendations of redesign activities to correct the identified interaction design issues. This step comprises the reconstruction of the designer's message, which is aided by a metacommunication template stated as follows:

"*Here is my understanding of who you are, what I've learned you want or need to do, in which preferred ways, and why. This is the system that I have therefore designed for you, and this is the way you can or should use it in order to fulfill a range of purposes that fall within this vision*".

5.1.1.1. Observed scenario

Since CEM is an observational method, this study involved a user who performed a series of predefined activities. Additionally, two HCI experts collaborated to perform the evaluation, though only one interacted with the CAS control panel at a time. Their collaboration happened outside of the CAS infrastructure, because the support for collaborative registration was not implemented in the solution at the time.

The evaluation consisted of an analysis of the interaction between a user and PoliFacets. The experts asked the user to analyze the design facets of a game (Paintball) developed with AgentSheets. We registered the steps of application and tagging of this evaluation, the latter also involved part of the interpretation stage. These specific steps comprise activities that can benefit greatly from an integrated technology to record heterogeneous media and synchronize them in hypermedia documents.

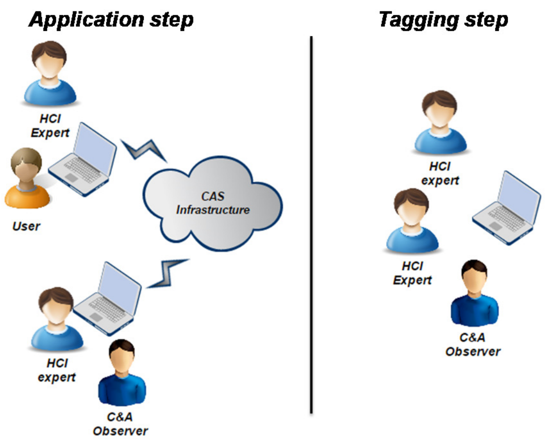

Figure 19 – Scenarios observed in the two steps of the first case study.

Figure 19 illustrates the observed and registered scenario in both steps of the case study. In this and all subsequent registrations discussed in this thesis, my role was as an observer (indicated as C&A observer), without direct participation in evaluation.

5.1.1.2. Registration

The two stages of the first case study occurred on November 22nd and December 12th in 2013. In the first stage of registration (application step) that involves the user, we captured information such as the user interaction (video of screen recording), the user's externalized attitudes (video) and his verbal protocol (audio). In addition, evaluators generated temporal annotations (text) concerning a preliminary tagging process, and attached files to the document (software) with the description of the activities the user should perform and the agreement form signed by him.

In the second stage (tagging step) that occurred subsequently, we recorded the analysis of HCI experts that took the previously generated document as a basis. The captured information was similar to the recorded content in the first stage, but reflecting the experts' activities rather than the user's. Similarly, we recorded their interaction with the prior document, their externalized attitudes, verbal protocols, new temporal annotations (the consolidated tagging) and again attached files. Table 3 summarizes the registration of the observed evaluation, showing the procedures for which we created documents, the evaluated element, the involved actors or participants, the captured information (along with an indication of the digital media used in its registering, meaning A for audio stream, V for video stream, T for text and S for software, e.g. binary files).

Table 3 – Summary of the registration of the first case study.

Procedures	Evaluated artifact	Participants	Captured information		Duration
Collection + analysis (application step)	User interaction	1 user + 2 HCI experts	Interaction	V	00:37:32
			Ext. attitudes	V	
			Verbal prot.	A	
			Annotations	T	
			Files	S	

Analysis (tagging step)	Collection + analysis document	2 HCI experts	Interaction	V	02:25:15
			Ext. attitudes	V	
			Verbal prot.	A	
			Annotations	T	
			Files	S	

5.1.1.3. Lessons learned

The layout of the automatically generated documents by CAS postprocessor component at the time of this study did not provide a facilitated and parallel viewing of two main video streams, which would have enabled emphasis according to the viewer's needs. This mechanism is useful to any HCI evaluation where the parallel analysis of user interaction with a software interface along with their externalized attitudes is relevant. Starting from this requirement identified in this study we created a first document layout to enable an intuitive evaluation of the recorded interaction.

The documents generated for this preliminary study was a proof of concept in order to HCI experts evaluate their usefulness. We created them in HTML5 language with JavaScript libraries, such as jQuery[25] for user input handling and interaction elements and Popcorn.js[26] to assist the manipulation of interactive temporal media with HTML5.

Figure 20 – First document layout proposed to support review of HCI evaluations.

25 http://jquery.com/

26 http://popcornjs.org/

Figure 20 shows the initial document layout proposal to support the analysis activities in the case study, the interaction elements identified by 1-7. The participants' identity is preserved in the image. The following elements are present in the first proposed layout: 1) list of attached files during the captured event; 2) video (and audio) of the user and over-the-shoulder expert evaluator, showing their externalized attitudes and verbal protocols; 3) screen video with user interactions; 4) temporal annotations comprising observations made during the first and second steps, including tags with communicability breakdowns identified by experts. The tags follow the particular color pattern defined in the provided textual annotator interface (in the CAS control panel). The screenshot shows a partial communicability failure (in orange) with a "*Where is it?*" tag; 5) Interactive mechanism to allow resizing to emphasize one of the videos; 6) Control that allows for seeking the time of the next or previous note (through the arrow icons), and also the toggling of audio (central icon); and 7) help Item that opens a popup menu when clicked. This dialog displays the color pattern defined for annotations and shortcut keys through which one can control playback and media navigation.

The tagging stage highlighted a conceptual limitation in the document generation process in the CAS infrastructure (and in the traditional C&A process generally) related to the support for iterative analysis commonly observed in qualitative research. The tagging performed in the second stage should be incorporated to the preliminary tagging in the first document, resulting in a document with user interaction merging tags from the two moments. However, the document generation process in the infrastructure dictated that the notes taken would be incorporated in the current document (tags created in the tagging step would only be inserted in the second document). In order to achieve this, we performed a manual merging process. This issue caught our attention for the need to support editing features in the document creation process.

5.1.2.
Inspectional study with SIM

SIM (de Souza & Leitão, 2009) is an inspection method for investigating software communicability. It focuses on the message created by the designer through the exploration and analysis of interface signs, which can be static (interface elements that do not change), dynamic (elements that appear in interaction with the artifact) and metalinguistic (which explicitly refer to other static and dynamic signs). The researcher has to instantiate the metacommunication template (also used in CEM) for each class of signs.

The method has two distinct stages involving the deconstruction and reconstruction of the designer's metacommunication message, assisted by the analysis of the interface signs. This method specifies five main steps: analysis of metalinguistic signs, analysis of static signs, analysis of dynamic signs, comparison of the three metacommunication messages and global evaluation of the communicability.

5.1.2.1. Observed scenario

Unlike observation methods, inspection methods do not involve user engagement, making the evaluation process centered on the HCI expert's analysis. This evaluation involved only one HCI specialist who chose to register a procedure condensing the first three steps of the method (sign analyses) and then a second procedure consolidating the results. The planned scenario was a communicability inspection of the SideTalk's interface, a Firefox browser plug-in developed by SERG to aid website navigation through textual dialogues.

The backdrop that guided the interaction through this inspection study was to create dialogues in SideTalk to assist the navigation through a web portal (VoteNaWeb[27]), through which users can vote on draft laws in transit in the Brazilian National Congress. At the end of voting period, those in charge of the system take the results directly to Congress. The purpose of the HCI expert was to inspect the SideTalk plug-in's interface, simulating the interaction of a user while analyzing metalinguistic, static and dynamic signs, to reconstruct iteratively the designer's metacommunication message for each type of sign. Figure 21 illustrates the two steps observed and registered in this case study

[27] http://www.votenaweb.com.br/

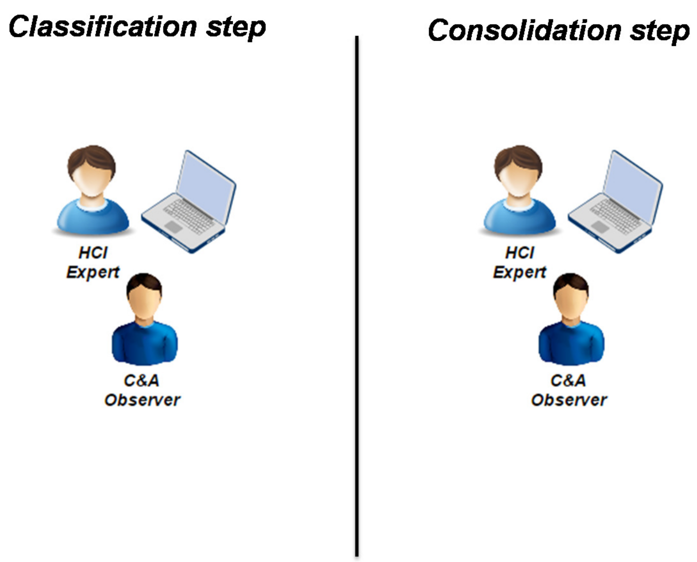

Figure 21 – Scenarios observed in the two steps of the second case study.

5.1.2.2. Registration

The two stages of the second case study occurred on February 11th and March 7th in 2014. Regarding the registration of the SIM, static signs communicate their meaning independent of time. For instance, a static image can fully capture their meaning. Dynamic signs communicate their meaning in a time-dependent manner demanding a continuous media (e.g., video) to capture and transmit their meaning adequately. Metalinguistic signs are signs that reference other signs (static or dynamic). Their meaning is a description or indication of other interface signs (typically registered in textual material, e.g. help and instruction manuals).

In terms of registered information, both stages (classification and consolidation step) had similar configuration. We captured information such as the expert's interaction (screen recording video), his externalized attitudes (video) and verbal protocol (audio). In addition, the HCI expert generated temporal annotations (text) concerning his classification and findings, and attached files to the document (software) with drafts that he created. A relevant difference between the registered procedures concerns to the evaluated element. While in the first stage, the expert focused on the software artifact's interface, in the second step he analyzed both this interface and the document generated in the previous stage. Table 4 summarizes the information captured in this case study.

Table 4 – Summary of the registration of the second case study.

<table>
<tr><th>Procedure</th><th>Evaluated artifact</th><th>Participants</th><th colspan="2">Captured information</th><th>Duration</th></tr>
<tr><td rowspan="5">Collection + analysis (classification step)</td><td rowspan="5">SideTalk plugin</td><td rowspan="5">1 HCI expert</td><td>Interaction</td><td>V</td><td rowspan="5">01:23:09</td></tr>
<tr><td>Ext. attitudes</td><td>V</td></tr>
<tr><td>Verbal prot.</td><td>A</td></tr>
<tr><td>Annotations</td><td>T</td></tr>
<tr><td>Files</td><td>S</td></tr>
<tr><td rowspan="5">Analysis (consolidation step)</td><td rowspan="5">Collection + analysis document, SideTalk plugin</td><td rowspan="5">1 HCI expert</td><td>Interaction</td><td>V</td><td rowspan="5">00:35:50 (+10min)</td></tr>
<tr><td>Ext. attitudes</td><td>V</td></tr>
<tr><td>Verbal prot.</td><td>A</td></tr>
<tr><td>Annotations</td><td>T</td></tr>
<tr><td>Files</td><td>S</td></tr>
</table>

In the same way that the first step in the CEM study, we observed that the generated document in the first stage (classification) assisted the second stage analysis (consolidation). However, the registration this study resulted in an inverse duration of the events, the inspection process carried out in the first stage was more intense (approximately 1h23m) than the consolidation phase (only 36m). In addition, we had to interrupt the recording session of the second step around the 10 minutes mark because the control panel was not properly configured to capture the screen (interaction of the expert). After we restarted the recording, the expert inserted the previously made annotations to the new recording session. Therefore, one can estimate the duration of the second procedure in about 46 minutes.

5.1.2.3. Lessons learned

The preliminary experiments served as a proof of concept that the C&A infrastructure provided by the CAS project had the necessary facilities for registering and instrumenting activities of IHC evaluations. The conducted case studies have proved useful in identifying limitations and requirements considering the CAS use in such context.

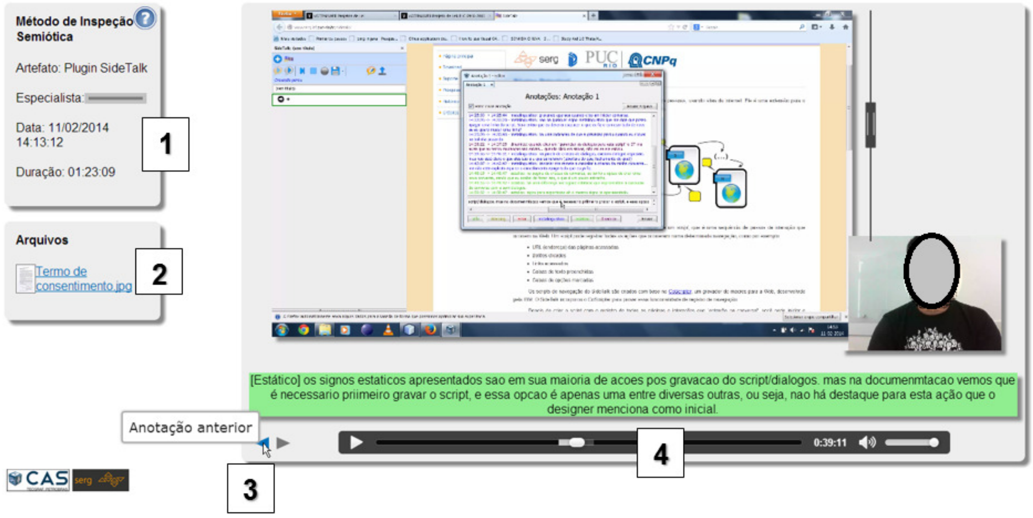

Figure 22 – Second layout proposal, generated from the second case study.

During the two preliminary studies, we identified layout requirements for the documents by observing communication breakdowns and feedback for improvements collected from the experts. Considering this information, we proposed a second document layout (depicted in Figure 22) including the following advancements: 1) addition of an information box with event metadata. Along with repositioning the help icon to the upper corner of this box; 2) Possibility of visualizing documents (Office, LibreOffice and PDF formats) and images attached through a jQuery slideshow mechanism for images, and though Google Drive for documents; 3) Control mechanism for seeking to next/previous annotations alongside the central control. In the previous proposal, it was next to the resizing mechanism between videos; 4) implementation of a central control that seeks all media. In the first layout, this control was linked to the video of the expert and there was no clear indication of its operation;

In addition to these elements, we developed of a full-screen mode, where it is possible the display of all media with a greater viewing area. We added hotkeys so that the experts can quickly emphasize one of the main videos with user interaction or externalized reactions. Finally, we made general visual improvements and added dynamic media resizing effects with the jQuery library. When resizing occurs, the small video becomes overlaid on top of the large video, allowing it to be dragged and repositioned.

In the methodological aspect, SIM is a method that highlights the segmented analysis feature of the qualitative research. This made us more aware of the expert's need for accessing previously generated C&A artifacts and their relevance for generating new results that may comprise parts of them.

5.2. Consolidation studies

After verifying that the CAS infrastructure could handle the registration of qualitative procedures, we decided to conduct other experiments focusing on different methodological aspects, such as studies with combined methods and semi-structured studies similar to ethnography, comprising an emergent perspective without explicitly established procedural steps other than a macro-level research design orientation.

We conducted three further studies to consolidate our research with the registration of two HCI evaluations with combined methodology, namely, an evaluation of the VisualParadigm[28] tool for designing UML diagrams guided by the methods SIM and CDNf (Cognitive Dimensions of Notations framework) (Green & Blackwell, 1998; Blackwell & Green, 2003) and a qualitative analysis of bug reports guided by a combination of SIM, CEM and CDNf methods. In addition, we registered a semi-structured qualitative evaluation involving the development of a wearable assistive technology. This technology aims at assisting a user with motor impairment to control home appliances and devices, such as TV, smartphone and lights through a hat equipped with sensors and microcontrollers.

Our aim with these studies was to observe how a detailed registration of methodological procedures could aid scientific research conduction. Through the preliminary case studies, we could observe how experts felt some relief regarding technical and practical issues in registering, publicizing and accessing empirical media concisely. However, we saw the possibility of C&A technology assisting in planning and conducting scientific research processes as well, which is what we report in the following subsections.

[28] http://www.visual-paradigm.com/

5.2.1. Interface inspection using SIM + CDN

Researchers often apply a combination of methods as a form to triangulate results (both in quantitative and qualitative research) to overcome weaknesses or intrinsic biases and problems that may come from applying single methods. In this study, we registered an evaluation combining methods focusing on communicability (SemEng's SIM) and usability (CDNf). This way, the researcher targeted performing a more comprehensive inspection about issues in the interaction with software artifacts.

CDNf (Green & Blackwell, 1998; Blackwell & Green, 2003) is a vocabulary that designers can use while evaluating cognitive aspects of notational designs. It establishes a common terminology to support researchers talking about their judgments about many factors in notation, UI or programming language design. This method provides experts with an adequate set of terms aiming at leveraging their judgment, and guiding them to reflect and discuss about cognitive issues in design explicitly. Originally, the authors proposed 14 notational dimensions for creating or evaluating information artifacts.

5.2.1.1. Observed scenario

The registration of the evaluation of the VisualParadigm[29] tool comprised five separate procedures. We recorded the SIM application, as well as a validation procedure with peer review. Unlike the preliminary study using SIM, the researcher in this study chose to create a registration artifact (CAS document) for each of the sign analysis steps and the consolidation step (comparison of the three sign analysis and global evaluation of communicability). Although we did not capture the triangulation activity itself in this study, the generated documents aided its conduction.

A leading expert conducted the research process, but some steps involved other participants as well. The first step of this registration (analysis of metalinguistic signs) involved a second HCI expert who observed the activity. The

[29] VisualParadigm for UML is a CASE tool supporting UML 2, SysML and Business Process Modeling Notation (BPMN) from the Object Management Group (OMG).

following two steps (analysis of static and dynamic signs) involved only the leading expert. Later in the consolidation step, a second expert participated again observing the process. The registration of the validation procedure included the leading expert and a peer who reviewed all the activities, making comments and questions about the research. Figure 23 illustrates the configuration of the scenarios observed in the registration of this study's activities.

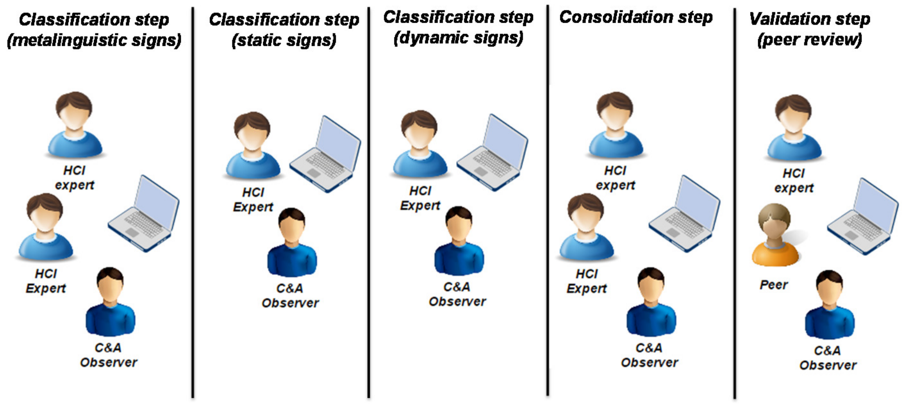

Figure 23 – Scenarios observed in the five steps of the third case study.

5.2.1.2. Registration

The five registered procedures in the third case study occurred respectively on June 16th and July 1st, 3rd, 10th and 17th of 2014. The recording of the steps in this case study were similar in terms of the captured content. Since it was an inspection analysis by a leading expert, the media produced in this study is centered on his analysis and findings. We captured his interaction with the evaluated software artifact (screen video), his externalized attitudes (video), his verbal protocol (audio), temporal annotations with signs classification and other notes (text), and files (software) comprising images describing certain aspects of the evaluation and documents in the VisualParadigm's proprietary format. In each of the analysis activities, the researcher interacted with the evaluated software artifact along with the previous generated documents. In the validation procedure, we captured the same set of content, although in this case the recorded media relates to the peer reviewer (peer's interaction, attitudes, annotation and files), instead of the leading expert. Table 5 recaps the information collected during the procedures of this case study.

Table 5 – Summary of the registration of the third case study.

Procedure	Evaluated artifact	Participants	Captured information		Duration
Collection + analysis (metalinguistic signs classification)	VisualParadigm tool	2 HCI experts	Interaction	V	01:40:05
			Ext. attitudes	V	
			Verbal prot.	A	
			Annotations	T	
			Files	S	
Collection + analysis (static signs classification)	Collection + analysis document, VisualParadigm tool	1 HCI expert	Interaction	V	01:11:09
			Ext. attitudes	V	
			Verbal prot.	A	
			Annotations	T	
			Files	S	
Collection + analysis (dynamic signs classification)	Previous documents, VisualParadigm tool	1 HCI expert	Interaction	V	01:14:46
			Ext. attitudes	V	
			Verbal prot.	A	
			Annotations	T	
			Files	S	
Collection + analysis (consolidation step)	Previous documents, VisualParadigm tool	1 HCI expert	Interaction	V	01:39:02
			Ext. attitudes	V	
			Verbal prot.	A	
			Annotations	T	
			Files	S	
Peer review	Previous documents, VisualParadigm tool	1 HCI expert, 1 Peer	Interaction	V	00:51:15
			Ext. attitudes	V	
			Verbal prot.	A	
			Annotations	T	
			Files	S	

5.2.1.3. Lessons learned

The SIM registration as previously mentioned exposes the iterative nature and the segmented analysis traits of the qualitative research. Again, we realized the need to allow for access to previous analyzes, which together with the current analysis generates new results.

Considering the aspects of the tool, this study led us to reflect on the possibility of implementing a mechanism to relate documents that may assist in a holistic view of the research process. Since the registration of this study generated a particularly large analysis iteration chain with four artifacts composing a trail of evidence of this analysis, such mechanism would help to structure and access similar research. This requirement resulted in the design of a post-processor component for creating data contexts and procedures, discussed later in Section 5.4.2.

On the methodological side, the registration of the validation procedure showed that the reviewer might need access to all analysis iterations, preferably with some indication of the natural order of occurrence of events for consistent reviewing. Another relevant point identified in this procedure is the possibility of capturing the evaluated software artifact. By integrating it as part of the registration artifact, we allow for direct interaction by those who access the registry later on, promoting a better judgment regarding the results of the research.

5.2.2. API inspection using SIM, CDN and CEM tags

Differently from the previous case studies where we registered evaluations of interactive interfaces, this study focuses on API assessment. It aims to observe how communicability problems in API design can cause further issues in software implementation and eventually in its usability. The researcher conducts the evaluation through a combined analysis of bug reports in PHP language involving three methodological sources, SIM (de Souza & Leitão, 2009), CDNf (Green & Blackwell, 1998; Blackwell & Green, 2003) and communicability tags used in CEM (de Souza & Leitão, 2009).

5.2.2.1. Observed scenario

Concerning the combination of methods, the researcher's analysis in this study is particularly attractive from a registration perspective. In a way, we partially recorded the emergence of the researcher's methodology as he experimented with available methodological resources, observing among other things if a particular order in triangulation could lead to different results.

We recorded two procedures of this study, the combined analysis of two bug reports and a validation procedure with the presentation of results. The analysis involved only one HCI expert, while the presentation involved the expert and an audience of peers that contributed feedback for research. Figure 24 illustrates the scenarios noted in the two procedures in this case study.

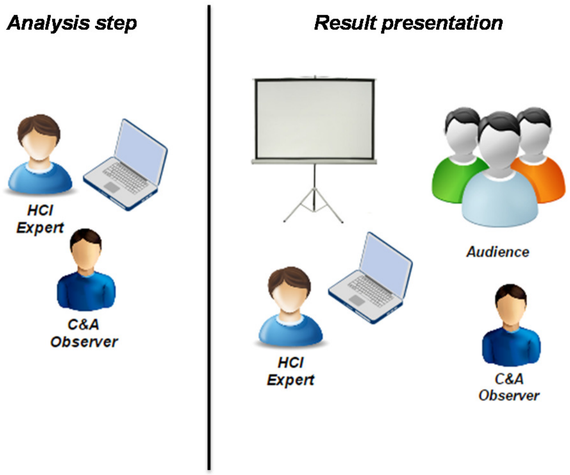

Figure 24 – Scenarios observed in the two steps of the fourth case study.

5.2.2.2. Registration

The two registered procedures in the fourth case study occurred respectively on July 31st and August 14th of 2014. In this registration, we captured the researcher's classification of two bug reports, selected from a list of more than six thousand bug reports he previously gathered. The researcher classifies them considering different dimensions assisted by the selected combined methods along with other defined categories.

The researcher uses CEM tags to classify communicability breakdowns in bug reports. He also applies the SemEng's metacommunication template to assist the classification of aspects where API designers were unclear or simply not considered for its use, potentially leading to issues on the communicability of the artifact. In addition, the researcher uses the CDNf taxonomy to characterize the cognitive impact of the analyzed bug reports on programmers.

Table 6 – Summary of the registration of the fourth case study.

Procedure	Evaluated artifact	Participants	Captured information		Duration
Analysis	2 bug reports	1 HCI expert	Interaction	V	00:54:45
			Ext. attitudes	V	
			Verbal prot.	A	
			Annotations	T	

<table>
<tr><td rowspan="4">Result presentation</td><td rowspan="4">Analysis document</td><td rowspan="4">1 HCI expert, Audience</td><td>Ext. attitudes</td><td>V</td><td rowspan="4">01:30:19</td></tr>
<tr><td>Verbal prot.</td><td>A</td></tr>
<tr><td>Audience</td><td>V</td></tr>
<tr><td>Slides</td><td>S</td></tr>
</table>

The document created for the analysis procedure used the layout experimentally designed during the previous case studies, while the document created for the presentation procedure used the final layout integrated to CAS Project (discussed later in Section 5.4).

5.2.2.3. Lessons learned

From a technical point of view, the registration of this study shows that the use of a C&A tool may affect the application of the method, depending on the implementation strategy adopted and the methodology applied. For example, for a consistent structuring and registering of a qualitative research it may be interesting that researchers record each procedure in a separate artifact, to reflect the study's rationale and facilitate access to captured data by the researcher and other stakeholders. On the other hand, if a single analysis session comprises triangulations or other activities involving multiple resources without explicit delineation, it may be impractical to operate a C&A tool to delimit these boundaries. If the tool requires some action on the part of the researcher to outline the registration artifacts, it is likely to entail an operational difficulty besides the issues about applying the method itself.

A further methodological result of this case study is the experimentation with research protocol registering. Through a verbal statement (highlighted in the analysis document by an annotation), the researcher explicitly details the activities of his research, reporting what has been achieved so far and the activities he will perform during the capture session.

5.2.3. Semi-structured evaluation

In contrast to the studies previously presented, we also explored the record of a more flexible evaluation. This registration comprises a semi-structured action-research study in which many details of the research methodology have emerged over its development. The researcher applied a participatory approach promoting development and change within the user's social group. In addition, he made detailed observations in the research field similarly to ethnography studies.

Unlike the previous case studies, the procedures of an action-research occur in longer time-frame cycles. That is, the researcher iteratively observes (ethnography), creates an artifact, intervenes (tests his artifact) and analyzes the results. In this case study, we recorded the steps of intervention (testing) and analysis of this testing. This intervention comprised the testing of the researcher's technology in field (user's home). This also included a parallel observation by the researcher, who created annotations during the observed interaction of the user with the artifact.

The evaluation registered in this study targets to explore practical phenomena from the participant's point of view. The research concerns the development of an assistive technology with wearable and voice-activated devices aimed at a specific user with severe motor disabilities. By means of a headset and hat equipped with sensors and microcontrollers, the technology enables a tetraplegic user to interact with different devices such as a computer, a smartphone, a TV set and lamplights at his home, by moving only his head, mouth and using his voice.

5.2.3.1. Observed scenario

The registration of the first step of the study (observation and preliminary analysis) was the richest in terms of variety of the captured content. The observed scenario involved the simultaneous observation of user interaction and preliminary analysis of the researcher. The apparatus in this scenario comprised a headset, from which the user could switch and control his laptop computer (via a voice command software, called Motrix[30]) or his mobile phone (through the software developed by the researcher, called aHub). The prototype hat captures the user's movements and transmits it to the software on his smartphone (an Android device), which acts as a hub, sending commands to other devices via an infrared transceiver. Additionally,

[30] http://intervox.nce.ufrj.br/motrix/

the researcher used an online service (Mobizen[31]) to stream the smartphone's screen to the user's laptop, so he could see what is going on in the phone.

We observed four scenarios in this study. The researcher defined a case study to observe the user's first contact with the prototype hat, which he had built earlier. We registered the observation of this first interaction with the proposed technology along with a subsequent analysis on the generated document. In addition, we registered a result presentation procedure and a statement where the researcher tried to clarify his bias on the study. Figure 25 illustrates the four scenarios captured during this case study.

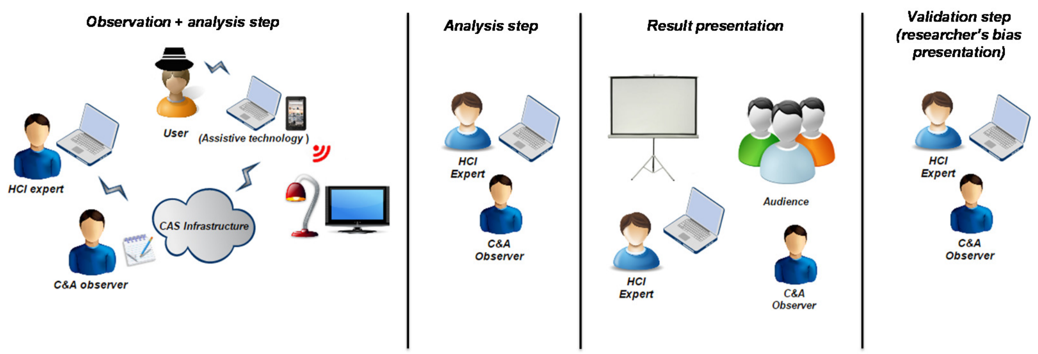

Figure 25 – Scenarios observed in the two steps of the fifth case study.

5.2.3.2. Registration

The four registered procedures in the fifth case study occurred respectively on December 4th, 18th and 23rd (two procedures) in 2014. The registration of the first step of this case study involved capturing user related information, such as his interaction with the proposed technology captured in video depicting the use of the prototype hat (along with externalized attitudes) and videos from his computer and smartphone screens (reflecting his controls). His verbal protocol was also captured (audio). The researcher related information comprises his interaction with the capture tool and textual annotator (provided by CAS), his externalized attitudes (video), his verbal protocol (audio), generated annotations (text) and attached files (software).

In the second step, we recorded a strict analysis scenario, focused in the researcher. We captured his interaction with the previously generated document

[31] https://mobizen.com/

with the observation and preliminary analysis, his externalized attitudes (video), his verbal protocol (audio) and notes with comments (text).

The third step involved a result presentation to third parties aiming a validation of the results. We captured information such as PowerPoint slides (software), presenter's externalized attitudes and verbal protocol (video and audio) and feedback from the audience (video and audio).

Finally, in the fourth procedure we experimented with registering of the researcher's bias exposure. In this registration, the researcher presented verbally some information about his graduation and technical background, research motivation and its goals and his interests as a researcher.

Table 7 – Summary of the registration of the fifth case study.

Procedure	Evaluated artifact	Participants	Captured information		Duration
Collection + analysis	User interaction	1 user, 1 HCI expert	User's interaction	V	01:25:12
			User's ext. attitudes	V	
			User's verbal prot.	A	
			Researcher's interaction	V	
			Researcher's ext. attitudes	V	
			Researcher's verbal prot.	A	
			Annotations	T	
			Files	S	
Analysis	Collection + analysis document	1 HCI expert	Interaction	V	00:25:47
			Ext. attitudes	V	
			Verbal prot.	A	
			Annotations	T	
Result presentation	Previous documents	1 HCI expert (presenter), Audience	Presenter's interaction	V	01:55:27
			Presenter's ext. attitude	V	
			Presenter's verbal prot.	A	
			Audience's verbal prot.	A	

			Audience's ext. attitudes	V	
			Slides	S	
			Files	S	
Bias presentation	None	1 HCI expert	Interaction	V	00:06:35
			Ext. attitudes	V	
			Verbal prot.	A	
			Annotations	T	

5.2.3.3. Lessons learned

The researcher defined a general plan in advance to guide his research. However, in qualitative research, especially in scenarios such as this, there is no way to anticipate all the details of the study. During the registration of the observation procedure, several unforeseen factors mainly from technical issues altered the study's design. The planning included performing two activities, but only one was conducted due to the delay caused by various technical problems, such as connectivity problems, failures in the online service used for the streaming the smartphone's screen to the computer, and some errors in CAS infrastructure during the distributed recording. However, this did not weaken the conducted study, since investigating a single scenario proved to be valuable for the researcher's analysis.

This study demonstrated that a possible instrumentation of the user-manipulated software could be relevant to the recording and analysis of the interaction. That is, researchers could instrument the evaluated software to provide metadata about the interaction activity implicitly. In this case, the software playing the hub role in the smartphone could record user interaction events, internal errors and other information that could be part of the generated document as textual media.

5.3. Cross-study comparison

The conduction of the five case studies promoted relevant reflections regarding methodological and technical aspects about registering qualitative studies. During thirteen months, we planned and conducted different studies to observe issues concerning observation, analysis and validation procedures. We registered five different methodologies, including three explicit methods (CEM, SIM and CDNf) and a semi-structured study. Fifteen registration artifacts were produced. The third case study (evaluation combining SIM + CDNf methods) had the highest number of generated C&A artifacts, with a total of five. Concerning the duration of the events, this study was also the longest with approximately 6h36min.

Considering the observed methodological aspects, the case studies were important to emphasize inherent issues of the qualitative methodology applied to HCI, which may be common to other research areas as well. In the first case study, the CEM tagging step highlighted the iterative aspect of qualitative research. That is, analyses carried out may refer to previous results leading to its completion or correction (editing).

SIM has a defining characteristic of segmenting the analysis. The first three steps of the method lead the researcher to conduct a segmented analysis of data. The researcher analyzes classes of signs separately and then combines them, interpreting them altogether in a meaning-making process to build his analytical categories. This iterative process including segmented analysis, meaning-making process and categorization targets the creation of categories to assist the interpretation of phenomena with an increasing abstraction level. The second and third case studies reflected this feature. The third case study also highlighted the relevance of a possible relational semantics to define explicitly the relation between procedures, thus facilitating an overview of the research process.

The fourth and the fifth case studies were relevant to the perception that the registration of a research protocol may be valuable for stakeholders wanting to be informed about the research process. This is true especially when the research methodology has an innovative format, i.e. different from the traditional ones used in qualitative research. The fifth case study was also important to reaffirm the emerging feature of this type of research, where it doesn't make sense to define a completely detailed plan ahead of research execution.

The case studies were also relevant with respect to technical aspects and the identification of requirements for development of C&A tools focused in qualitative research documentation. In the first study, we identified the requirement for document editing, an activity that often is not explicitly supported by C&A tools. In addition, we have identified the importance of enabling a parallel viewing of videos depicting the interaction and externalized attitudes of users, along with the possibility of emphasizing one of the videos.

The segmented analysis of the studies involving SIM (second case study) also led us to reflect on the feasibility of document agglutination. That is, the possibility of attaching documents in the generation of new C&A artifacts. A mechanism with such functionality would facilitate the aggregation of information scattered among different artifacts. In addition, along with the identified methodological feature of creating relational semantics to procedures, we identified the possibility of relating data and documents in contexts, which would minimize the cognitive impact on the user when accessing this information. In this study, the researcher also suggested a list comprising all the annotations to facilitate the analysis process.

Another aspect that promotes the access process was observed in the third case study. We have identified the relevance of capturing and making available the evaluated software artifacts into access documents. This would allow that external validators or people simply interested in the research manipulate this software artifact directly themselves, generating empirical evidence by themselves (which may be collated with previous results from evaluations) and thus minimizing possible biases of an indirect description of this artifact.

In the fourth case study, the researcher developed a combined methodology without a clear delineation of this combination. A mechanism making it possible to separate these procedures and at the same time not affecting the methodology itself would certainly be relevant. Finally, in the last case study involving different devices in a ubiquitous setting, we identified the relevance of instrumenting the manipulated software artifacts so that they provide metadata about this manipulation implicitly. Table 8 summarizes the information discussed contrasting the results shown in each case study.

Table 8 – Cross-comparison between results and features observed in the registration of case studies.

Case study	#1	#2	#3	#4	#5	Total
Applied method(s)	CEM	SIM	SIM+CDNf	SIM +CDNf+CEM tags	Action-research + ethnography	5
Registered artifacts	2	2	5	2	4	15
Duration	03:02:47	01:58:59	06:36:17	02:25:04	02:27:49	16:30:56
Observed methodological aspect(s)	Iterative analysis	Segmented analysis	Segmented analysis, Relational semantics	Research protocol definition	Research protocol definition, Unpredictability	5
Observed technological aspect(s)	Video comparison, Document edition	Document agglutination, Annotation list	Document and media contexts, Capturing of software artifacts	Procedure delimitation	Software artifact instrumentation	8

5.4. Prototype implementation

Throughout the conduction of the case studies, it was necessary the development of some features that were not available in the CAS infrastructure, the main one being documents with appropriate layout elements to assist HCI evaluations, as stated before. Additionally, other activities in the case studies identified potential features regarding the structuring of data and recorded procedures.

5.4.1. Layout elements

We implemented the initially proposed layouts for conducting the case studies as proof of concept, developing them directly in HTML5 and JavaScript. We created the preliminary documents one by one after the registration of the procedures. That is, we used CAS infrastructure to record the events (qualitative procedures), but the document generation process was carried manually, since we needed to experiment the effectiveness of different interactive elements in the documents.

Later, several of the layout requirements identified and addressed experimentally in the case studies were integrated into the CAS Project as a post-processor component for automatic document generation. This post-processor component also uses HTML5 and JavaScript to create documents and handle media synchronization. This component takes an intermediate representation of the event described in the Raw profile of the NCL language as a base to create the access documents.

Considering the possibility of generating documents for different purposes, we designed the post-processor component in a modular approach based on document templates. Currently, there is only one generic template, which supports document generation with an arbitrary media configuration. Nevertheless, its design allows it to be further expanded with different templates that could be generated by third parties, such as web designers. Figure 26 shows the layout elements incorporated into the post-processor for document generation in CAS infrastructure, the elements indicated from 1-8 are discussed as follows.

Figure 26 – Final layout elements integrated to the CAS post-processor component for document generation.

We fully incorporated some of the elements designed in the experimental document layout in the post-processor component, such as the case with the help dialog that became a menu on top of the document (item 1). In addition, another menu incorporated some of the resizing features to allow for emphasizing one of the main media. The event's metadata (item 2) was also fully incorporated to the component's features. Besides, we contemplated the concept of side-by-side view for two main videos comprising the user's externalized attitudes (identified by 3) and his interaction (item 4).

The HCI experts also pointed out that a list comprising all notes taken during the recording could facilitate the analysis process, allowing for a quick and complete view of their notes. We incorporated this requirement in the sidebar on the document's right side (identified by item 5). This area has tabs through which it is possible to switch between the list of annotations and a list of additional visual media (if any). Figure 27 illustrates the expansion of this area holding extra visual media, it is possible to drag-and-drop them to one of the two central positions.

The post-processor for document generation retrieves the files attached through the text annotator (SpeedCar for text media) during recording and automatically includes them in the document, resulting a file list similar to the preliminary layout (item 6). There are also buttons for hiding and showing the left and right sidebars of the document (items 7 and 8).

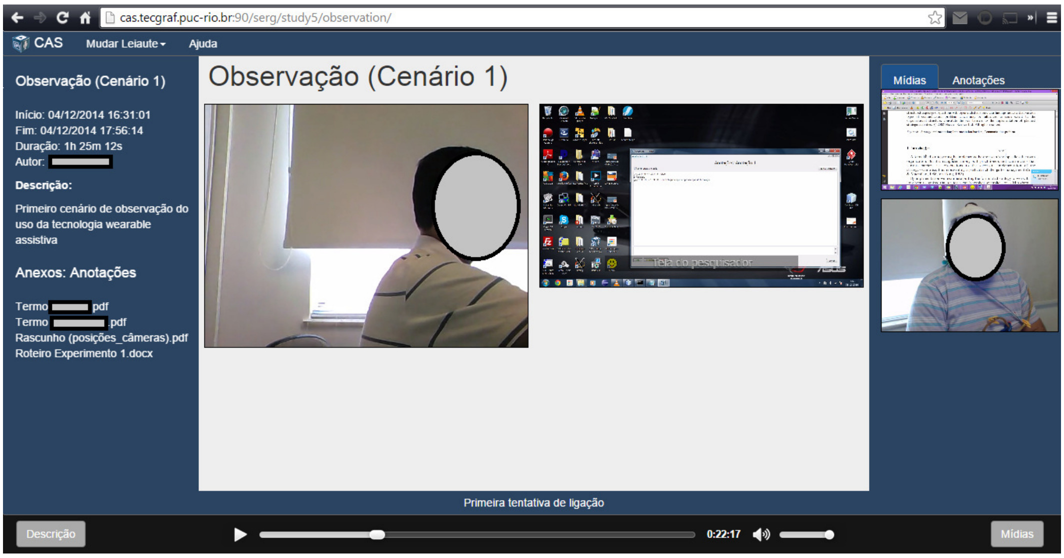

Figure 27 – The right side area allows additional visual media in the document.

5.4.2.
Context post-processor

The case studies have shown that the analysis of empirical data and the diversity of procedures conducted in a qualitative methodology may comprise a complex process with a large amount of digital continuous media. This has reinforced the need for a post-processor component in CAS Infrastructure to create contexts to build relations between captured data and events. This is a requirement that we had already observed before the preliminary case studies, but until then we wanted to create only two types of contexts defined by time interval and by media files. That is, the user could relate a certain time interval of the event recording to a specific context, or a particular set of media (or parts of them) as a context. Accordingly, the document post-processor component can use this information to provide contextual links in the document, allowing users to seek for a defined context's time or to visualize separately different media from a specific context.

We designed and developed a post-processor component to support this feature along with an interface for user data input in the post-processing role of the CAS control panel. The component reflects the user-created contexts in the intermediate description of the event, by means of NCL contexts. Figure 28 shows the implemented interface to define these contexts by time and media.

The detailed record of qualitative research (or a single stage of it) may produce a large number of events reflecting scientific procedures. Thus, one needs some sort of basic structuring among these events to facilitate access to the data set.

This goes together with the need for a relational semantics observed in the case studies involving SIM.

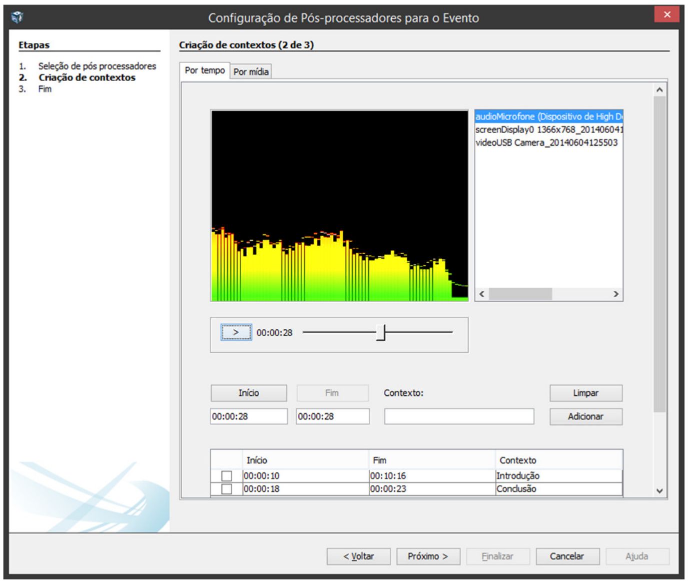

Figure 28 – Implemented post-processor interface for creating contexts by time interval and media in the CAS control panel.

In this sense, we intend to extend the post-processor's functionality allowing the user to create relationships between events. To give the reader a sense of what this amounts to, the mockup shown in Figure 29 presents an interface proposal to allow users define these relationships. In it, the user can associate the event he is currently post-processing with previously recorded events. These relational properties are discussed further in Section 6.4.

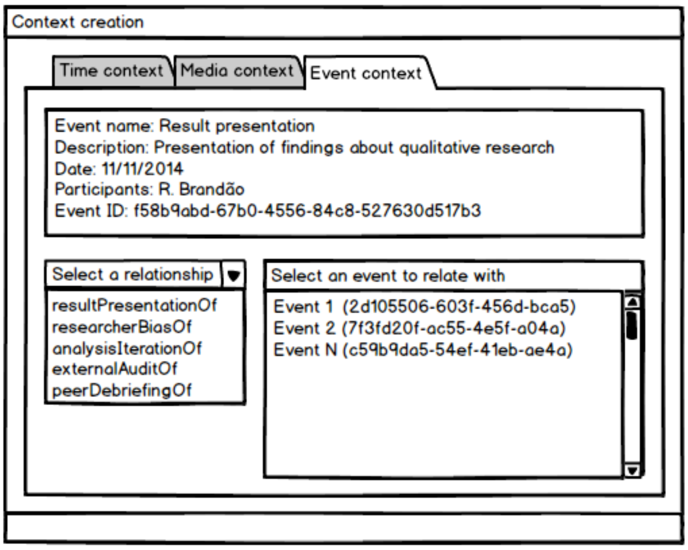

Figure 29 – Mockup of the proposed interface for creating contexts among events.

5.4.2.1. Contribution to the NCL Raw profile

The NCL Raw profile does not have reuse mechanisms and other kinds of syntactic sugar. A document described in this profile may produce code hard to read by humans, but it eliminates redundancies and enables a simpler interpretation of it. It can also serve as an intermediate notation for other declarative languages such as SMIL, SVG, LASER and others (Lima et al., 2010).

During the definition of this profile by the TeleMídia Laboratory at PUC-Rio, which is responsible for the development and maintenance of NCL language, the use of contexts by the CAS infrastructure using the Raw profile provided evidence about the relevance of this mechanism in the profile. Thus, the design and development of the context post-processor in the CAS infrastructure contributed to this definition.

6
The C&A4Q model

This chapter presents the main contribution of this thesis, the proposal of a conceptual C&A model targeted at supporting the registration of qualitative research procedures applied to HCI. These procedures typically involve scenarios with analyses on empirical data and observation of software interaction, both cases effectively supported by continuous media. The model represents the registration of the procedures as components, highlighting the context surrounding them, their relation, and data access flows. This model is the result of reflections over the registration and exposure of qualitative methodology carried out in previously addressed case studies, and builds on works in qualitative research design, C&A and HCI literature. We named this Capture & Access model for qualitative research as “C&A4Q model”.

Different authors within the Social Sciences offer distinct approaches to model and support planning in the development of qualitative research. Commonly, these models address the issue of qualitative research design in two different ways. By offering a variety of basic designs so researchers can choose one to guide their actual study, e.g. Creswell (2013, 2014). Or, by listing and discussing the components from research design, with a rundown of critical aspects the researcher should take into account when planning and performing qualitative research, such as the interactive model proposed by Maxwell (2013), and the discussions by Flick (2009).

The C&A4Q model subscribes to the second approach described above. Strictly as a conceptual model, it can support researchers to design and conduct a thorough registration of their qualitative inquiry, by addressing issues for this purpose on important components of the research design. Additionally, an innovative aspect of the C&A4Q model is that it draws on qualitative research design fundamentals on top of a C&A concept. Thus, it is computationally attractive and amenable to a software implementation for practical registration of qualitative investigation encompassing different stages of the process. In this sense, this model can further benefit both software designers interested in developing tools for supporting qualitative research, and the users of these tools implementing the conceptual model. The users (including researchers again) can use these tools to register, retrieve, and visualize the course their investigation is taking. Therefore, these tools can aid the qualitative research process altogether providing a concrete visualization of the investigation, as a holistic view that users can use for reflecting upon the registered (or missing) procedures, creating new meanings about it.

Although the model's conceptualization takes HCI evaluations as a basis, which naturally shapes some of its characteristics, we recognize the potential of broadening its application to other research fields as well. Works from the qualitative research design within the Social Science's literature directly inspired the model. Thus, the registrations proposed in the C&A4Q model may be adequate to qualitative procedures that researchers apply across different areas. The model has been designed to assist researchers in planning procedures, in reflecting on the collection of data and corresponding interpretations, as well as in, structuring and accessing empirical data that lie at the basis of the entire process.

The resulting solution of this conceptual model grounded on a C&A theory gets together into a single rationale multimedia documentation the steps that constitute a qualitative investigation process. That is, with all possible iterations and revision cycles at intermediary stages, to plan, collect, analyze, validate, publicize, and probably start the entire process all over again. Reflecting on these events as a whole can highlight significant characteristics otherwise hard to perceive or probably going unnoticed along the way.

The C&A4Q model aims to support planning by anticipating key procedures the researcher should register to communicate explicitly the research's protocol. We use a broader notion of the research protocol concept, covering activities from the very basic definition of a qualitative research plan, such as the research question and the conceptual framework underlying the study, as well as the presentation of the researcher's bias with his/her background and methodological choices. It could encompass ethic issues too, when they are relevant to the research. Analysis and validation of the findings are also relevant issues addressed by the model. It anticipates a series of procedures related to validity and reliability of qualitative studies. Qualitative validity explores procedures and means to achieve a higher level of accuracy of the findings (Creswell, 2013). Whereas, qualitative reliability procedures tackle the consistency of the approach across different researchers and distinct projects (Gibbs, 2007).

Data collection closely relates to the nature of C&A technologies, and can greatly benefit from this field's foundations. A detailed capture of the performed procedures promotes deep investigation, allowing the comparison of particular aspects of an investigation activity that otherwise probably would go unnoticed. A C&A perspective helps to establish criteria for data collection, making media properties explicit and stressing vital aspects about the design dimensions to produce an appropriate registering.

The C&A4Q model is proposed to assist the analysis process leading the researcher to reflect upon the investigation process "through doing it". Since researchers cannot completely describe a qualitative research *a priori*, our approach is to offer this model as a tool for delineating the process on the fly, or after completing some procedures. This way, researchers can ponder on the course their research is taking through a visual aid, and can reflect on the next step to take.

The C&A4Q model contemplates the validation process within the qualitative investigation by laying down procedures of validity and reliability for this purpose. The model suggests a list of procedures based on the literature of qualitative research design aiming at increasing the conducted research trustworthiness, but is not restricted to these components. One can integrate new or adapted components by drawing a parallel on the issues about registration of the addressed components. Validation procedures can be internal, carried by the researcher inside his/her own context, or external, done by outer personnel. In the latter case, a publication procedure is required.

The publication process in any scientific research is vital to their development. Whether for the purpose of presenting its results to the scientific community, or in seeking for external validation. The model adopts a flexible publication concept, not necessarily tied to a traditional publication (e.g., in periodicals, conferences and journals). We employ the publication concept as the activity of externalizing research properties. In this sense, the researcher is in charge of defining what the desired characteristics to be published are, which specific aspects (say, a single analysis or result presentation) can or should be externalized and how, as well as the publication of only a selection or of all procedures performed in their entirety. The publication can comprise edited versions (with cuts and selection of excerpts) or anonymized versions of certain recordings, since preventing the exposure of research participants' identities is the ethical norm in most cases.

There are fundamental differences between the C&A4Q model and the models typically seen in the qualitative research design literature. The following sections attempt to shed some light on the unique characteristics of our model: the conceptual support of a C&A technology and the significance of using recordings or registrations (as opposed to procedures) as components; the features motivated by the selection of HCI evaluations as the specific case; the contemplated procedures and the context surrounding them; and finally, the use of this model as a tool for supporting abductive reasoning.

Figure 30 shows the main elements involved in the designing and use of the C&A4Q model. It displays the analysis and validation procedures discussed in the context of qualitative research design as the basis for the model; the model in turn, draws on aspects of the C&A, HCI, as well the qualitative research design field. A possible software implementation of this model should consider issues addressed by Software Engineering, C&A, and HCI areas. In addition, on a higher level of abstraction, the study of the cognitive processes of abductive reasoning are of particular interesting for disciplines such as Artificial Intelligence, Cognitive Sciences, Logic and studies of the Philosophy of Science.

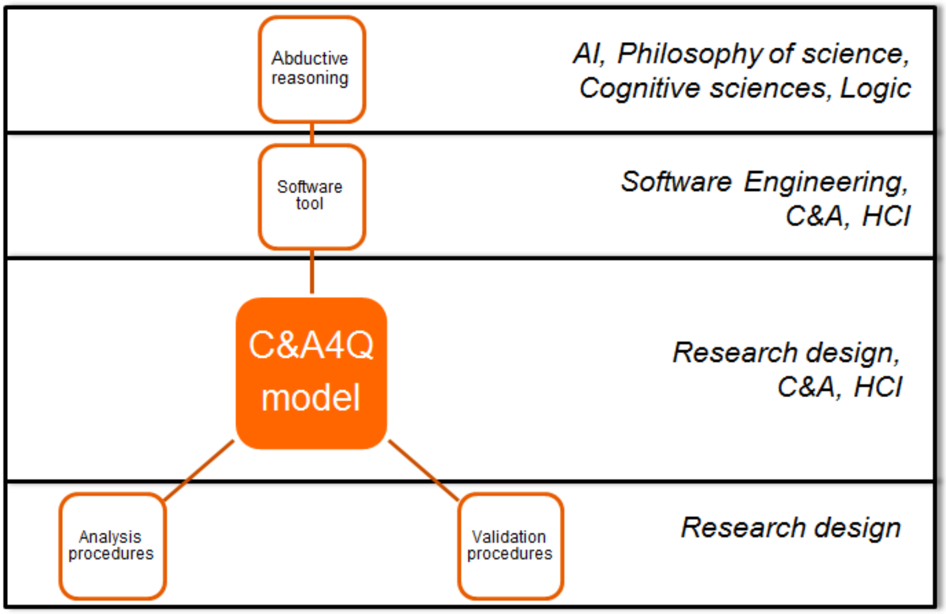

Figure 30 – Related research topics and the elements involved in the C&A4Q conceptualization and usage.

6.1. C&A technology groundings

The use of a C&A technology as a support to the conceptualization of our proposal introduces important definitions to the C&A4Q model. Primarily, components in this model represent registrations (or recordings) of qualitative procedures, not the procedures themselves. This creates a completely different scenario in terms of the aspects the researcher should ponder on, besides all of those elements discussed about actually carrying out the qualitative procedures. Our model's focus is on supporting researchers on how to adequately register his/her qualitative process from a C&A perspective. That is, it promotes reflecting on data collection details to produce a rich registration of analysis and validation activities, ultimately allowing people interested in these events to access them in an informed way.

As discussed in Chapter 4, anyone trying to capture and access information faces issues that go beyond the record of the data itself. As highlighted by Truong, Abowd & Brotherton (2001), designers in a ubiquitous context should also take into account users, devices, media, time and locations involved in the recorded setting. In this work, they synthesize five design dimensions in the following questions: who are the users (or participants) involved in the recording? What is to be captured and accessed? When is capture and access to occur? Where? And, how? This approach assisted the design of the proposed model giving insights about general aspects originating from the C&A domain concerning the registration of live experiences.

Additionally, multimedia and hypermedia features are also inherent attributes of the C&A research, as it relies on capturing, indexing, and presenting heterogeneous (continuous and discrete) data. Conceptual hypermedia models are useful to represent structural concepts, events and relationships regarding these types of data. They can define rules and operations for manipulating these structures. Some of these models' grounds have inspired the design and conceptualization of the proposed conceptual C&A4Q model, in particular the NCM model (Casanova et al., 1991; Soares et al., 1995; Soares & Rodrigues, 2005). This hypermedia model uses a concept of nodes (information fragments) and links (relationship among nodes). There are two basic nodes, content and composite nodes. The composition of nodes is a key point to define structuring and relationship in the model.

The NCM conceptual model has inspired the nesting mechanism proposed in our model for component structuring. Researchers relying in the C&A4Q model can reference sub-artifacts that make up a composite component. This abstract mechanism targets at the agglutination of different components in order to support a convenient representation of a public artifact, as discussed later on over the publication features of the model (in section 6.5).

6.2.
The HCI case

Differently from the models observed in the perspective of the Social Sciences, the C&A4Q model evolved through an HCI stance and, as such, inherited some of its traits. A considerable number of HCI research studies involve observation of interaction between users and software artifacts. These studies build on a temporal facet wherein the recording of information in a chronological arrangement becomes crucial to depict consistently the observed events, therefore leading to a proper analysis on them.

Consequently, a clear distinction between the two perspectives relies on the language utilized and manipulated in the studies and the appropriate media for its transmission. Authors in the qualitative research literature often emphasize speech and writing activities, and the importance of verbal and textual language, which one might expect, since this type of research explores social problems and this is the natural form of communication in such context. In addition, researchers typically produce textual reports and narratives both in data collection and in analyses of the studied situations. Of course, images, videos and other empirical media also play a role on the traditional qualitative research, but mainly as a support to analysis, or used to record specific situations.

In turn, HCI evaluations similarly depend on a variety of empirical data, but temporal information, and hence, continuous media, both play a key role within this environment. In scenarios including user observation, the actual language the researchers are interested in is the interaction itself. By adopting a particular communication-centered perspective on HCI, namely Semiotic Engineering (de Souza, 2005), the use of continuous media stands out.

SemEng characterizes the interaction between the user and a software artifact is a metacommunication process that is a central phenomenon. The theory considers systems (and other software expressions) artifacts of a mediated communication through which the designer sends users a message expressed through the software interface (the designer's proxy), this message's content is the conceptual model of the application. The designer's message has a dynamic and interactive nature as it is formed by a set of signs (texts, images, sounds, and other data) exchanged by the user and the system during the process of interaction in a given period of time. In scenarios with inspection purposes where supposedly there is no user engagement, HCI experts may still explore interactive aspects by manipulating software artifacts by themselves, simulating user's behavior. In such contexts, where this particular kind of communication is a main issue, the use of continuous media allows the registration and presentation of the conversations held between humans and software artifacts.

Three classes of actors stand out in qualitative activities performed in the HCI context: researchers (as evaluators and/or observers), participants (commonly, users interacting with software artifacts) and stakeholders. Researchers usually observe participants, but participants can also act as external validators. For example, in a member-checking procedure, researchers may take back their results to participants, so they can express their feel over the accuracy of the findings. Stakeholders have different interests and perform different roles. They may be peers and auditors acting as external validators aiming to refute or confirm researchers' findings and procedures. Alternatively, they may be other researchers just interested to inform themselves about the details of the inquiry process.

Typically, the qualitative research process unfolds itself over different "time frames", which lead to different opportunities of observation and analysis of the research question. The object of study occurs in a first time frame (evidence space) that is captured and transposed so that an analysis can happen in a second time frame (research space). In the research space, the investigator manipulates and analyzes evidence registers (signs, to put in semiotic terms) representing the subject matter. These evidence signs may be transposed to a third time frame as well, where any interested person in the process, or stakeholders acting as external validators may manipulate them directly. Outside the evidence space, there are only representations of the evidences, even if the transposed evidence has the same content. For instance, a text document transposed from the evidence space to the research space has no longer the same meaning, even if it is a copy or the same document; the sign interpreter is unable to consider aspects of the physical locations where the evidence was conceived, for example. Thus, a transposed evidence becomes a sign that represents concepts or events in the evidence space. The activities of the researcher involve analyzing and interpreting these signs, generating other representations or signs, typically by categorizing data until his/her findings reach a configuration deemed satisfactory. These findings are expressed in a representational system belonging to the second time frame, which may or may not match the "language" of the evidence. The evidence signs manipulated by researchers and stakeholders in the second and third time frames are connected to the evidences in the first time frame through a semiotic continuum.

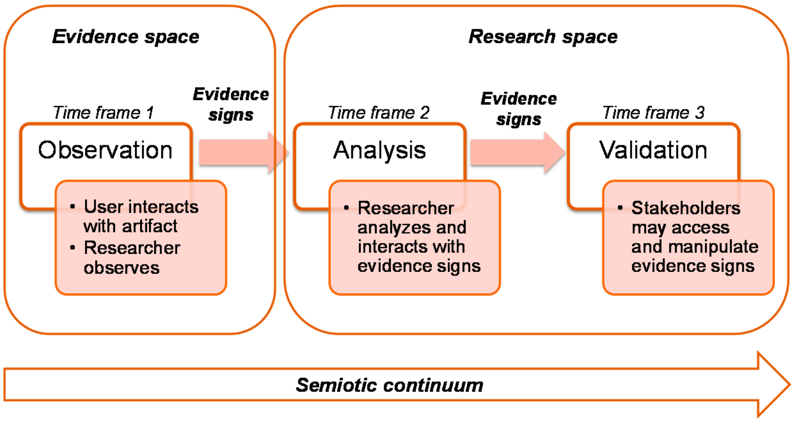

Figure 31 – A temporal view of the qualitative research applied to HCI based on a semiotic perspective.

One can correlate this scenario with the HCI case. In the first time interval, researchers typically observe and register user interaction with software artifacts. The registered evidences become signs in the research space, which the researcher may manipulate and analyze creating new meaning in a specific representational system. In the proposed C&A4Q model, researchers achieve this representation by creating multimedia documents with their procedures and findings. As with the case of the text documents that can be transposed in its original format to other time frames, one might think that software artifacts are also subject to such transposition. It is possible to transpose them in their entirety enabling a direct manipulation outside the evidence space. This allows for the researcher to manipulate this artifact at will as an empirical evidence generator. Although generated in the second time frame, the generated evidences may be collated with evidences from the first time frame. This direct manipulation also makes it possible for third parties to experiment and build their own meaning of the evidence through this sensorial access, possibly minimizing the researcher's bias by avoiding an indirect description about the artifact. Figure 31 illustrates a temporal view of the qualitative research applied to HCI with evidences and their signs linked by a semiotic continuum throughout the process.

When there is a continuity of the carrier medium through the object of study and the object of analysis, e.g., if evidences, analyses and findings are written in natural language or are expressed as software, it creates a scenario where it is difficult to assess the research findings. This representational continuum makes it particularly tricky to distinguish the researcher’s discourse from the evidence itself. There is nothing preventing the researcher’s interpretation to cross to the evidence space, which can lead to misleading interpretations by third parties. Therefore, we believe that the choice of HCI as the specific case to base the C&A4Q model is especially appealing. We hope that the structuring proposed by the model can assist in this distinction between the evidence and research spaces, i.e. the researcher's discourse and the evidences.

6.3. Contexts and procedures

The C&A4Q distinguishes between two major contexts within the registration of a research process: the researcher’s own context, and the scientific community’s context that may be interested in validating or simply studying the research. In the proposed concept, we consider the capture of analyses and validation procedures carried out by researchers as “internal” activities within the researcher’s context. Validation procedures performed by people outside this context are “external” activities, carried out in the larger scientific community’s context. The later provide feedback to researchers regarding publicly available material. Figure 32 illustrates the featured contexts in the C&A4Q model and the interaction between them.

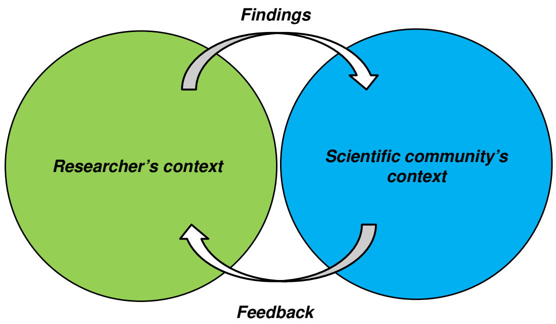

Figure 32 – The model distinguishes two top-level contexts, the internal (researcher) and the external (scientific community).

From a strictly registration viewpoint, one can classify procedures as either mandatory or optional. Evidently, the more validation procedures are performed and registered, the better the research becomes in terms of trustworthiness, but from the perspective of creating a record, it is viable to register a minimum set of components for future reference, e.g. comprising only observation or analysis. Thus, researchers should make available at least some procedures from inside their context along with some sort of public representation of these registrations. However, our intention is that researchers reflect upon and register as many contemplated procedures as they deem necessary in order to allow for a detailed inspection and increase of the investigation process' robustness. Although this work focuses in qualitative research, we envision the integration with a quantitative approach that researchers can exploit in different ways (as discussed in Chapter 2). Figure 33 shows a slightly more detailed view of contexts and the main activities they enclose.

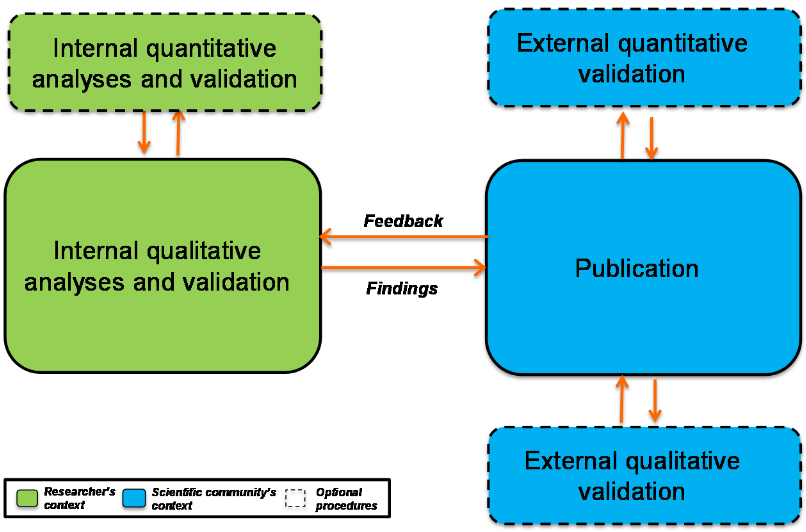

Figure 33 – Main activities within the two C&A4Q's top-level contexts.

Based on the discussions raised by Creswell, Flick and Maxwell about the research conduction and trustworthiness of qualitative research processes, the C&A4Q model suggests the registration of different procedures in order to support planning and structuring of both analysis and validation. The following subsections discuss these procedures and the rationale involved in their registering. For each component of the model, a discussion lists the main aspects related to its registration. In addition, a table presents the summary of the answers to the five questions that comprise the design dimensions grounded on the C&A foundations. Who are the users capturing and accessing these components? What kind of information could researchers capture? When is it possible to register these components in the research process? Where they can occur? How can researchers deal with capturing?

In addition, a discussion about the publication of recordings attempts to elaborate on issues involving anonymization to preserve participants' identities, the possibility to create edited versions of C&A artifacts, the forms of publication, and the concept of component nesting to support the modeling of publication processes.

6.3.1. Analysis procedures

A prominent feature of the analysis in qualitative research lies in its iterative nature, i.e. its accomplishment through a series of segmented inquires. An explicit and organized representation of such iterative steps in analysis allow for an organized expansion of breadth or depth of analytical segments. The model characterizes this segmentation by means of a context we called the “iteration chain”, which is nested inside the researcher’s internal context. This mechanism allows for the reification of an important aspect in the research process. According to the number of iterations, researchers can get a sense of how much effort they spend in pursuing specific results. A long chain is a sign that the researcher is putting a lot of investigation energy in exploring that particular situation. Figure 7 depicts our visual interpretation from the sub-context of the segmented analysis in the C&A4Q model.

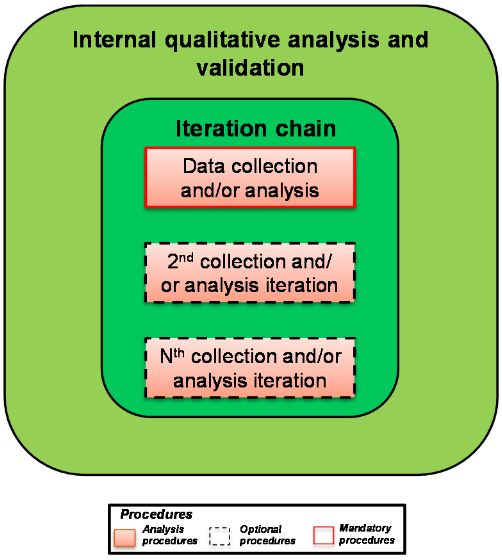

Figure 34 – Iteration chain nested within the researcher's context.

With the cases studied in our own research, we have seen that HCI experts often perform a preliminary analysis already during the data collection stage. Thus, we feel that a model component to represent a step in the iteration chain may encompass both collection and analysis, i.e. this component can signify exclusively a collection activity, a collection along with preliminary analysis, or an analysis only.

The analysis process in the context of qualitative research, and particularly in HCI, often involves a categorization of the empirical data in a procedure known as *coding*. It consists of an analytical process in which the researcher forms categories (or codes) to label chunks of the captured data to facilitate analysis. From the generated codes, researchers can form broader categories known as *themes*, which aggregate different codes under a common feature. Some qualitative methods may provide a set of codes and themes *a priori* for using in this classification, e.g. SemEng's CEM and SIM methods define different tags and sign classifications in their approach.

Since researchers can opt to record an exclusive observational scenario, i.e. only with data collection (user's interactivity) and no analysis activities, the registration of this component may have two different designs. A strict observation event would capture only the user's interactivity with the software artifact. Optionally, the recording of his/her externalized attitudes could further enrich the captured scenario. HCI experts can take advantage of this information. For example, perceiving the user's sentiment may be crucial to study and understand what is really going on in the interactive process. The interest of accessing this registration is mainly the researcher's, but external peers and stakeholders may also be interested in it. The recording of an observation can take place at any time, without any causal restrictions from a general inquiry point of view. It is a self-contained event and does not necessarily depend on any external factor or previous activity. Regarding the location, this scenario can occur both in a field of study (the user's natural setting, e.g. at his/her home or workplace), or in a specific site for data collection, such as a laboratory or instrumented rooms with specialized devices. It is also possible that researchers carry out the recording in the context of a ubiquitous and collaborative process, with multiple participants. This scenario could proceed in both implicit and explicit registration modes. Researchers can collect information automatically, e.g. they can instrument the software artifact the user interacts with to create data about its manipulation. Alternatively, they can guide the registration process through the operation of specific tools for this matter.

On the other side of the coin, in an analysis scenario that can coexist along with an observation, the main actor involved in the capturing process is the researcher (and the user, if observation occurs simultaneously). Stakeholders and the researcher himself are possibly the most interested parties in accessing the registered information. Despite from the different purposes and practices between an observation and an analysis their registrations are analogous in some aspects.

The main contents to capture are the researcher's interaction with specific tools and manipulation of the empirical collected data (comprising his reasoning), attached files concerning specific topics, and, optionally, the recording of externalized attitudes. Notes with findings are also of particular interest in this scenario. These notes could be discrete textual annotations, or texts associated to timestamps resulting in a temporal annotation. These annotations can act as links to parts of other information (interactivity, visual and audio notes) regarding some aspect of the analysis. We call these parts of data that links can refer to "anchors", borrowing the term used in various hypermedia models, including the NCM (Soares & Rodrigues, 2005). By using links and anchors, researchers can highlight relevant points to those who will access this record, leading the viewers to specific moments in the analysis process. For this scenario to take place, it should happen along or after an observation. It has no constraints regarding location; it could occur at the researcher's work place (e.g., laboratory) or home. The researcher is in charge to operationalize explicitly the recording of his/her analysis activities. However, as is the case with observation, researchers can instrument software artifacts involved in the analysis to provide metadata regarding the interaction process.

Table 9 associates the activities performed in the collection and analysis component with the C&A design dimensions, highlighting relevant information that researchers may be interested when registering these procedures. This table (and the following tables addressing other components as well) summarizes the five C&A dimensions for each activity in the component (in this case, observation and analysis). It shows *who* are the involved parties and their roles in the capture and in the access stages distinctively (indicating C for capture stage and A for the access stage). *What* kind of information (e.g. software artifacts, activities, and other evidences) researchers may be interested in capturing. Commonly, this information includes interaction with software interfaces, the software artifact itself, verbal protocols, visual depiction of externalized attitudes during interaction, produced or related files, annotations, etc. Along with this information, the table indicates an adequate medium type to register this information (meaning A for audio stream, V for video stream, AV audio and video stream, I for image, T for text and S for software, including binary files). The table presents aspects of the *when* dimension highlighting possible causal relations resulting in sequential activities during the qualitative process. If there is no such relation then the activity can occur at any time. In the *where* column, the table presents terms regarding the location at which researchers usually perform the activity, it can be one or more terms defining single locations or a ubiquitous scenario. Finally, the *how* column indicates if researchers can record the activity implicitly, through the instrumentation of software artifacts to provide interaction metadata, or through the explicit operation of specific tools for this purpose.

Table 9 – Association of activities in the collection and analysis component and the C&A design dimensions.

<table>
<tr><th>Activity</th><th>Who?</th><th colspan="2">What?</th><th>When?</th><th>Where?</th><th>How?</th></tr>
<tr><td rowspan="4">Observa-
tion</td><td rowspan="4">C: User
A: Researcher</td><td>Artifact</td><td>S</td><td rowspan="4">Any time</td><td rowspan="4">Field,
Lab,
Ubiqui-
tous</td><td rowspan="4">Implicitly,
Explicitly</td></tr>
<tr><td>Interaction</td><td>V</td></tr>
<tr><td>Verbal prot.</td><td>A</td></tr>
<tr><td>Ext. attitudes</td><td>V</td></tr>
</table>

Analysis	C: User, Researcher A: Researcher, Stakeholders	Artifact	S	During or after observation	Anywhere	Implicitly, Explicitly
		Interaction	V			
		Verbal prot.	A			
		Ext. attitudes	V			
		Annotations	T			
		Files	S			

In addition to the collection and analysis component, we observe that two additional elements can generally promote the registration of the analysis process, the presentation of results synthesizing the research findings, and making an explicit statement about the research protocol.

The recording of a presentation of the research findings is essential to expose adequately the knowledge generated in qualitative studies. Given the inherent subjectivity in the qualitative results, all clarification that can aid the knowledge transference process is valuable, especially when it comes from the researcher's own criteria. This is in line with the "thick descriptions" in qualitative studies, which are selected, presented and structured according to the researcher's view. It is an opportunity to expose the reasoning by linking the observed evidence to the achieved results. Moreover, the recording of this view leaves a concrete evidence trail that stakeholders can conveniently revisit at their will. Scenarios of this nature often involve slide presentations, along with the researcher's explanation (verbal protocols, and optionally, externalized attitudes during the presentation). As in the analysis activity, temporal annotations can provide links to specific anchors. It is possible that this presentation involves an audience too, which can give feedback on the presented issue. A clear causal relation restrains the registering of this scenario in the inquiry process. For this component to exist, researchers must have carried out previous analysis, whose results they would present as new knowledge derived from the research. Researchers do presentations in many different locations, particularly in classrooms, laboratories, seminars, meeting rooms, etc. In practice, they conduct the capture process explicitly by commanding specific tools for recording the experience. Table 10 below relates the only activity (presentation) of this component with the C&A dimensions for this component.

Table 10 – Association of the activity in the result presentation component and the C&A design dimensions.

Activity	Who?	What?		When?	Where?	How?
Presentation	C: Researcher, Audience A: Stake-holders	Slides	S,I	After analysis	Lab, Seminars, Classroom, Meeting rooms	Explicitly
		Verbal prot.	A			
		Ext. attitudes	V			
		Audience feedback	A, AV			

The establishment and registration of a research protocol may enhance the assessment of the research. Researchers can also benefit from this component, since by revisiting this record they can recall research design details, e.g. current research question, description of activities, plans, etc. We see the research protocol in a broader sense, including such elements as the question, the exposure of the researcher's bias, his/her background and theoretical framework, the motivation behind the study and methodology details and implications (including risks and validation). The researcher is the main actor involved within the capture stage, who can benefit from the exposure of internal features throughout his/her research. Such exposure may enhance the research credibility and allows for external stakeholders to access its details and have a deeper understanding on the addressed issues and results. The researcher can also benefit from accessing this component, revisiting the research protocol to recall details about the investigation process, as the current question, planned activities, etc. Similarly to the result presentation component, the researcher can present information regarding the research protocol in different ways, such as verbal protocols and external attitudes, file attachments, slides, etc.

Although in terms of research design a qualitative research process probably starts with the definition of an open question, when concerning the registration of the methodological process one can see the research protocol design differently. To begin with, the act of establishing and registering such protocol raises two separate issues. In practice, a study can have an established protocol that is never registered, for some reason. This certainly would lead to a poorer communication of the investigative process, but still this is possible from a strict registration point of view. However, the registration of the research protocol may strengthen the trustworthiness of the process. For the researcher, it can play a supporting role throughout the inquiry (in which case it is better be done right at the beginning). The researcher may define an umbrella protocol, referring to all stages of the research, or multiple separate protocols, for one or more steps in the process. The tracking effort creates an assessable evolution trail of the principles that guided every step of the process, increasing the research credibility. The researcher is free to decide the time, place and format of this record. Regarding the location of the registering, it may occur at workplace, but since there is no constraint for this recording, it could happen anywhere. Table 11 highlights the relation between the activity in this component and the C&A design dimensions for its registration.

Table 11 – Association of the activity in the research protocol component and the C&A design dimensions.

Activity	Who?	What?		When?	Where?	How?
Protocol definition	C: Researcher A: Stakehold-ers, Researcher	Verbal prot.	A	Once or in each stage, at any time	Anywhere	Explicitly
		Ext. attitudes	V			
		Slides	S,I			
		Files	S			

During the recording of the research protocol of the fifth case study (dealing with pervasive assistive technology), we realized the convenience of providing some kind of guidance for the audiovisual recording of the researcher's statement. A simple list with commonly relevant issues to be addressed can facilitate this registration, making it faster and more effective. Otherwise, the researcher can get a bit overwhelmed with the different topics to be exposed. In this sense, we propose a template for communicating the research protocol (blatantly inspired by the SemEng's metacommunication template) as a simplified and natural statement, which researchers can use to aid the registration of this component. It reads as follows:

Here is who I am; this is what I work with, my background and my interests. These are the details of the research I develop (or will develop), and the motivation behind my work as a researcher.

6.3.2.
Validation procedures

As discussed in Section 6.2, the transposition of software artifacts from the evidence space to the research space to be used as empirical evidence generators can benefit validation procedures. This feature assists the role of external validators enabling them to create their own meanings over the evidence, possibly minimizing the researcher's bias. However, this experimental inspection on software artifacts does not mean that all elements of the observation and analysis time frames are available to validators. For example, the physical context signs in which participants and researcher were when performing their activities may be out of reach. Moreover, there is no way to state whether losing the access to these elements is detrimental to the validation process or not.

As previously discussed in Chapter 2, the assessment of the research quality is a much contentious topic and depends on the approach adopted in the investigation process; there is no way to define systematically a workflow to achieve it. Despite the fact that the process of validation in qualitative research permeates all activities performed by the researcher, works from the qualitative research design literature generally suggest two approaches. The first is the discussion of critical validation factors, such as the discussion on tensional fields raised by Flick (2007, p. 64). The other is carrying out of specific procedures to promote aspects of validity and reliability, such as the validity strategies proposed by Lincoln & Guba (1985), Gibbs (2007), Maxwell (2009, pp. 126–129) and Creswell (2014, pp. 201–204). The latter approach involve some activities that are subject to registration, thus we think it is appropriate to model them as components of the C&A4Q model.

Among the suggested procedures, we highlight the registration of the following groups of activities, which are useful in the validation process: triangulation and analysis of negative or discrepant cases, which we see as part of the researcher’s context; and external audit, peer debriefing, member-checking and cross-validation, which are external activities relating to the scientific community’s context. All activities have to do with validity, except for cross-checking, which aims at promoting the reliability of the process. It amounts to weighing the consistency of the coding between different researchers.

However, there are some validation strategies among the ones suggested by cited authors that do not fit in any specific registration. Such is the case, for instance, of the use of a rich and thick description to convey findings and spending prolonged time in the field. We think that the use of a C&A technology already provides, in some sense, thick descriptions (and not only of the collected data, but also of the analysis process). Another strategy much discussed by authors is the exposure and clarification of the bias that the researcher brings to the study. Again, the C&A4Q model provides at least partially for this strategy in the registration of the research protocol.

Triangulation is the most common validation strategy in qualitative research. This procedure involves gathering information from a number of different individuals, scenarios and methods in order to minimize the risk of inconsistency in categorization and of systematic bias due to the use of a particular method. However, triangulation does not automatically guarantee the validity of the research. Triangulated methods can have the same biases and sources of invalidity, giving a false feeling of scientific solidity to researchers. Maxwell (2009, p. 128) argues that researchers should "*think about what particular sources of error or bias might exist, and look for specific ways to deal with this, rather than relying on* [their] *selection of methods* [for this matter]".

The registration of a triangulation procedure is analogous to the collection and analysis component. Indeed, a triangulation is an analysis based on new perspectives. This is a recording of the activities of the researcher, for later review, with provisions for comparison with previous collection and analysis components. Stakeholders may also be interested in accessing this record. Similarly, the researcher's interaction with specific tools, verbal protocols and visible reactions, annotations with findings, and related files are the main content one should register in this component. For the registration of a triangulation to be relevant, it is necessary that the researcher has a previously registered analysis, in order to enable an informed comparison between two procedures. This activity often occurs in workplace and home, but in practice, it can occur anywhere. As in the collection and analysis component, researchers can instrument the manipulation of software artifacts in order to record transparently aspects of their interaction. Table 12 shows a wrap up of the relation between the activity in the triangulation component and the C&A design dimensions.

Table 12 – Association of the activity in the triangulation component and the C&A design dimensions.

Activity	Who?	What?		When?	Where?	How?
Triangu-lation of findings	C: Researcher A: Researcher, Stakeholders	Artifact	S	After analysis	Anywhere	Implicitly, Explicitly
		Interaction	V			
		Verbal prot.	A			
		Ext. attitudes	V			
		Annotations	T			
		Files	S			

The analysis of negative or discrepant cases is of particular interest in qualitative research. Specific situations that do not fit into an established interpretative framework can point to relevant problems in the researcher's explanation (or not). This activity is similar to triangulations; it is a type of analysis, focused on data collected with a new observation or use of further empirical material. The registration of this procedure is also equivalent to the registering of triangulations, as it focuses on the researcher's analysis activities, aside from the exposure of the discrepant evidence. The registration of this component targets at the researcher's interaction with specific tools and creation of empirical materials with his verbal protocol, externalized attitudes, annotations and files. It demands a previous collection and analysis registration to enable comparison between artifacts. This activity often occurs at workplace or home but it practice could occurs anywhere. It admits implicit and explicit registrations. Table 13 synthesizes the relation of the activity in this component and the C&A design dimensions.

Table 13 – Association of the activity in the negative or discrepant case component and the C&A design dimensions.

Activity	Who?	What?		When?	Where?	How?
Negative case analysis	C:Researcher A:Researcher, Stakeholders	Artifact	S	After analysis	Anywhere	Implicitly, Explicitly
		Interaction	V			
		Verbal prot.	A			
		Ext. attitudes	V			
		Annotations	T			
		Files	S			

Given that the registration of peer debriefing, external audit, and member-checking validation procedures follow a similar methodology, the analyses of the C&A design dimensions of these components will be clustered in order to facilitate their view. In addition, a discussion over the cross-checking component for qualitative reliability completes the C&A4Q model's components for validation purposes.

The peer debriefing strategy can promote the accuracy of the results through the involvement of a third party (peer), usually a researcher with knowledge of the process. This peer has to review and make questions about the qualitative process, so that other skilled readers and researchers can analyze the investigation process and its findings.

Similarly, the strategy of an external audit validation aims at sharing the results and other research details with people outside of it. In this case, a person playing an auditor's role can provide objective reviews either throughout the research process, or at the time of its completion. However, unlike the peer debriefing strategy, the external auditor must not be familiar with the researcher, nor with the conducted research process, in order to produce an independent review. This auditor may access research data and analyze it through a broader perspective, e.g. querying about the relationship between the research question and the collected data.

Researchers can also use member-checking to assess the accuracy of the research results. That is, they can take final reports or specific parts of their analyses back to participating members for feedback. Of course, is counterproductive that researchers use the entire collection of captured material in this strategy. Instead, they should use artifacts that allow for a quick understanding of the main results. This strategy can also involve an interview with members to obtain some comments over the research findings.

The registrations of these three validation components involve different individuals with distinct roles in the investigation process, but all with the same goal of reviewing and validating the study and its findings. To make this happen, researchers have to elaborate an artifact that allows for peers, auditors and participant members to understand their vision of the process. The capturing of the external reviewers' interaction with this artifact, along with the data they create as a result of this interaction, comprise together the essential information about these three C&A4Q's components. Besides, reviewers' verbal protocol (further enriched with their externalized attitudes) and annotations are relevant information for giving detailed feedback to researchers. Researchers may be interested in the same types of information concerning the registration of the three components.

As for the chronological implications, researchers can rely on peer debriefing as early as their analyses start. Sharing initial results with peers to go beyond their interpretation can add validity promptly. The registration of this procedure often occurs in workplace (lab), but if no direct interaction between researcher and peer is expected, it may occur anywhere. External auditors in turn, may act at any time in the investigation process; likewise, the registration of this component has no causal implications in the model. Regarding location, the registration of this component seems closer to workplace environments, since there is some formal agreement between the parts involved, but again nothing prevents it to occur at any place. Member-checking is usually conducted at the end of the analyses, when researchers take their findings back to participants involved in the study. These participants are probably in the field where the researcher conducted the study, but they could go to the researcher's workplace for this activity. The documentation of these activities requires the explicit operation of tools that are able to register the reviewing process. Table 14 summarizes the relation of the activities from the three components and the C&A design dimensions.

Table 14 – Relation of the activities in peer debriefing, external audit and member-checking components with the C&A design dimensions.

<table>
<tr><th>Activity</th><th>Who?</th><th colspan="2">What?</th><th>When?</th><th>Where?</th><th>How?</th></tr>
<tr><td>Peer debriefing</td><td>C: Peer
A: Researcher, Stakeholders</td><td>Interaction</td><td>V</td><td>During or after analysis</td><td>Anywhere</td><td rowspan="4">Explicitly</td></tr>
<tr><td>External audition</td><td>C: External auditor
A: Researcher, Stakeholders</td><td>Verbal prot.</td><td>A</td><td>Any time</td><td>Anywhere</td></tr>
<tr><td rowspan="2">Member-checking</td><td rowspan="2">C: Participant, User
A: Researcher, Stakeholders</td><td>Ext. attitudes</td><td>V</td><td rowspan="2">After analysis</td><td rowspan="2">Field, Lab</td></tr>
<tr><td>Annotations</td><td>T</td></tr>
</table>

All the validation components discussed so far fall within the validity category discussed in the qualitative research design. Nevertheless, the last validation component of cross-checking falls into the reliability criterion. This procedure aims at verifying if the categories (codes) applied in a study are consistent across different researchers' perspectives. External researchers are queried to check whether they think the applied codes are adequate or not in their view. By comparing independent results in the *coding* process, one can assess the research reliability across different interpretations. There are studies aiming at establishing a suitable consistency within predefined standards (e.g., Miles & Huberman (1994) suggested a minimum of 80% of coding agreement for a good qualitative reliability).

The registration of this component involves publicizing an artifact with all the categories elaborated and applied in the study that researchers are assessing. External peers can return the results simply through a set of annotations with their view on each of the codes in the artifact. One can further enrich the cross-checking registration with verbal comments on each code evaluation. Of course, there is a causality constraint in this component, which requires a complete analysis prior to its performing. This activity does not require interaction between the researcher and the external peer, so that location is irrelevant. Peers and external researchers are in charge of explicitly operate this registration. Table 15 synthesizes the C&A dimensions for the cross-checking component.

Table 15 – C&A design dimensions for the cross-checking component.

Activity	Who?	What?		When?	Where?	How?
Cross-checking	C: Peer A: Researcher, Stakeholders	Annotations	T	After analysis	Anywhere	Explicitly
		Verbal protocol	A			

Figure 35 depicts the contexts, analysis and validation procedures addressed by the C&A4Q model, overlapping components indicate the possibility of multiple artifacts dealing with the same topic. So far, this work discussed the role of each of these elements, raising relevant issues on the recording of the associated activities. However, an important element is the exposure of artifacts for external access. All the components that involve third parties require some sort of publication of an artifact, so third parties can participate of the process. The C&A4Q model aims at the registration of the research process, and therefore it favors methodology. In principle, it has no specific components to support the drawing of conclusions about implications, limitations, and follow up questions from the results achieved; but nothing prevents the researchers to record these findings and attach them as a complement or final document of their research (explicitly labeled by them).

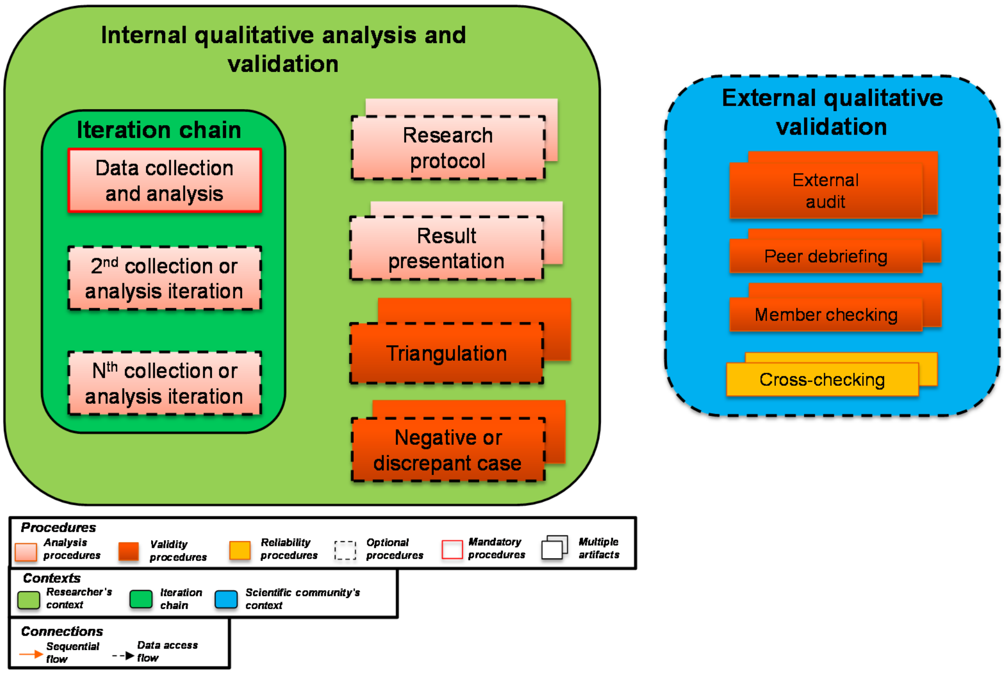

Figure 35 – Contexts, analysis and validation procedures in C&A4Q model.

6.4. Relational semantics

Aiming at creating an explicit relationship among the C&A4Q model's elements, we propose a simple relational semantics from which researchers can select properties reflecting their use of components. These properties can refer to an entire artifact or part of it; researchers can apply one or multiple properties to a given artifact, depending on its content. Through an explicit representation, the model tries to minimize the possibility of mistakes in the interpretation of components and the relations among them. Table 16 displays the properties defined to make the explicit relation between artifacts and their purpose in the research process.

Table 16 – Relational properties to associate artifacts with their purpose in the research process.

Property	Description	Type
researchProtocolOf	An artifact with a general research protocol presentation	Analysis, Validity
researcherBiasOf	Artifact comprising the exposure of researcher's bias	Analysis, Validity
researchMethodologyOf	Artifact containing methodology details	Analysis, Validity
researchQuestionOf	An artifact with presentation of the research question	Analysis, Validity
researchGoalOf	An artifact with presentation of research goals	Analysis, Validity
resultPresentationOf	An artifact with presentation of findings	Analysis, Validity
analysisIterationOf	A registration of an analysis iteration	Analysis
observationOf	Registration of an observation (e.g., user interaction)	Analysis
externalAuditOf	An artifact containing an external audition	Validity
memberCheckingOf	An artifact containing a member-checking	Validity
peerDebriefingOf	An artifact containing a peer debriefing	Validity
triangulationOf	An artifact containing an triangulation with different sources or methods	Validity
crossCheckingOf	An artifact containing a cross-checking activity	Reliability
anonymizationOf	An artifact comprising a anonymized version of another artifact	Publication
editedVersionOf	An artifact comprising an edited version of another artifact	Publication
fullVersionOf	An artifact comprising a full recording	Publication

6.5. Publication

The publication of the C&A artifacts created throughout the inquiry process demands awareness of researchers when disclosing their findings. Here, we define the concept of publication as the externalization of an assessable artifact, not specifically relating to traditional forms of publication. Researchers are in charge of selecting from the mass of collected empirical data the information that will compose the public artifact. They are responsible for defining the information they will publish, and to what extent.

To represent the transition of artifacts generated in the research context to external readers and examiners, we chose to include a publication sub-context to refine the scientific community context. Only one particular type of component is available in this context, a composition element that we call access component. When performing component publication researchers must specify any artifacts that will compose this access component. In addition, they must define if these artifacts (and sub-artifacts) will be published in their entirety (full recordings), partially (edited versions, with cuts to avoid publication of not-to-be-disclosed information), or as anonymized versions (protecting the identity of participants, when necessary).

The C&A4Q model adopts a component-nesting concept as a possibility to incorporate previously generated information in the creation of a public artifact. Therefore, if needed, researchers can make available the content of previous recordings when defining a new component by referencing them. To put it in other terms, previous artifacts can serve as input material for new ones. The resulting component would be a composition of the information in prior artifacts and any information created in the new component. Researchers must decide whether to externalize artifacts formed by a single component, or a composed artifact representing this agglutination of different components. In addition, an indication of the artifact's type (full, edited and anonymized) can be useful in structuring and visualizing the data disclosed in the research project. Researchers can also indicate how they will make available the public artifact (e.g., through offline or online access). Figure 36 visually exemplifies the proposed nesting concept in the publication of artifacts. In this sample, a public access component comprises two full artifacts with the research protocol presentation and another presentation with the findings. In addition, two analyses with anonymized collections plus some iterations representing the investigations the researcher carried, there is also a triangulation of the findings in an effort to validate the study.

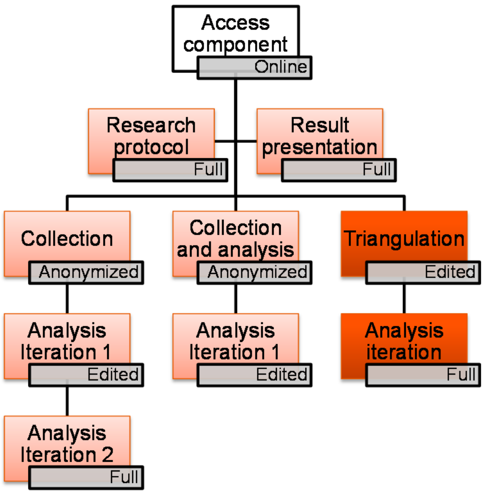

Figure 36 – Component-nesting proposed in the C&A4Q model for a public artifact (access component) and its sub-artifacts.

HCI experts often have to deal with questions involving the protection of the identity of the participants in their research, with terms explicitly regulated in the research ethics protocol. This is a complex discussion and the anonymization procedure is specific to each case studied. This model does not go into details on necessary procedures to preserve the identity of participants in the generated artifacts, but it provides a way to represent this form of the exposed artifact.

Researchers may consider producing an edited version of a registered component, omitting parts of information they deem unnecessary in artifacts. They can select essential parts of certain aspects in the components, thereby facilitating the understanding by third parties. On the other hand, disclosing artifacts in their entirety may be interesting to certain scenarios as well.

6.6. Sequentiality

The C&A4Q model consists of the registration of procedures in a qualitative research study and the relationship among these components. It does not presuppose any particular order for these procedures, but some activities may have causal relations that inevitably imply certain chronological restrictions, as discussed in the design dimensions of each component.

Unlike the interactive model proposed by Maxwell, which promotes a research design discussion regardless of any temporal characteristic, i.e. assuming its components are not "linked in a linear or cyclic sequence" (2013, p. 4), the C&A4Q model has a hybrid nature. We recognize the unpredictability and emerging traits of the qualitative research and the implication that all the research elements have in each other. We also observe the researcher's need of accessing components whenever required, regardless the stage of where he/she is in the investigative process. However, our approach is different in that we also observe key events in the scientific process that imply temporality.

Concerning the discussions on C&A design dimensions over the C&A4Q's components, one can notice diverse sequential flows both between procedures in the same context and between distinct contexts. Evidently, for the scientific community to give any feedback to the researcher there needs to be some previously published findings made available by researcher. For the same reason, internal validation procedures cannot make any sense if there is no analysis or results that require confirmation. Moreover, in-depth research analyses making use of mixed methods, with the support of additional quantitative methodology, only make sense if there are previous results. Figure 37 shows a graphical representation of all the sequential flows (depicted as unidirectional continuous arrows) discussed in the C&A4Q model. Components that have no causal constraints (no arrows) may occur at any time.

In addition, it is possible to create multiple artifacts of a same component. For example, to maintain different versions of a research protocol leaves an intra-component audit trail that can be useful to ponder on the evolution of the foundations that guided the process. Furthermore, one can group all activities contemplated in the C&A4Q model and see it as a single step in the qualitative study. Therefore, if we think of an external context that encompasses the representation of this step, we can have a glimpse of the emerging sequentiality in the scientific process in the long-term. Note that this does not aim at establishing a project for executing the process (or a workflow); it only supports the representation of research history, that is, what actually occurred. Figure 38 shows a possible visualization of this long-term perspective the model can support.

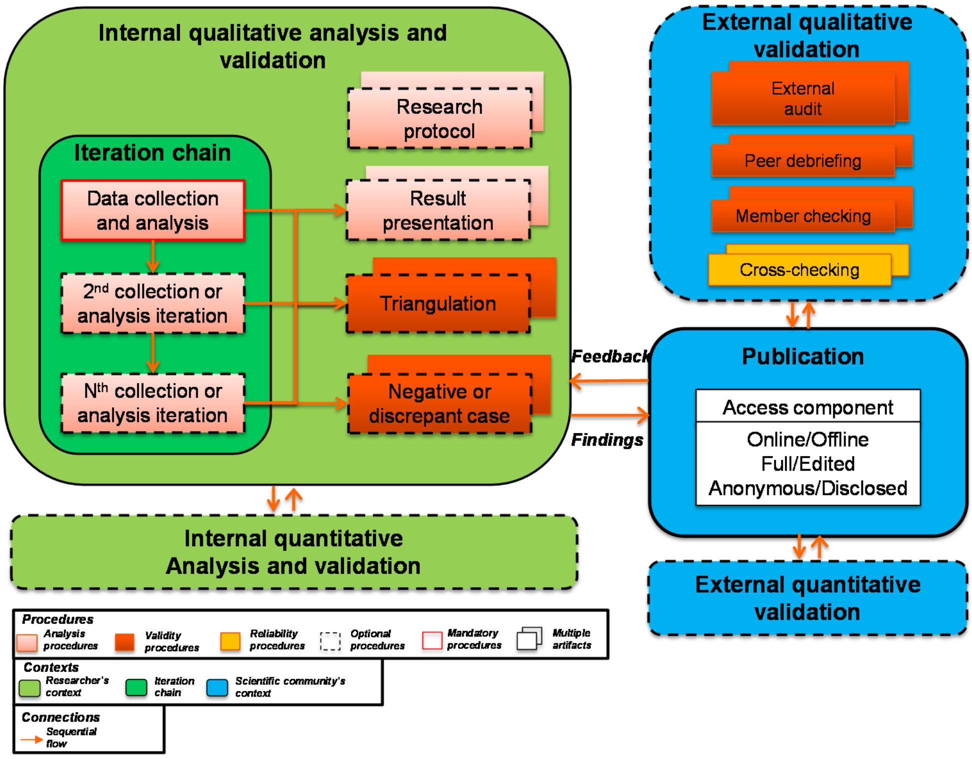

Figure 37 – Sequential flows in the C&A4Q model.

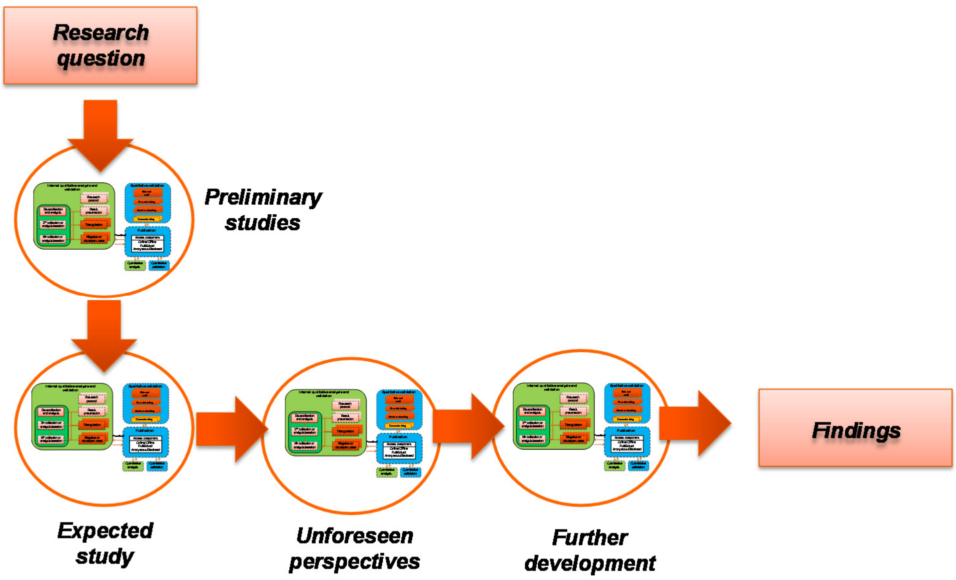

Figure 38 – Example of a long-term view on the history of a qualitative research process registered with the support of C&A4Q model.

6.7.
Data access flows

The access and manipulation of the captured empirical data comprises an essential activity in the qualitative process. The identification of data access flows can clarify the dependency between components and highlight conduction possibilities according to the available information.

In the researcher's internal context, access to the research protocol at any time is essential. Enabling access to this component's elements whenever the researcher wants to retrieve details of the current goal of the process is crucial. Thus, access to this component may occur during the recording of the analysis, result presentations or any internal validation. Within the iteration chain, when developing new steps the researcher surely needs to access the previous analysis iterations, since iterative-segmented analysis is a major feature of the qualitative approach. At the same time, accessing internal validation components and result presentations may be useful for the analysis too. This is also true in the opposite direction, when registering result presentations, triangulations or analyses of a negative case, researchers may be interested in accessing components within the iteration chain. Access to data between distinct contexts occurs through a public artifact. Either the researcher has to publish an artifact with findings to allow the community access his data, or the scientific community has to publish an artifact with feedback as an external validation. Figure 39 illustrates the data flows (depicted as unidirectional or bidirectional dashed arrows) between components and contexts identified in the C&A4Q model.

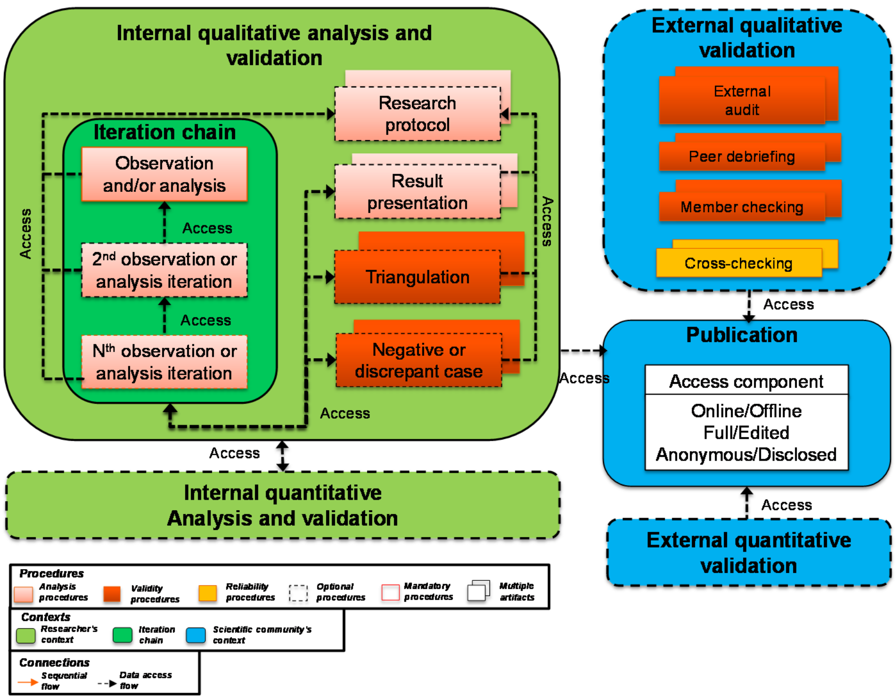

Figure 39 – Data access flows between the C&A4Q model components.

6.8. Abductive perspective

In the qualitative research process, the researcher acts as an instrument of his/her own research, inevitably generating data through a process of interpretation. Without interpretation, there is no data to access. The subjectivity that this interpretation process brings is frequently a contentious subject between researchers.

Several philosophers and researchers have discussed the possibility of modeling an interpretive process throughout history. The research developed by the Semiotic Engineering Research Group (SERG), from where this work comes, relies on a specific theory that characterizes the human interpretive process in the context of "discovery of the new", in particular the "discovery of new knowledge". This is Peirce's theory about abductive reasoning (Peirce, 1992).

From a logical point of view, one can draw on the C&A4Q model as a support for an abductive process, which allows the explicit and formal modeling of hypotheses generation. Unlike the logical deduction process, which goes from the reasons in search of consequences, abduction goes from the consequences in search of the reasons (explanations).

Peirce (c. 1900) suggested the logical abduction reasoning (first using terms as "guessing", "hypothesis", then "retroduction") as a creative process in which someone does a precipitate generalization as an explanation for observed facts. Then, this generalization is put into test against evidence that can refute or confirm it until another test is performed. Logicians classify this reasoning as a formal fallacy in classical logic called "affirming the consequent". Its argument takes the following form:

- If A, then B (conditional statement);
- B (observed fact);
- Therefore, A (conclusion).

A practical example is "if there are cars, then there is pollution. There is pollution. Therefore, there are cars". This reasoning provides an explanation for an observed fact (what caused the pollution), but it is fallacious. In reality, cars are not the only source of pollution.

According to Peirce, the production of habits is a major mental activity. He affirmed that a set of strong habits constitutes beliefs, from which one can detect novelties. Peirce directly relates these novelties to the experience of surprise, which triggers the process of generation, change and expansion of beliefs. Then it disappears when abductive reasoning is completed. Hence, the absence of surprise is a characteristic of a good (completed) abduction (Gonzalez & Haselager, 2005). In other words, the aim of abduction is to avoid further surprises. Figure 40 depicts Peirce's interpretation of the abductive reasoning and the role of surprise in it.

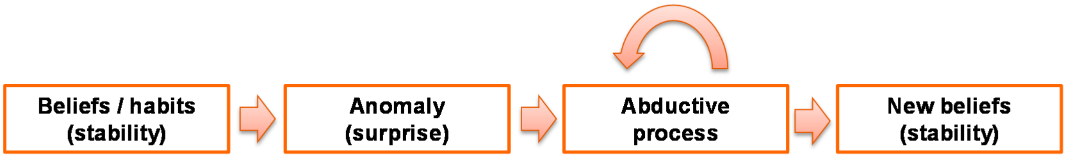

Figure 40 – Peirce's view of the role of surprise in abductive reasoning.

Considering its use in the scientific context, a relevant feature of the abduction process as defined in Peirce's semiotic theory lies in its fallibility and self-correction of the meaning-making process (Gonzalez & Haselager, 2005; Magnani, 2005; Santaella, 2005). The theory characterizes more realistically the scientific research activities within a human scale, where each researcher has finite resources (means, data, methods, perspectives, and even lifespan) that prevent him/her from reaching an absolute truth. In this sense, researchers contribute with parts of the knowledge, resulting from their systematic interpretation and analysis of the evidences accessible to them, which are subject to further revisions.

This reasoning is fragile and fallible, but is very useful for creating new concepts in the process of ridding the mind from doubts. One can relate abductive reasoning to creative thinking; indeed, it comprises the essence of knowledge creation and problem solving activities. Magnani (2005) argues that abduction is a relevant type of scientific reasoning, particularly when defining the first concepts of a new theory. He defines as creative abduction the reasoning processes that deal with the whole field of "growth of scientific knowledge". He also suggests a difference between theoretical and manipulative abduction, the latter involving the concept of epistemic mediators as a way of representing the manipulation of external objects, which are useful in cases involving "thinking through doing". In this approach, one can see scientific experiments as states and the manipulation and observation activities over these epistemic mediators as operators leading to transition from one state to another. We think that this kind of action-based abduction can be related to the interaction and manipulation of a conceptual model such as the C&A4Q we propose here.

Although fallible and subject to further corrections, the conduction of an abduction process is neither groundless nor impossible to be approached methodically. In the scientific context, it contemplates self-correction cycles, such as the validation procedures discussed in C&A4Q model, which may enhance the self-correction of the reasoning process. These cycles lead to a stable interpretation that others can confirm or refute through validation procedures. The stability of the interpretation relates to the concept of "saturation", i.e. when collecting new data or analyzing different aspects of evidences does not lead to further information in the study (Mason, 2010).

The specific cognitive aspects of the abduction process are not in the scope of C&A4Q model, but the detailed registration that it promotes can capture all the abductive effects on the activities of the researcher. During the modeling of an inquiry, one can perceive the effects of abductive reasoning in a fine-grained view, when modeling analysis of a particular research stage (exemplified in Figure 41), or in a coarse-grained view, with the modeling of long-term research history (depicted in Figure 42).

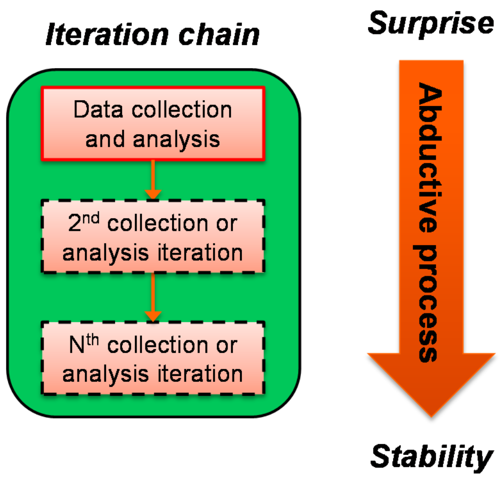

Figure 41 – Fine-grained view of the perceived abductive process effects in the C&A model.

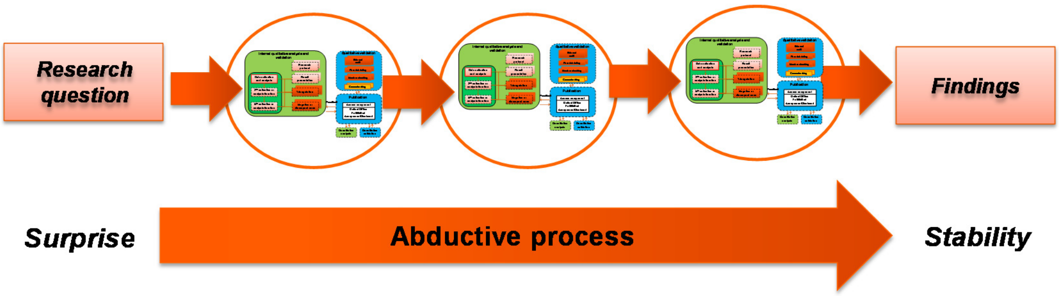

Figure 42 – Coarse-grained view of the perceived abductive process effects in the C&A model.

The technology that we propose here aims at capturing and providing access to the self-correction procedures performed by the researcher. This allows for validators and interested users assessing the research process by themselves. By manipulating the registered artifacts externalized by the researcher during the qualitative process, they can evaluate research quality aspects, such as validity, reliability, generalizability, applicability of the results and the value of the findings.

To summarize, tools that implement the C&A4Q model may assist the conduction and registration of partial or final results of an abductive reasoning process, which is the basis of any qualitative research where the interpretation process is crucial. The model shows that this interpretation in the scientific context is a complex and rich process, whose results have solid and methodological foundations that are amenable to systematic evaluation. Thus, these tools may assist in evaluating what comprises a good quality research and what does not.

7
Final remarks and future work

The aim of this thesis has been to understand issues involved in performing a systematic and structured registration of qualitative research, in order to promote an informed expansion of the field. Accordingly, we have investigated its general characteristics, breaking the process down into manageable elements, discussing its usefulness and benefits. We have also contrasted it to quantitative research, which has a close relationship with Computer Science, to reflect upon their complementariness under different perspectives. Throughout this thesis, we identified and discussed several questions that researchers may face when registering and structuring common qualitative procedures. Part of our results was summarized in a conceptual model to support planning and registration of qualitative activities grounded on a Capture & Access (C&A) perspective.

Chapter 1 provided an overview of the approach that we applied in this study, presenting the addressed problem and theoretical groundings supporting our conceptions. In addition, this chapter presented motivations, contributions and the planned methodology for this research. It also clarified the researcher's bias, which fundamentally shaped the development of this research.

Chapter 2 presented the main elements of the qualitative approach, showing how researchers use and create theories supported by qualitative procedures and analytical generalizations. This chapter also discussed validation strategies that support assessment of research quality, which comprises a problematic issue in this approach. Finally, this chapter concluded with a comparison between qualitative and quantitative approaches. It briefly discussed that these two approaches are not mutual exclusive. On the contrary, they are complementary, so that mixed designs can benefit from the best of both approaches.

Chapter 3 outlined the current approach to design and model analysis and validation procedures in qualitative research. It presented conceptual models and research design solutions that promote a structured development of qualitative studies. In addition, this chapter addressed the predominant software tools concerning qualitative analysis, the Quantitative Data Analysis (QDA) tools. It discussed analysis strategies supported by QDA tools, support for multimedia content and contrasted these tools with our solution. This chapter concluded drawing a parallel between quantitative studies in e-Science context with the systematic structuring we envision for qualitative research. We highlighted some concepts of scientific workflow systems that relates to our solution and could show a direction we can follow with the qualitative research.

Chapter 4 presented the C&A research area, discussing its foundations on Ubiquitous Computing (UbiComp) and its main concepts. It outlined the process of recording and retrieving data commonly observed in C&A systems. This chapter also presented the CAS Project, an initiative focused towards the development of a generic C&A infrastructure for recording different and simultaneous live events. This infrastructure supported the registration of the procedures discussed in case studies.

Chapter 5 covered five case studies performed over a thirteen-month period. In each of these studies, we discussed the observed scenarios, issues and particularities in recordings and summarized with lessons we learned from the study. This chapter presented two preliminary studies that we carried as a proof of concept for this study. Afterwards, this chapter presented consolidation studies where we explored the registration of richer scenarios, involving combined methodologies and recording of an action-research. A qualitative cross-study elaborated on the case studies raising characteristics pertaining to two main themes: technical and methodological aspects. This chapter concluded presenting prototype software components, which we have implemented on top of the CAS infrastructure based on requirements identified during the conducted studies.

Chapter 6 presented the main contribution of this thesis, the C&A4Q model. It is conceptual C&A model targeted at supporting the registration of qualitative research procedures applied to HCI. This chapter showed how a C&A grounding is beneficial to the registration of analysis and validation procedures. It also discussed particularities from the HCI case that influenced this model. Besides, it presented different aspects such as, the existing sequentiality between procedures, publication of artifacts and data access in different research stages. Finally, we concluded this chapter discussing how the C&A4Q model can be related to abductive logic reasoning.

Our solution comprises a conceptual model along with a software prototype for registration of qualitative research. We see this combination as a tool that researchers may use at their will, it should not be seen as an imposition to be used as some kind of “employee monitoring” technique. Instead, our solution supports qualitative researchers who *want* to expose their process, in order to enhance the scientific trustworthiness of their research. Our goal is to promote an organized and well-informed expansion in qualitative research, allowing its tracking and documenting in a scalable way, somewhat analogous to quantitative experiments in the e-Science context. We see qualitative and quantitative research as distinct approaches, but not as conflicting or mutual exclusive. Integration of both approaches can be complementary and may benefit researchers in different scientific processes.

With the advance of massively parallel systems using “big data”, along with problem-solving and learning techniques such as Computational Thinking and Machine Learning, it became practicable to create software that generalize solutions to open-ended problems based on a massive amount of evidences. Imagine a hypothetical situation in which a physician could make queries to such systems about a disease he is trying to diagnose in a patient. These systems can analyze massive data sets, processing and correlating data according to the executed query and present evidences as result. On the one hand, the procedures performed on these systems usually involve quantitative processes, supported by mathematic and statistic models. On the other hand, the physician will probably make use of these data through a qualitative analysis involving an abduction process where knowledge will be created. In the physician’s analysis, he may classify the case as a previously known disease or could identify it as a new disease based on the evidences he gathered. The quantitative side is well defined and tracked in this process, but the qualitative side lacks a systematic approach. The solution we propose in this thesis could be used to support this systematic registration on the qualitative side, leaving an evidence trail of the physician’s abductive process that led to the results. After a series of registrations such as this, a catalogue with qualitative analysis recordings emerges. By comparing different qualitative analysis registrations in such catalogue, one could probably extract relevant meaning.

We think that both qualitative and quantitative researchers should strive for integrating procedures with specific purposes in mixed designs, which may be key to current and future cutting-edge research.

7.1. Our trace

As previously discussed, the conception of C&A4Q model is a result of this work. That is, it was not available during the case studies. Some of the procedures we carried out could have been better registered if we were already aware of all the components discussed in the model. In spite of this, we created a broad representation of the qualitative research described in this thesis to illustrate the use of the model, as shown in Figure 43.

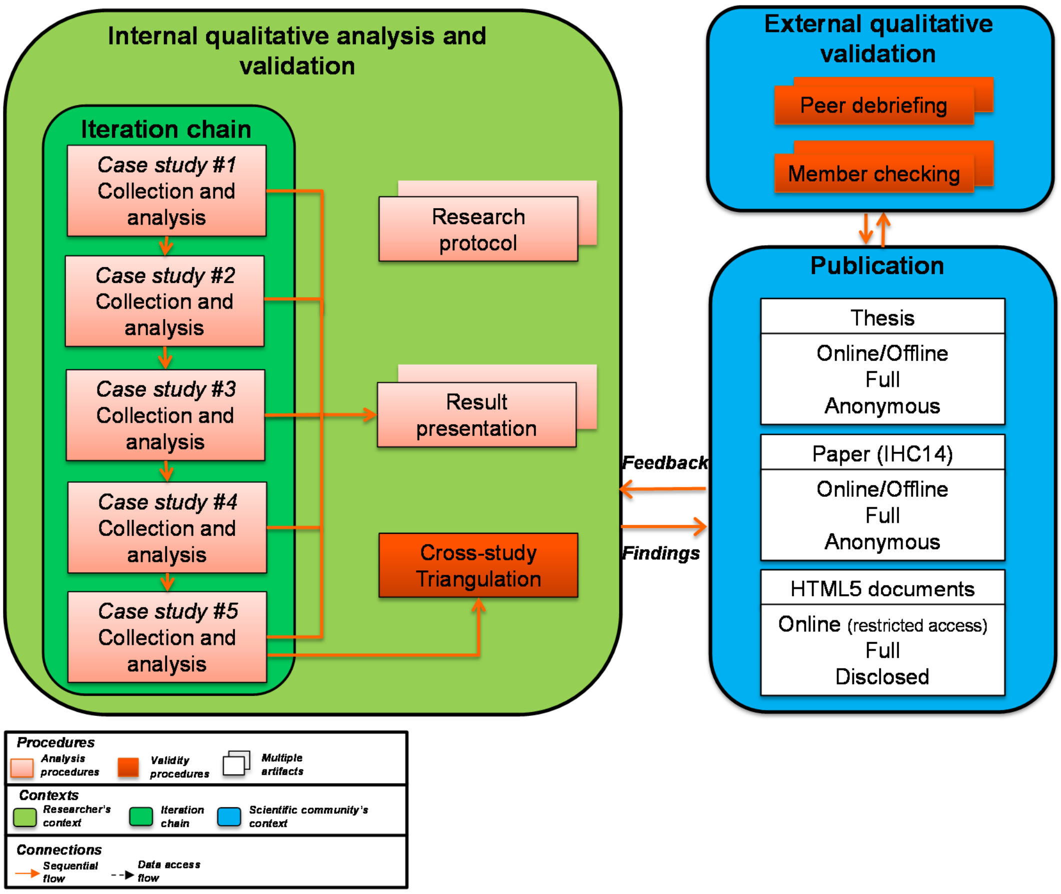

Figure 43 – Overview of registered procedures and public artifacts of this work, represented as an instance of C&A4Q model.

In total, five case studies with observation and analysis procedures occurred sequentially. The research protocol has evolved over these studies, during the preliminary studies the research question was related to the feasibility of capturing qualitative procedures using CAS infrastructure. During the consolidation studies, our focus changed to a methodological stance, but we also remained sensitive to issues involved in registration. After each of the case studies, we conducted presentations in the Semiotic Engineering Research Group (SERG) weekly seminars, to expose and discuss our findings with HCI experts. By the end of the case studies, a triangulation procedure was performed with a cross-study analysis contrasting the five inquiries. Three public artifacts enabled external validation procedures: HTML5 documents generated throughout the studies, a paper published in IHC14 conference (Brandão, de Souza, & Cerqueira, 2014) and this thesis. The online documents comprise full recordings, but have restricted access in agreement to ethical protocols. Participants used these documents during the studies to perform their HCI evaluations and to validate our solution (member-checking). Similarly, the doctoral advisor of this thesis used them to validate the studies (peer debriefing). The published paper addresses the preliminary studies, preserving the participants' identity. Finally, this thesis discusses all the case studies, protecting participants' identity when necessary as well. Both the published paper and this thesis enable external validations (similar to peer debriefing).

7.2.
Relevance for teaching

Besides assisting researchers in planning and carrying out their studies, the C&A4Q model along with the prototype implementation for structuring and recording of HCI qualitative procedures may be used to support education in HCI disciplines.

The use of a qualitative approach in Computer Science (CS) is significantly greener than in the Social Sciences, which naturally leads to a lower maturity regarding application of methods and reporting of findings (Blandford, 2014). This is still a controversial point whose solution is not trivial. Given the rather quantitative profile commonly observed in CS students and professionals, learning subjective concepts and ontologies entirely different from what they are familiar with can be challenging.

In quantitative research, for instance in e-Science context, less experienced researchers can benefit directly from artifacts generated by experienced peers. Beginners can learn by example, re-executing experiments and reflecting on results. In the qualitative approach this scenario does not occur. There is no way to replicate entire qualitative studies, they have a unique character and each researcher may face particular problems. However, upon a detailed registration throughout the process comprising chains of evidences, less experienced researchers may learn about specific methodological aspects of experienced peers' research trails.

A future work that would promote the use of our solution in the teaching context is the possibility of C&A systems allow for researchers to configure the method they will apply during registration. With a pre-configuration of the method's major procedures and the relationship among them, C&A systems could assist researchers during their investigative process, suggesting options for the next steps to be performed in the scientific process. Additional future work is discussed in the following section.

7.3. Future work and perspectives

Throughout the development of this thesis, we have identified different perspectives that can be explored to create further knowledge about aspects that may influence conceptual models, as well the implementation of C&A systems targeting registration of qualitative research.

Qualitative researchers often need to anonymize participants' identities in their research records, since this is common norm within ethical protocols. However, analyzing externalized attitudes from participants may be valuable for qualitative researchers. This analysis is particularly interesting for HCI evaluations, where researchers may infer aspects of the user's experience by observing their behavior during interaction with software artifacts. This could be an issue for external researchers and stakeholders that cannot access raw research data. That is, the current anonymization process (e.g., blurred videos, distorted audios or editions to cut specific portions of data with identifiable information about participants) can eliminate valuable information.

In this context, a potential future work that can lead to implications for both conceptual models and C&A systems targeting qualitative research registration is the possibility of automatizing anonymization and analysis of participants' sentiment. If systems are able to detect participants' identities and sentiments (e.g., through computer vision techniques), it would be possible to publicize this information through some sort of an avatar representing the participant. Thus, external researchers interested in specific attitudes of the participants could perform their analysis without disclosing participants' identities. Moreover, avatars in a public artifact could also represent the manipulation of physical objects by participants, without necessarily identifying the object in question. For example, the hat developed as an assistive technology described in the fifth case study (in Chapter 5) could be represented in the public document via an avatar. This avatar could display relevant metadata implicitly captured such as, configured size of the hat, tilting and spatial position with x, y and z coordinates via oscilloscope and accelerometer sensors, etc.

Finally, a further envisioned perspective is that in the long-term C&A systems may act fully implicitly and transparent, i.e. non-intrusive and at the same time completely aware of the methodological process. With a full instrumentation of tools and objects manipulated by researchers and other participants in their natural environments, it would be possible to C&A systems to identify and structure methodological procedures. The researcher could configure the system for a long-term use, for instance, defining that "for the next two months I will investigate a particular topic". During this period, the system would monitor for user activity trying to identify interaction patterns that match to research procedures. Spontaneously, the system could notify the researcher of new generated documents, comprising tags labeling these identified patterns (e.g. triangulation between data sources and coding could be automatically detected). Additionally, the system could anticipate quasi-statistics in generated artifacts, counting basic things such as, number of procedures, time duration of procedures, number of identified tags, etc.

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