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Modeling for Analysis and Design in Regulated Artifacts Ecologies (MADRAE): a Case for Cooperative Practices in Telemedicine

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Abstract. The results of CSCW studies should be more effectively incorporated into software engineering practices. This paper focuses on two concepts supporting software component choice and development in IS architecture: artifact ecologies and data work. Using a case study in telemedicine, we propose MADRAE, an extension of the UML component diagram, for modeling practice-based artifact ecologies that emphasize the necessary data work. In the hospital where we tried MADRAE, it was considered helpful by the head of the IS department to analyze existing artifact ecologies and generate design and architecture proposals.

Introduction

Despite the better understanding of cooperative work offered by CSCW findings, designing applications that support cooperative work embedded into the work practice and usable by the different actors remains a significant challenge (Lewkowicz & Liron, 2019; Ludwig et al., 2018). We hypothesize that a significant contributing factor to this issue is the difficulty in incorporating these complex and intricate insights into the daily processes and toolkits of software engineers and Information System (IS) managers.

Many essential findings and design recommendations in CSCW still need to be translated into operational solutions (Christensen, Lars Rune et al., 2020; Hartswood et al., 2003). Indeed, cooperation is a dynamic process that requires ongoing support, and the systems that support collaboration must evolve and adapt over time (Bødker et al., 2016; Pipek et al., 2009). In addition, introducing a new application that supports cooperation becomes more arduous as the space of any intervention is already full of systems that might be difficult to replace or ignore (Korsgaard et al., 2022; Monteiro et al., 2013; Pollock & Williams, 2010). Thus, many CSCW researchers have shifted their focus to 'large scale' with concepts like artifact ecologies to describe the phenomena and identify challenges (Bødker & Klokmose, 2012; Lyle et al., 2020).

Considering the artifact ecologies suggests studying the relationships between technology artifacts (such as computers, software, and other digital media) and the social, organizational, and cultural contexts in which they are used. This approach emphasizes these relationships' dynamic, interconnected, and evolving nature and seeks to understand how technology and society co-evolve over time. Focusing on the artifact ecologies provides insights into how new technologies are adopted, used, and transformed in various settings and how they shape and are shaped by the people, organizations, and communities that use them.

Such an approach poses a fundamental challenge for the design of technology that supports cooperation. Thus, new systems that support cooperation often must integrate with various existing systems, devices, and platforms. This can create challenges with interoperability and increase the number of tasks humans need to perform, such as collecting, analyzing, and interpreting data from multiple artifacts. Bonde et al. (2019) refer to these activities related to data management as *data work*. Data work can require collaboration and coordination among individuals with different backgrounds and expertise and are essential for decision-making, problem-solving, and sense-making in various domains (Grisot et al., 2019; Islind et al., 2019). However, data work is sometimes perceived as a burden due to its magnitude, redundancy, and invisibility (Bjørnstad & Ellingsen, 2019; Cabitza, Ellingsen, et al., 2019; Vallo Hult et al., 2019).

In order to effectively support cooperative practices in complex domains like healthcare, it is essential to make the ecologies of artifacts and data work visible to software engineers and IS managers. One way to achieve this is through modeling, which plays a critical role in software design and development. Enriching modeling with insights about artifact ecology and data from CSCW research can help software engineers and IS managers better consider the complexity of cooperative practices. Modeling is often used in software development to analyze how a system is used (Kramer, 2007). Models provide a shared understanding of the system and can be used to identify design flaws and catch errors early on, improving the efficiency and quality of the software (Kautz et al., 2018). Furthermore, modeling can improve communication and collaboration between stakeholders with different technical backgrounds.

We propose MADRAE (Modeling for Analysis and Design in Regulated Artifacts Ecologies) as an extension of the UML component diagram based on a telemedicine case study. MADRAE allows for modeling practice-based artifact ecology, emphasizing the data work needed in the system. Although there is no specific UML diagram for representing artifact ecologies, the component diagram is a good candidate for the job. This diagram shows the structure of a set of systems or subsystems and can represent the components and artifacts that make up an artifact ecology. However, the diagram notation still needs to be extended to fully capture the social and cultural aspects of the artifact ecology. MADARE extends the diagram to represent the complex and dynamic relationships between artifacts, tools, people, and social and cultural norms in collaborative work environments.

Based on a case study in telemedicine, we present the use of MADRAE to enable the modeling of practice-based artifact ecology that emphasizes the data work required in the system. We present the results of a formative evaluation with the head of a general hospital IS department and discuss the benefits and limits of our approach and future work for MADRAE.

Related work

In this section, we first analyze the existing literature on artifact ecologies and data work to highlight the importance of considering these aspects when designing technologies. Then, we focus on modeling languages and their role in reflecting the complexity of work practices.

Artifact ecologies

Whether to work, communicate, or play, everyone creates and evolves within their digital environment, their *artifact ecology*, i.e., “the set of physical artifacts that a person possesses, and that allows a certain level of interactivity through digital technologies” (Jung et al., 2008).

Three decades ago, Krippendorff (1989) already argued that it was impossible to distinguish between software, hardware, and devices when it came to computing. In line with this work, Bødker and Klokmose propose integrating these three components in their definition of artifact ecology (Bødker et al., 2016; Bødker & Klokmose, 2012).

The concept of artifacts ecology allows for the study of the practices of individuals in isolation (Dittmar & Dardar, 2014; Jarrahi et al., 2017; Jung et al., 2008; Sørensen & Kjeldskov, 2014), and how individuals collaborate through these technological artifacts (Bardram & Bossen, 2005b; Bødker et al., 2016; Larsen-Ledet et al., 2020). Larsen-Ledet and colleagues (2020) show, for example, that during a collaborative writing task, the individual artifact ecology of the co-authors partially overlaps to form an aligned one. The authors describe how the actors gather and construct their individual artifact ecologies to support their practices, some of them being collaborative. We can relate the work of Bardram et Bossen (2005a) on coordination in hospitals with those of (Larsen-Ledet et al., 2020) when certain artifacts of the aligned ecology (whiteboards, schedules, post-it notes, etc.) play a particular role in the coordination of activities between actors.

Aligned artifact ecologies are dynamic and evolving as activities change and new needs arise (Bødker et al., 2016). For example, within an organization that is not very constrained, such as a volunteer association, the initially aligned ecology is primarily shaped by the individual ecologies of its actors. However, as the organization grows and structures itself, the ecology evolves to meet new needs. For example, when a communication department is created within an association, the FACEBOOK page created by the founding members and serving as the only intermediary for internal and external communication is replaced by a newsletter sent by MAILCHIMP for internal communication and supplemented by TWITTER and INSTAGRAM accounts for external communication (Bødker et al., 2016).

Many synonyms for 'artifact ecology' are used in the literature, from digital assemblages to artifact constellations. Still, we agree with Lyle et al. (2020) to use the term artifact ecology to describe the set of artifacts (software, hardware, and devices) that a person (or a group of persons) uses and that allows a certain level of interactivity through digital technologies, while supporting their cooperation.

Data work

The notion of *data work* refers to the activities and tasks performed by a human actor that are related to collecting, managing, analyzing, and interpreting data (Bonde et al., 2019). Many researchers in CSCW highlight the role of data work to support decision-making, problem-solving, and sense-making in various domains such as organizations, communities, and networks. These studies show that data work involves individual and collective efforts and often requires collaboration, coordination, and communication among people with different backgrounds, expertise, and perspectives.

For example, Islind et al. (2019) describe the manual work of translating and compiling data from different sources in oncology follow-up and remote patient monitoring. Similarly, Grisot et al. (2019) highlight how nurses in a Swedish hospital who follow remote monitoring device users identify relevant and clinically valuable data and collaborate with patients to collect it. Thus, using data collected by a third party or reusing data requires organizing “data interoperability” that often requires “data work” (Vassilakopoulou & Aanestad, 2019).

While data work is essential for being able to make use of data (Callon & Law, 2005; Islind et al., 2019; Moser & Law, 2006; K. H. Pine, 2019; Vassilakopoulou & Aanestad, 2019), it is sometimes perceived as a burden because of its magnitude. According to several studies data work can represent up to 50% of a physician’s work time (Arndt et al., 2017; Sinsky et al., 2016).

A literature review by Cabitza et al. (Cabitza, Ellingsen, et al., 2019) characterized the different forms of redundancy, namely a particular type of data work, distinguishing replicated, duplicated, complementary, and supplementary data. Their work shows that duplicating data (i.e., putting the same data into different artifacts) has adverse effects, increasing the risk of misinterpretation and data desynchronization. When coming to health, the burden of redundancies is on the one hand, heightened when it serves non-clinical purposes such as organizational or monitoring needs. On the other hand, redundancies can support collaboration between healthcare professionals by enhancing the transmission of relevant information (Cabitza, Locoro, et al., 2019; Langstrup, 2019; Morrison et al., 2013).

Finally, data work is often associated with the notion of *invisible work* (Star & Strauss, 1999). For example, Bonde et al. (2019) show that data collected for clinical purposes need considerable but invisible and qualified data work before ready to serve research purposes (e.g., collection, standardization). For Bjørnstad et Ellingsen (2019), the visibility of a task depends on who performs it. For example, when a task is performed by a physician - who is listened to and has a high social status, it becomes recognized as “important”. They additionally argue that, by considering data work, organizations can use technology more effectively and efficiently, leading to better decision-making and sense-making.

Through our research, we seek to make the ecologies of artifacts and data work visible for designers and prescribers of systems supporting cooperative practices. We have explored this topic by looking at the potential of modeling approaches of information and socio-technical systems, which we develop in the following section.

Socio-technical Modeling and Software Engineering

Modeling can play a crucial role in supporting the design of digital tools (Kramer, 2007). Using appropriate modeling approaches may enable considering the complex and interrelated social, technical, and organizational aspects of work (Kautz et al., 2018). CSCW research has studied and offered various modeling approaches that consider the socio-technical character of digital work and help designers understand users' practices and create digital tools that support these practices.

In their work, Simone, Divitini and Schmidt proposed ARIADNE, a notation that represents coordination mechanisms (Divitini et al., 1996). It provides a graphical language that allows designers to formally specify the coordination protocols and artifacts that form coordination mechanisms. ARIADNE allows designers to model the structure, behavior, and interconnections of components in a system and to define how they coordinate with each other to achieve their goals. The notation allows the designing of computational coordination mechanisms that are malleable and linkable, which, as we have seen above, are two important requirements for artifact ecologies.

Herrmann et al. (1999) proposed SEEME, a formal language used to model the behavior and interactions of software systems that make it possible to deal with the vagueness and imprecision inherent in socio-technical systems, as some knowledge and work organization cannot be definitively posited. SEEME provides a systematic way of identifying users' goals, motivations, expectations, constraints and dependencies between actors and systems. Using these models, designers can create digital tools tailored to the users' specific needs that effectively support their work practices.

However, both ARIADNE and SEEME has not been widely adopted in universities' syllabus or the industry and seems less known or used than other "classical" software modeling languages or notations as UML.

UML (Unified Modeling Language) is a widely used graphical language in the software development industry for visualizing, specifying, constructing, and documenting software systems. It was defined in the 1990s to unify the three existing languages for object-oriented modeling previously developed by Grady Booch, Ivar Jacobson, and James Rumbaugh, respectively. Despite its wide diffusion, UML remains controversial (Grossman et al., 2005) and is sometimes presented as unnecessarily complicated and paradoxically imprecise (Kobryn, 2002). Also, it focuses mainly on the technical aspects of the systems, hardly translating the socio-technical phenomena (Herrmann et al., 2004). UML makes it hard to reach the situated and nuanced aspects of software systems, such as collaboration and coordination among users (Suchman, 1987).

Over the years, UML has become a widely accepted language for software modeling, and many organizations and individuals rely on it to design and document their software systems. UML provides a powerful and flexible means of communicating software design information and is an essential language in software engineering curricula.

Translating key insights from fieldwork into operational systems is challenging and earlier work give essential direction towards this endeavor (Heath & Luff, 1991; Kaplan & Seebeck, 2001; Randall et al., 2005). However, our approach is less concerned on helping software engineers to embrace CSCW perspectives or to train them for fieldwork (Hartswood et al., 2003). We think worth to explore the pathway of accommodating the current tools and practices used in software engineering as an area for work. The issue then become to documents for discussion and negotiation with software engineer and IS manager, as CSCW researchers embedded in sociotechnical project.

We propose MADRAE, an extension of the UML component diagram, that allows describing insights about ecologies of artifacts and data work and, therefore, incorporates them into the design of the software. We illustrate this approach with a study conducted in the context of a telemedicine project.

MADRAE Motivation and Methodology

Before introducing our approach in developing MADRAE as well its principles and notation, we first presents the motivation for this UML extension that comes from a research in which we were involved that aimed at integrating teleconsultation tools in healthcare professionals' practices at a general hospital.

Motivation: An Inquiry about Teleconsultation Practices

The onset of our approach has been the study of teleconsultation practices at a general hospital (GH) in the Great East Region, France. In 2018, teleconsultation was inscribed in the law as a medical act reimbursed by national health insurance (Cormi et al., 2020). The hospital wanted to improve its telemedicine activities and technological support and welcomed us to get a better understanding of teleconsultation practices. The first author has been engaged in a three-year-long field study inquiring about the different teleconsultation practices at GH, observing and interviewing health professionals about their use and their work to integrate the available teleconsultation software into their work practices - in line with (Rossitto et al., 2014).

The analysis of this fieldwork (Cormi et al., 2022) accounts for various practices at the GH regarding teleconsultation. We highlight that making a full teleconsultation, in other words, a teleconsultation that matches the legal definition and can therefore be reimbursed, requires using more than one software application. Health professionals work on aligning (that is, learning, choosing, configuring, and adapting) an artifact ecology to achieve routine teleconsultation with the Hospital Information System (HIS) (Bødker & Klokmose, 2012; Lyle et al., 2020). The diversity of the reported teleconsultation practices is mainly supported by two teleconsultation software systems with their respective artifact ecology: TELECONSSYS and TELECONSAPP.

TELECONSSYS is the central support of an ecology that supports inter-organizational cooperation among health professionals for achieving teleconsultation with residents at nursing homes. It is an application hosted by an external vendor with different components that allows for requesting teleconsultation appointments and handles asynchronous and synchronous communication up to post-consultation reporting.

TELECONSAPP is the central element in the artifact ecology doctors use during face-to-face consultations in the hospital's outpatient department. For instance, it supposes using the HIS to access and modify electronic health records. TELECONSAPP is hosted by the regional health authority and mainly provides an audio and video channel over the Internet for achieving teleconsultation with patients already recorded in the HIS.

We found that data work is essential for conducting teleconsultations, whatever system is used. Indeed, many software components are far from interoperable (Iroju et al., 2013). We have identified that if part of this data work is overwhelming for the professionals (in particular, copy-pasting data or duplicating documents from one software to another), an essential part of this data work involves ‘artful coordinating’ (Pine & Mazmanian, 2017) that cannot qualify for automation (for instance, managing the notifications and reminders of patients’ appointments for teleconsultations).

We report more specifically about TELECONSSYS and TELECONSAPP while presenting MADRAE. As highlighted by Bødker et al.(2016), ecologies of artifacts are evolving due to users’ practices and organizational constraints, as policies, that lead to a need for knowledge. Therefore, we propose MADRAE as support for the analysis, design, and reflective choice of components of the artifact ecology.

Methodology: Modeling principles and notation

In order to incorporate insights about artifact ecology and data work into the daily processes and toolkits of software engineers and IS managers, we use to work on UML modeling language for its wide use. While there is no specific UML diagram that is designed to represent artifact ecologies and data work, we argue that structural diagrams better fit the job of representing a large artifact ecology.

Behavioral diagrams like activity and sequence diagrams help represent activities and interactions between objects in a software system. However, they do not provide a comprehensive overview of the entire system architecture, which is necessary for understanding the complex relationships between different components and their interactions with the environment. These diagrams focus on specific aspects of the system and can become overly complex and difficult to read if we want to represent large-scale artifact ecologies.

We choose to work on the UML Component Diagram, which is used to model the internal structure of a system or subsystem and thus can represent the components and artifacts that make up an artifact ecology. The diagram shows the relationship between the components and their interactions with each other and external entities. With MADRAE, we extend the UML Component Diagram to represent artifact ecologies and data work, as the standard diagram may not fully capture all the social and cultural aspects of the artifact ecology. In this section, we will introduce the UML component diagram notation and our proposed extensions. These extensions are designed to help model aligned artifact ecologies within an organization and emphasize the importance of data work.

In order to check the applicability of MADRAE for IS analysis and architecture we developed several models grounded in our study of teleconsultation practices. We have then conducted a formative evaluation with the management of IS department of CHT concerned with our research. These elements are developed in the last parts of the present paper.

The Component Diagram of UML

The component diagram of UML offers a static representation of a software system as related components. While behavioral diagrams (for instance, the activity diagram or the sequence diagram) account for the behavior of software system along a temporal dimension, the interaction between component diagrams provides an overall snapshot of a complex software system architecture. A component diagram uses two key primitives:

- Component derives from the concept of Class. A component is a software module with defined requirements. A component can be substituted by another if it offers the same feature and interface. Components are connected and have interdependent relationships that respect a defined interface.
- Interface defines a contract about the availability for other components of a set of operations with their signature (i.e., parameters and return values). Each component is dependent on a set of required and provided Interfaces for its proper functioning. An interface defines an identifier that can be reused across different components as a generic element.

The inner working of a component can be detailed through diagrams too. Component diagrams are handy for showing the dependencies between components in a software system and which component provides and requires which operation from another component.

For instance, Figure 1 shows a simplified and idealized version of the schedule component of Teleconsultation software (TCSchedule) that shares data with the general hospital planning system (HISPlanning). The detail of the IAppointement interface highlights that TCSchedule publicly exposes the exportSchedule() operation that allows HISPlanning to retrieve sets of recorded teleconsultation appointment data to stay up to date. Here we can say HISPlanning has a dependency relationship with TCSchedule. A lollipop connector notation emphasizes which component provides or consumes the operation.

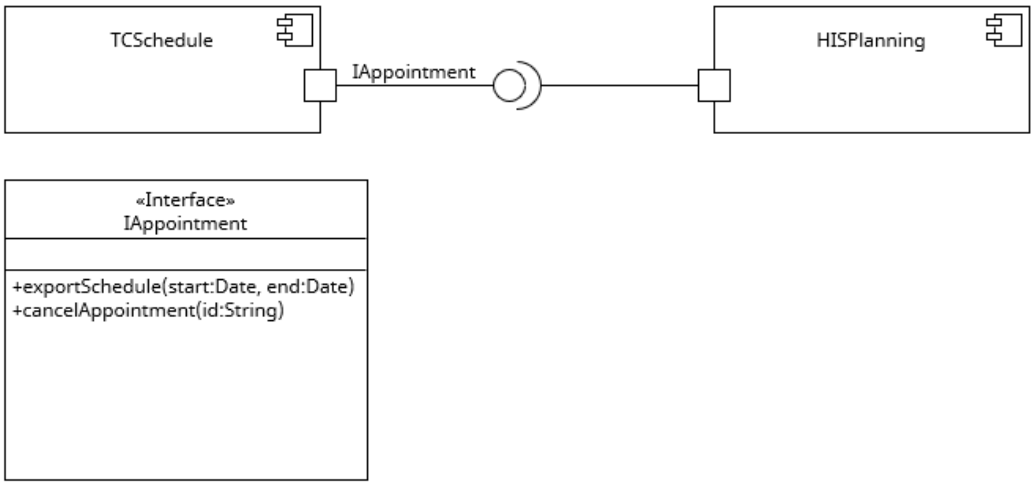

Figure 1. Top: a component diagram representing interoperability of two components with respect to the IAppointment interface / Bottom: a detailed view of the IAppointment interface definition.

As illustrated in our example, the component diagram is a key tool for exposing interoperability issues (Iroju et al., 2013). When provided and required interfaces match, as in Figure 1, the components are interoperable within the scope of the interfaces they are using.

Extensions with MADRAE

With MADRAE (Modeling for Analysis and Design in Regulated Artifacts Ecologies), we propose to reuse the UML component diagram as a basis for modeling an aligned artifact ecology that translates the knowledge gained from the fieldwork about one, or a range of, software-supported practices. The practice at stake can span across multiple organizations, as in the case of a teleconsultation where part of the software components belongs to the hospital and another to a nursing home information system, for instance.

Modeling an aligned artifact ecology and organizations

MADRAE uses the UML component diagram primitives:

- Each software that is in use in the artifact ecology is presented as a component.

- The required and provided interfaces allow accounting for automated information exchange. This also allows keeping the links with other forms of UML diagrams like the class one.
- As aligned ecologies of artifacts are not limited to the boundaries of one organization, we propose to use the UML Package notation to indicate the location of a component (see Figure 2).

Representing data work

We have frequently observed during our fieldwork that human intervention is essential to make the different artifacts of an ecology work together. We propose to highlight this data work by extending the interface notation to show actors' contributions to the information exchange between components. This way, when information exchanges between components require a human intervention, we represent this aspect as a dependency between the component and a UML Role. Another case is when an actor needs information (or triggering action) from a component; we represent this as a dependency relation between the role and the component. For instance, Figure 2 shows a situation we have observed where a medical secretary has to manually copy the appointments recorded in TCSchedule in the hospital information system (HIS) planning component HISPlanning. Classical required and provided interfaces relationships are represented to represent interoperable dependencies (i.e., IHealthRecord).

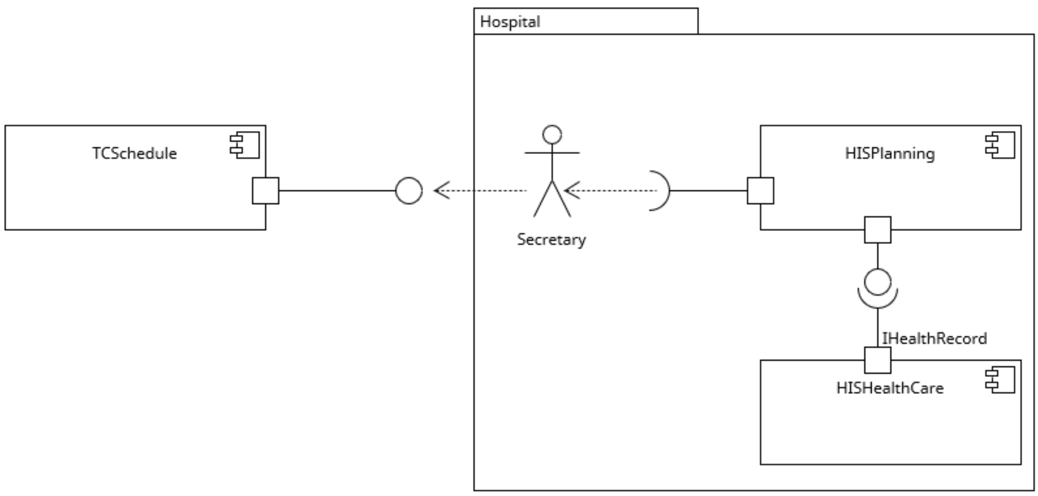

Figure 2. A basic MADRAE extended component diagram highlighting the dependency of HISPlanning software to Secretary actor to get updated information about teleconsultation appointments from TCSchedule. Note this data work can coexist with the representation of interoperable components as with HISHealthCare.

Acknowledging how a software component depends on human knowledge contrasts with the current usage and representation of UML, which scarcely deals with human actors. Therefore, emphasizing the share of human work in the sociotechnical system by making it visible is a core aspect of MADRAE.

In order to ease the reading of diagrams, the interfaces' names that define the list of available operations can remain hidden to manage the model's level of detail. However, interfaces' names still exist and have the same status as in the original component diagram (and can be detailed as in Figure 1). The introduction of the UML role in the required and provided interface relations refers to an operation triggered with the help of a graphical user interface or a form (that would be out of reach of an external software component).

Combination with other design documents

MADRAE connects with other software specifications or documents the same way UML allows for the cohabitation of multiple views in a model. In particular, the model's elements identifiers, such as interfaces or components' names, can serve as references for adding fieldwork memos, scenarios, workflow diagrams, or interface mockups that describe or define the interaction between the actors and the component. Figure 3 provides the idea of such usage.

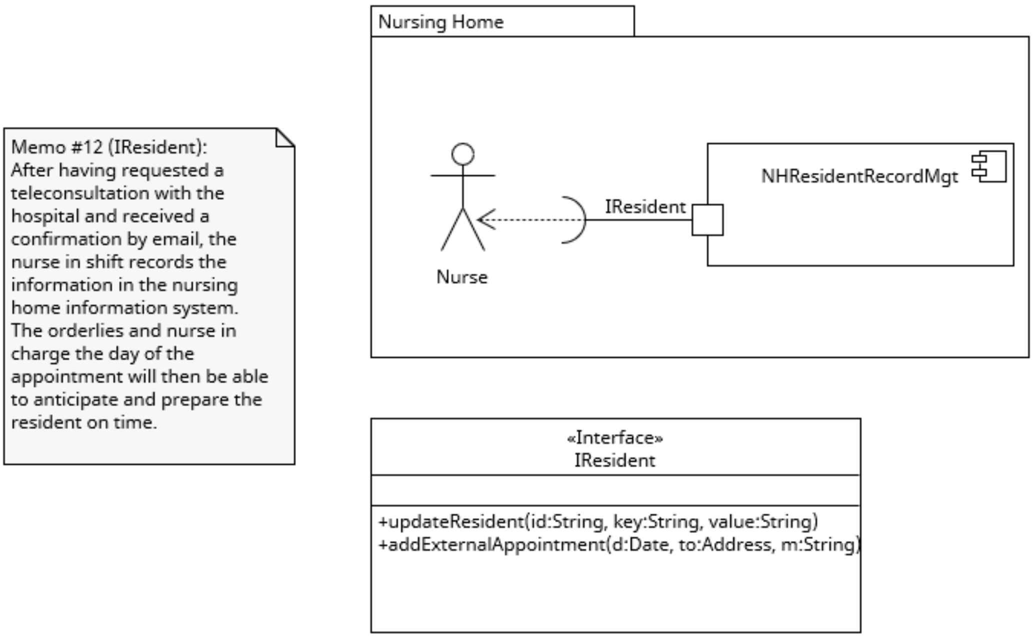

Figure 3. MADRAE extended component diagram can be used in combination with other design or fieldwork documents, here a memo.

The MADRAE component diagram extensions can be drawn using most of the current UML diagramming solutions. For instance, we have used UMLETINO (Auer et al., 2003) and LUCIDCHART to make our models.

Analysis and System Proposal with MADRAE

We demonstrate the use of MADRAE through two possible uses of the notation. The first case presents the use of the notation for analyzing an existing system (TELECONSSYS), highlighting part of the complexity of fieldwork, and spotting sociotechnical issues related to the practices of conducting inter-organizational teleconsultations. The second case shows how MADRAE can be used to generate and discuss a proposal for a new alignment of the artifact ecology (TELECONSOPT) that would improve the organization and respect the different practices.

Case 1: Analyzing an Existing Aligned Artifact Ecology

We have used MADRAE to get an overview of the artifact ecology around TELECONSSYS which supports teleconsultation between the hospital and 26 nursing homes of the region. TELECONSSYS has been designed as a standalone teleconsultation system with its own scheduling, health record, document sharing, and audio-video components, independent of the organization's information systems. The following diagram (figure 4) shows how we can represent with MADRAE the aligned artifact ecology between the hospital and one nursing home that we have observed.

A teleconsultation with TELECONSSYS starts with a nurse from a nursing home filling out a form to request an appointment among the available medical specialties at GH. The nurse indicates contextual (next availability, contact, and particular precaution) and medical information about the resident. At the hospital, a secretary checks for a nearby availability in the physician's schedule and then confirms a request for teleconsultation. The confirmation triggers the creation of a health record for the teleconsultation and the booking of an audio-video channel timeslot. A notification is also sent by email to the nursing home email box to confirm the appointment, with the useful links.

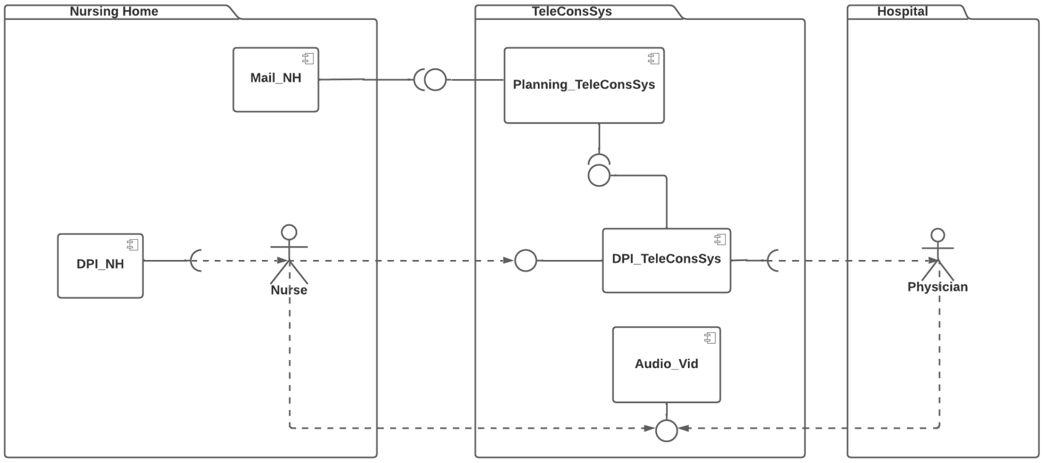

Figure 4. The ecology of artifacts and data work supporting a teleconsultation with TeleconsSys.

A teleconsultation with TELECONSSYS requires an important amount of data work; after the teleconsultation, the nursing home nurse has to copy the report and prescriptions the physician has recorded on TELECONSSYS (DPI_ TELECONSSYS) in the nursing home information system. Again, automation and interoperability are complex here, as nursing homes generally use several software systems from different vendors.

From our inquiry, we also realized that only some teleconsultations made with TELECONSSYS were reimbursed to the hospital by the national health insurance. The issue is noticeable in our diagram as no interface or data work link with a component of the HIS. Indeed, the physicians' prescriptions recorded on DPI_TELECONSSYS are never copied into the HIS for further processing. From our interviews, we learnt that the physicians are not concerned or not aware of this requirement for the hospital to be reimbursed.

Our analysis also led us to consider an important issue that is not yet reflected in our model about the sustainability of TELECONSSYS in relation with national healthcare policies. Despite the system's capacity to support inter-organizational practices, the evolution of policy requirements in terms of security and privacy of health records put the system at risk of being unauthorized in the next few months. We will discuss the ability of MADRAE to highlight policy issues in the discussion section.

Case 2: Generating Design Proposals for Enriching an Aligned Artifact Ecology

The other teleconsultation system in use at the hospital, TELECONSAPP, offers an audio-video channel with a feature for document sharing while teleconsulting. Apart from the previous elements, the users of TELECONSAPP (e.g., healthcare professionals) depends entirely on the HIS components for scheduling an appointment, updating patient health records and prescription, and following up on consultation for reimbursement by health insurance. Therefore, the system is especially efficient for replacing face-to-face external consultations at the hospital with teleconsultation. However, an external organization like a nursing home has no access to the hospital's HIS, making TeleconsApp unable to support inter-organizational cooperation (Cormi et al., 2022).

Our analysis of both the TeleconsSys and TeleconsApp systems leads us to think of a teleconsultation system that could support inter-organizational cooperation and hospital's outpatient teleconsultation practices. MADRAE allows to present this proposal and then discuss it with the person in charge of the HIS at the hospital. This ideal system, which we name TeleconsOpt (figure 5), could support both current practices and limit time-consuming and unqualified data work.

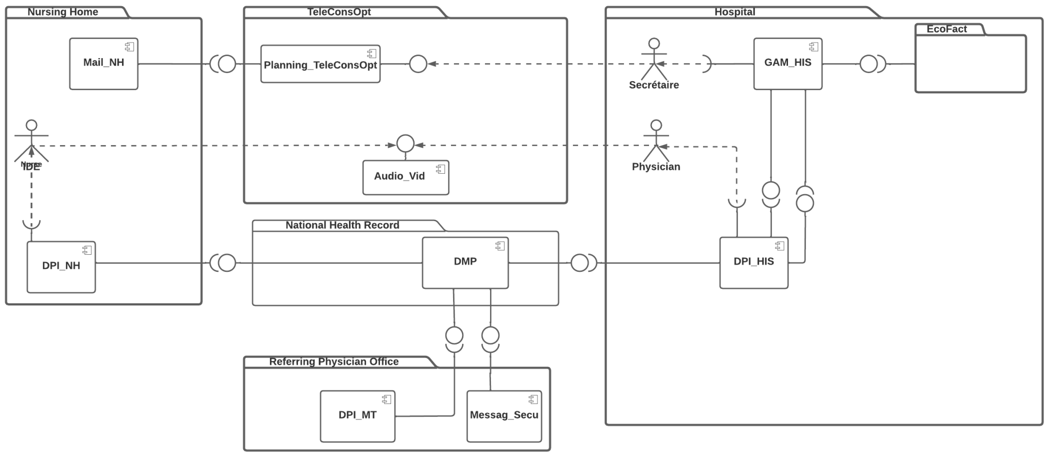

Figure 5. The envisioned ecology of artifacts and data work supporting a teleconsultation with an ideal system: TeleconsOpt. Apart from the nursing IS components intervening in a teleconsultation, the model figures the DMP component from the national healthcare record, the healthcare record (DPI_MT) and secure messaging software (Messag_Secu) of the patient referring physician. On the side of the hospital, GAM_HIS is a HIS component recording the patient administrative data in relation with payment and reimbursement (EcoFact). DPI_HIS is concerned with the patient electronic healthcare record (EHR).

As TeleconsSys, TeleconsOpt would allow external health organizations to request teleconsultations under the human screening of the hospital secretary, who could arrange the best timeslot. As TeleconsApp, TeleconsOpt reuse key software components from the HIS as a part of its artifact ecology. This strategy ensure health records are managed with software components that can interact with each other and are easily accessible within the hospital. The follow-up of teleconsultations to ensure reimbursement would then be straightforward and systematic.

After the teleconsultation, the patient's referring doctor would be notified that the report of the teleconsultation has been added to the national computerized healthcare record (this essential feature is lacking in the two current systems), which would ease the synchronization of health information while limiting the double entry of health records. We discuss that in the following section, as this improvement has been pointed out during the evaluation of MADRAE.

Formative Expert Evaluation

We have conducted a formative evaluation (Scriven, 1967) to get feedback from the perspective of the management of the hospital's information system about the potential use of MADRAE for analysis and envisioning a future teleconsultation system. The expert evaluation consisted of a 45-minute interview with the Head of the Hospital Information System (HHIS) in June 2022. The HHIS has followed the design, choice, and deployment of all teleconsultation software at the hospital before and while conducting our research work.

We presented the MADRAE model of the existing and already deployed TELECONSSYS and TELECONSOPT (as a potential future system). We aimed to collect appreciation and feedback from the HHIS on three dimensions: (1) the understanding of the MADRAE approach and notation, (2) the evaluation of the model of TELECONSSYS and TELECONSOPT, given their knowledge, (3) limits and suggestions for improvements.

The reception of the MADARE approach and notation (1) has been positive overall. Figure 4 of the TELECONSSYS model was presented first. The inspiration from UML has been immediately recognized and acknowledged:

> "I used it a long time ago"; "UML everybody knows what it is". (Interview_HHIS)

The overall approach with the connection between UML components, the artifact ecology, and the highlighting of data work has been well understood. The HHIS pointed out that in figure 4, the model could have accounted for extra data work when after the appointment confirmation email, the nurse is supposed to connect to TELECONSSYS to fill out detailed information about the patient that the specialist doctor needs to know before the teleconsultation.

> "The part when the nurse is filling out DPI_ TELECONSSYS before the teleconsultation is missing; this is especially that part that is a loss of time, and which motivates a solution with better integration." (Interview_HHIS)

As mentioned by the HHIS, the amount of information collected from nursing homes before teleconsultation is a significant drawback of TELECONSSYS as it burdens nurses. Therefore, we considered this aspect in the improved version of TELECONSOPT (fig. 5).

He also spotted and made fun of the absence of a connection between TELECONSSYS and a critical part of the HIS that enables the tracking of medical acts and, therefore, the reimbursement by health insurance.

> "I would have at least represented DPI_HIS with two required connectors and nobody at the end! [laugh] Just to better show that this link is clearly missing here and that a good teleconsultation software should be an extension of DPI_HIS, not the contrary." (Interview_HHIS)

About TELECONSOPT, the HHIS quickly spotted an issue with health record sharing across health organizations:

> "I would not have done it that way... because the national healthcare record [DMP] and secured message system are the pivot point for communication if you want to comply with national policies and standards. It would help if you stored nothing inside the teleconsultation software itself. [...] You do your teleconsultation in your tool, but at the end, the report is in the DPI_HIS, which will upload data in the DMP. The nursing home information system then goes to the DMP to get the report." (Interview_HHIS)

Overall, our expert has found MADRAE attractive. As highlighted above, the HHIS understand the approach (1) and the presented models support relevant and detailed discussion about technology and organization for teleconsultation at GH (2).

However, our expert also explained that the IT teams he manages in the service adopt a different approach "in between design and change management" and they "combine the study of users' process with the definition of the tools to deploy". He mentioned, "visualizing the users' process is mandatory aside from tools and architecture" from his point of view.

The results of this formative evaluation show that MADRAE seems effective in referencing existing systems and discussing future ones. Furthermore, the overview of the artifact ecology and the associated data work helped strengthen our proposal for TELECONSOPT. Nonetheless, the approach appears incomplete to our expert for dealing with whole IT projects as we develop in the following section.

Discussion

Our approach starts from the challenges of transferring rich and nuanced results from our field study of teleconsultation practices to software engineers and information system managers. Earlier work gives essential direction towards this endeavor (Heath & Luff, 1991; Kaplan & Seebeck, 2001; Randall et al., 2005). We suggest developing another path in accommodating the current tools and practices used in software engineering and IS management as an area for work.

Based on our case study in telemedicine, we highlight the importance of better accounting for the ecologies of artifacts Lyle et al. (2020) and data work (Bonde et al., 2019). We proposed MADRAE as an extension of the UML component diagram that supports the analysis of an existing artifact ecology at the scale of a collaborative practice and that has the potential for generating design and architecture proposals for discussion with IS practitioners.

MADRAE succeeded in pointing out when data work is taking place, allowing for reflecting upon where it is needed and where interoperability should be considered. For example, data work is irrelevant for duplicating data from the hospital planning system to the teleconsultation one, especially considering that it can increase the risk of errors and is burdensome (Cabitza, Locoro, et al., 2019). Thus, MADRAE extends Cabitza and colleagues' work as it helps identify where qualified data work is, therefore, where it is needed (and where it is not). Our approach has the potential to incentive software design and information management professionals to consider data work better and envision an alternative to automated interoperability when relevant.

As shown above, the HHIS pointed out MADRAE's weakness in specifying the temporal sequence of events which he considers essential. We agree that MADRAE does not allow specifying the temporal aspects directly. Nevertheless, we have witnessed many variations in practices during our fieldwork from one medical department to another or even from one teleconsultation to another. We can assert that this diversity did not prevent health professionals from carrying out teleconsultations. While the request for modeling a temporal dimension and "user process" reported by the HHIS is interesting, it brings with it the difficulty of accounting for a diversity of practices. Therefore, we have chosen a structural modeling approach for MADRAE, leaving the actors to decide on the sequence of actions according to the available components. The temporal dimension can also be supported by combining complementary forms of modeling (i.e., graphical interface models, scenarios) and documentation (i.e., field notes), which can be attached to the interface names of the component model, as suggested in figure 3. Also, our formative evaluation is limited to one expert and the approach would benefit from other perspectives and application context.

As pointed out in our analysis of TELECONSSYS with MADRAE, policies influence the software components that can take part in artifact ecologies. For instance, storing medical records outside of a health data warehouse will be forbidden in the near future due to the evolution of the regulations related to national healthcare policies. Some research in CSCW and healthcare points to policies as an important issue (Fitzpatrick & Ellingsen, 2013; Jackson et al., 2014). We are currently considering an approach for reflecting this aspect in MADRAE. That is why the "R" in MADRAE refers to "regulated," i.e., regulations and policies constraining technology, as we ambition to further this aspect. Our suggestion so far is to tie policies with the organizations participating in our model using UML package notation. However, we must be cautious about generalizing this notation, especially when several policies partly overlap. Further work is therefore needed to strengthen policy modeling in the MADRAE approach.

Conclusion and Future Work

In this paper, we presented MADRAE, a modeling approach for sociotechnical systems which, from the study of a complex cooperative practice such as teleconsultation, makes it possible to consider the artifact ecologies and the data work involved. The approach has been demonstrated based on different cases of teleconsultation practices.

The documentation of our approach and extended notation for the component diagram is publicly available: https://github.com/Clement-Cormi/MADRAE. MADRAE will of course benefit from further evaluations, revisions, and applications to different work contexts beyond the case of teleconsultation. For example, the issue of finding a way to account for regulations and policies in healthcare is a current line of work on our side.

Through this work, we also hope to contribute to the overarching reflection on the translation of CSCW analysis to software design and information system management practices (Christensen et al., 2020; Lewkowicz & Liron, 2019).

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