Interaction Design in Distributed Software Development: What we know and what we don't know

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Abstract: Human-Computer Interaction (HCI) is an area focused on human interaction with/through computational systems, among which tangent studies on interaction design stand out. In HCI, interaction design has been consolidated as a practice with the potential to support interactive systems projects. On the other hand, more and more organizations are developing software with geographically distributed teams. However, interaction design in distributed software development (DSD) has yet to be explored, mapped, or structured in the scientific literature. Although there are reports in the scientific literature about interaction design in DSD and some proposed solutions, how interaction design occurs in DSD is still being determined. In this paper, we present a summary of the results of a research that aimed to investigate how interaction design has been practiced in DSD, seeking to understand the practices, challenges, and limitations, as well as to promote and advance the state of knowledge in interaction design in the context of DSD. The research methodology was based on Charles S. Peirce's semiotic methodeutics, bibliographic research method, and mixed methods research to investigate the current state of knowledge and practice on interaction design in DSD. We hope that the results pointed out by this research contribute to the body of knowledge about interaction design at the research frontier between HCI and DSD by (i) providing an overview of research efforts on interaction design in DSD, (ii) providing an overview of the practice of interaction design in DSD, (iii) identify research gaps and discuss future research directions, and (iv) conceiving a set of recommendations for interaction design in DSD.

Keywords: Interaction design, distributed software development, free software and open source, recommendations for interaction design.

1 Introduction

Human-Computer Interaction (HCI) is a multidisciplinary area focused on the design of computational technologies and the interaction between humans and computers [Foundation, 2020]. Interaction design (human-computer) is the process of shaping digital things for human use [Lowgren, 2013] and a discipline that addresses how to design computing technologies to make them easy and enjoyable to use [Dix, 2009]. Interaction design has also been consolidated as a practice with the potential to support software projects towards improving product quality about various aspects of human-computer interaction. These include engaging users in the design process and development of interactive software; reducing negative aspects of user experience; and developing accessible, easy, and effective interactive products [Preece *et al.*, 2015].

On the other hand, Distributed Software Development (DSD) is the development of software artifacts in more than one location [Šmite *et al.*, 2014], and its main characteristics are geographic distance, time zone difference, and cultural differences [Carmel, 1999; Carmel and Agarwal, 2001]. In the context of this research, we use "distributed software development" or "DSD" as a generic term to designate software development with geographically distributed team members, for example, Free/libre open source software (FLOSS) projects and communities[1], virtual software development teams and software projects with collaborators located in various institutions/organizations (colleges, universities, research centers, software industry).

From a practical perspective, applying good interaction design practices in software development projects can have limitations with geographically distributed teams. Some studies have faced difficulties and challenges related to interaction design in the context of DSD, for example, problems associated with the quality of use criteria [Çetin and Göktürk, 2008; Lisowska Masson *et al.*, 2017; Alves *et al.*, 2014; Treviranus, 2009; Bach and Carroll, 2010] and the lack of solutions[2] for distributed interaction design [Alves and Matos, 2017c, 2019]. In addition, there are challenges in engaging users in software development [Luz and Masoodian, 2014; Bach and Twidale, 2010; Alves and Matos, 2022] and difficulties resulting from a lack of HCI specialists and/or their involvement [Bach and Twidale, 2010; Iivari, 2011].

With the increase in the number of DSD projects [Jiménez and Piattini, 2009; Ebert *et al.*, 2016b,a; Crowston *et al.*, 2008; Radtke *et al.*, 2009; One, Version, 2020; RedHat, 2019; Haff, 2019], there are also increasing concerns related to the adoption of good interaction design practices and the quality of use criteria (usability, accessibility, user experience, and communicability). When co-located, interaction design has its challenges and becomes even more challenging than tradi-

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[1]Generally, in FLOSS projects and communities, stakeholders are geographically distributed.

[2]In the context of this research, "solution" is considered a generic term to designate any method, technique, tool, strategy, approach, process, etc. that supports interaction design in the context of development software.

tional practices, when carried out geographically distributed stakeholders using technological resources (e.g., e-mail, chat, web conferencing, collaborative software).

Some characteristics of the interaction design process change according to the geographic dispersion of the participants. One such characteristic is related to the involvement of participants (including users, e.g. children, older people, people with disabilities) in the interaction design. The geographic distribution of participants leads to changes in the dimensions of time, space, and/or organization [Gumm *et al.*, 2006] and the need for computer systems and tools to carry out activities in collaboration while accommodating different cultures and organizational habits. In addition, solutions (models, processes, methods, techniques) for interaction design, usually designed for the context in which participants are co-located, may not be suitable for the context when the participants are geographically distributed.

Jackson *et al.* [2022] state that while DSD has been an accepted and adopted practice for a long time, the coronavirus (COVID-19) pandemic and the subsequent shift to remote work have placed collaboration tools more central than ever to the software development effort. However, Jackson *et al.* [2022] pointed out challenges that geographically distributed teams had to deal with during the COVID-19 pandemic. According to the authors, requirements elicitation, customer involvement, rapid design, prototyping, and software life cycle management were challenged by teams working in highly distributed configurations, without adequate methods and technologies. Given this, Jackson *et al.* [2022] highlight the need for the evolution of collaboration technologies to be successful.

From a research perspective, despite the importance and benefits of interaction design in software development projects, DSD challenges have not been widely addressed in the scientific literature on HCI [Iivari *et al.*, 2008; Çetin and Göktürk, 2008; Iivari, 2011; Alves and Matos, 2017c; Alves *et al.*, 2023]. On the other hand, software engineering researchers have made significant advances in identifying challenges and proposing new solutions for different domains related to DSD, such as risk management and requirements engineering, reporting these findings in the literature [da Silva *et al.*, 2010; Jiménez *et al.*, 2009; Prikladnicki and Audy, 2010; Lanubile *et al.*, 2010; Jiménez and Piattini, 2009].

In this research, we approach interaction design in DSD from two perspectives: i) research: providing an overview of research efforts on interaction design in DSD, and ii) practice: presenting how interaction design has been practiced in DSD.

The conduction of this study has been mainly motivated by advances in DSD; problems related to human-computer interaction in DSD; interaction design challenges in DSD; and the need for research because interaction design has not been completely explored and understood in the DSD context. Despite several studies and solutions proposed for DSD, it is unclear how interaction design has been conducted in DSD projects, what types of research have been carried out, and what solutions have been proposed for conducting interaction design in the DSD context. Thus, we identified the need to investigate the research efforts on interaction design in DSD and analyze how the interaction design process oc-

curs in the context of DSD.

Given the above, we problematize the following guiding research question (RQ):

RQ. How is interaction design practiced in DSD projects?

The main research question unfolds into the following secondary research questions (SQ):

- *SQ1. What interaction design solutions (models, methods, techniques, tools) have been proposed for the DSD context?*
- *SQ2. What are the main interaction design activities in DSD projects?*
- *SQ3. What approaches, methods, techniques, and tools have been used in interaction design in DSD projects? What are the interaction design practices in DSD projects?*
- *SQ4. What is the geographic distance of interaction design participants in DSD projects?*
- *SQ5. Have designers and HCI specialists been working on DSD projects? Is there an association between the adoption of good interaction design practices and the performance of a designer and HCI specialist in DSD projects?*
- *SQ6. Have users participated in interaction design activities in DSD projects? What are the strategies and practices for involving users in DSD projects? What are the roles of these users?*

In this context, this paper presents a summary of the results of a research that aimed to investigate how interaction design has been practiced in DSD, seeking to understand the practices, challenges, and limitations, as well as to promote and advance the state of knowledge in interaction design in the context of DSD.

With the consolidation of the main results of this research, we conceived a set of recommendations for interaction design in DSD, to support DSD professionals in the planning and implementation of interaction design practices in DSD projects.

We hope that the results of this research contribute to the body of knowledge about interaction design at the research frontier between HCI and DSD by (i) providing an overview of research efforts on interaction design in DSD, (ii) providing an overview of the practice of interaction design in DSD, (iii) identifying research gaps and discussing future research directions, and (iv) conceiving a set of recommendations for interaction design in DSD.

Section 2 provides a background on interaction design, distributed software development, user involvement, and some research that has been conducted concerning interaction design and DSD. Section 3 presents our research methodology. Section 4 describes the main results obtained in this research, as well as a discussion of these results and their implications for theory and practice related to interaction design in DSD. Section 5 highlights the main contributions of this research to the HCI area. Section 6 presents the consideration of ethical aspects of this research. Section 7 presents the limitations and threats to the validity of this research. Finally, Section 8 presents the final considerations of this research.

2 Background

This section provides basic concepts and theoretical foundation on interaction design, user involvement, DSD, and related work.

2.1 Interaction Design

2.1.1 What is Interaction Design?

A simple definition of interaction design is: "[...] the design of the interaction between users and products" [Yu Siang, 2020]. Interaction design aims to create interactive software products (in general, but not limited to) so that users can achieve their goals in the best possible way [Yu Siang, 2020].

For Preece *et al*. [2015, p. 8], interaction design is "designing interactive products to support the way people communicate and interact in their everyday and working lives." Preece *et al*. [2015] affirm that design is a practical and creative activity that aims to develop a product, taking into consideration the goals the users want to achieve by using the product.

The Interaction Design Association [IxDA, 2023] states that "interaction design (IxD) defines the structure and behavior of interactive systems. Interaction designers strive to create meaningful relationships between people and the products and services ranging from computers to mobile devices to appliances and beyond."

The Interaction Design Foundation [Foundation, 2020] defines interaction design as "[...] the design of interactive products and services in which a designer's focus goes beyond the item in development to include the way users are expected to interact with it."

Interaction design has been increasingly accepted as an umbrella term to cover multiple aspects of design, including user interface design, interactive systems design, web design, experience design, and user-centered design [Preece *et al*., 2015].

Interaction design can employ a variety of approaches, methods, techniques, and tools. The interaction design process can vary widely, depending on the domain of the application, the approach, the degree of user involvement, and the organization. However, Whittaker [2013] states that there is unanimity in the HCI area regarding the interaction design process, the consensus being that design consists of four iterative steps: understanding users, generating designs, prototyping, and evaluation.

Preece *et al*. [2015] established a lifecycle model for interaction design, which incorporates four interaction design activities (establishing requirements, designing alternatives, prototyping, and evaluating) and three user-centered design principles (early focus on users and tasks; empirical measurement; and iterative design).

Dix *et al*. [2003] present a simplified view of the interaction design process, consisting of four main stages (requirements, analysis, design, and implementation and deployment) and an iterative cycle.

There are other initiatives/proposals that can provide a roadmap for the interaction design process, such as a framework for human-centered design [ISO, 2019], UX design lifecycle process [Hartson and Pyla, 2018], usability engineering [Nielsen, 1993; Mayhew, 1999], Star Life Cycle [Hix and Hartson, 1993], and semio-participatory framework for interaction design [Rosa and Matos, 2016].

According to Whittaker [2013], a good interaction design process is very important for the development of interactive products. Several studies have pointed to guidelines for improving this process, especially with the development of new techniques and methods of interaction design [Whittaker, 2013; Choma, 2015]. Some studies have presented proposals for the integration of interaction design into the software development process [Silva, 2012; Choma, 2015; Ferre *et al*., 2005; Hussain *et al*., 2009; Chamberlain *et al*., 2006]. However, there is a lack of studies on interaction design solutions that take into account the distributed context [Lazarin and Almeida, 2016; Iivari *et al*., 2008; Çetin and Göktürk, 2008; Iivari, 2011; Alves and Matos, 2017c; Alves *et al*., 2023].

2.2 User Involvement in Interaction Design

Baranauskas *et al*. [2013] state that the user concept, in which some designers place themselves in the position of representatives of users, leaves no room for the person to define himself as an interested party in a design product and act in favor of his own interests. The authors proposed the Semio-participatory Model, in which this concept of user does not fit and is replaced by "interested party" in the design process, as a way of respecting the values, interests, and competencies of those involved in the design process [Baranauskas *et al*., 2013].

In interaction design, there is a Scandinavian undercurrent that goes back to the pioneering collaboration between Norwegian computer scientist Kristen Nygaard (and his colleagues) and the Norwegian Metalworkers Union on the ideologically and socially acceptable use of computer technology in the workplace [Binder *et al*., 2009].

One of the approaches adopted for interactive system design is participatory design (PD). The PD originated in Scandinavia in the 1970s through a partnership between academics and unions [Preece *et al*., 2015; Spinizzi, 2005]. Since then, several projects have taken the initiative to involve users in the design.

According to Muller *et al*. [1997], there is no single definition of PD that satisfies all researchers and practitioners in this area. The PD seeks to involve users in the design process to ensure that the user has a voice in the design and development of the products they will use [Preece *et al*., 2015; Muller *et al*., 1997]. Kensing and Blomberg [1998] state that PD is an evolving research area and practice among design professionals, whereby researchers seek conditions for user participation in the design and also in the introduction of computer-based systems in the work environment.

In participatory design, stakeholders make effective contributions that reflect their own perspectives and needs at some point in the software design and development lifecycle [Muller *et al*., 1997]. Stakeholder participation is active (more than being asked to provide information, answering questionnaires or being observed while interacting with the software) [Muller *et al*., 1997]. Stakeholder participation has

not been limited to the design itself, but has proven to be valuable in activities throughout the software lifecycle [Muller *et al*., 1997]. Muller *et al*. [1997] reported a set of participatory practices that can be used in the software lifecycle. These participatory practices include methods, techniques, and procedures that can be used by practitioners in software design and development.

Several researchers have proposed approaches, methods, and techniques to engage users in interaction design process activities [Baranauskas *et al*., 2013; Melo and Baranauskas, 2006; Lazarin and Almeida, 2016]. However, most participatory approaches of interaction design are conceived for face-to-face meetings [Gumm *et al*., 2006]. In addition, most participatory methods and techniques are applied or used with co-located participants [Gumm *et al*., 2006; Lazarin and Almeida, 2016]. Participatory techniques may be more difficult to apply in projects when participants are not co-located.

According to Danielsson *et al*. [2006], PD becomes challenging when stakeholders are geographically distributed. PD in distributed configurations may be denoted as distributed participatory design (DPD) [Gumm, 2006; Gumm *et al*., 2006; Danielsson and Danielsson, 2005]. Thus, the DPD research field arose from the need to make PD possible in DSD environments. Beynon and Chan [2006, p. 1] state that "DPD is concerned with design processes in which the stakeholders have different levels of expertise and competence and are located in different environments."

2.3   Distributed software development (DSD)

DSD [also termed global software development, distributed software engineering, and global software engineering (GSE) [Verner *et al*., 2014]] is defined by Šmite *et al*. [2014] as: "Development of a software artifact across more than one location."

According to Carmel [1999] and Carmel and Agarwal [2001], the main characteristics that differentiate DSD from traditional (colocalized) software development are distance, time difference, and cultural differences, whereby distance impacts coordination and control and has negative effects on communication.

Audy and Prikladnicki [2008] state that DSD is characterized by the physical and/or temporal distance between some stakeholders (users and developers, for example) involved in the development process.

Andres [2002] addresses virtual teams in the context of software development. For the author, these teams are formed by groups of people distributed geographically that collaborate in the execution of a project. Virtual teams have been created because organizations need to carry out projects quickly using the skills of people who are geographically distributed [Andres, 2002].

Software development projects are increasingly being driven by geographically distributed teams [Alho and Sulonen, 1998; Radtke *et al*., 2009; Crowston *et al*., 2008; Herbsleb, 2007].

The definition of DSD is comprehensive, encompassing cases in which stakeholders are distributed in groups located in different buildings in the same city, as well as cases in which stakeholders are distributed geographically in several countries [Siqueira, 2005]. DSD terminology is very diverse and, according to Šmite *et al*. [2014], it is often confusing and sometimes ambiguous.

For Šmite *et al*. [2010], the DSD gained momentum because of the promise of benefits. However, the challenges and complexity of DSD projects have attracted the attention of researchers, especially when teams are distributed globally. Challenges and solutions of DSD have been investigated in different domains related to the software development process, such as communication and coordination [Portillo-Rodríguez *et al*., 2012], risk management [Verner *et al*., 2014], requirements engineering [Ebling *et al*., 2009], process and process models [Jiménez *et al*., 2009; Prikladnicki and Audy, 2010], and project management [da Silva *et al*., 2010; Costa *et al*., 2010].

2.4   Related works

We identified few literature review studies addressing interaction design in DSD. The studies most related to ours are literature reviews addressing interaction design/usability in Free/Libre Open Source Software (FLOSS) and participatory design in DSD. We also identified empirical studies addressing user involvement in interaction design in the DSD context, generally empirical studies addressing interaction design in FLOSS and PD in DSD.

Gumm [2006] conducted a literature review to investigate how participatory design and DSD are linked up and whether the distributed participatory design is an inherent paradoxon. The study showed that participatory design issues are barely mentioned in DSD literature. Gumm [2006] states that "Distributed Participatory Design does not seem to be an inherent paradoxon", as there are some successful examples of adopting participatory design principles and goals in DSD projects. However, there is evidence that DSD and participatory design are only a little connected [Gumm, 2006].

Paul [2009] conducted a literature review on usability practices in FLOSS. The study identified publications of case studies on usability in FLOSS projects. The results showed for the lack of user research in FLOSS projects and the need for usability engineers to conduct user research studies and report the data in FLOSS projects [Paul, 2009].

Iivari [2011] examined PD in the FLOSS development context. The investigation was conducted using two case studies. According to the author, there are different types of user roles in the context of FLOSS development, namely, informative, consultative, and participative. The results of the study provide empirical evidence of the importance of intermediates that represent users in FLOSS development.

Hess *et al*. [2013] described an investigation conducted in a software development project in/with online communities, where most of the design and development was conducted with globally distributed users of different profiles. The authors report on the involvement of geographically distributed users in the software development process through an online community and PD [Hess *et al*., 2013].

Barcellini *et al*. [2009] investigated the artifacts (discussion lists, wiki, website) of a FLOSS community to verify participation forms and emerging roles in the FLOSS design process. This study addresses the emergence of specific roles

that promote mediation between users and developer communities. The study provides insight into the forms of participation in the FLOSS design process.

Blomkvist *et al.* [2015] report an empirical study conducted with User-Centered Design (UCD) specialists from a company that develops software with teams distributed within the same country. The study addressed problems and possible solutions for the integration of UCD and agile development. The focus of this research was communication through boundary objects in an agile DSD project.

Motivated by the social distancing that occurred during the COVID-19 pandemic, there are studies with proposed solutions and reports of experiences related to interaction design with geographically distributed stakeholders. Some of these studies are presented below.

Ali *et al.* [2021] formulated an iterative process for remotely designing interactions with the participation of users. The authors state that they created an online research and design platform to support distributed interaction design.

Constantin *et al.* [2022] developed a Distributed Participatory Design (DPD) research protocol based on the protocol template recommended by WHO's Research Ethics Review Committee (ERC) and on the data from two conference workshops. Constantin *et al.* [2022] state that a DPD research protocol for co-designing with children will be iteratively refined and will serve as inspiration for future research practices in Child-Computer Interaction, which will form the basis for many DPD project protocols.

Marques Correa *et al.* [2022] report the experience of conducting four studies in HCI research projects that were adapted to be executed remotely: a focus group study, a communicability evaluation study, a speculative design study, and a user observation study. Given the restrictions of the COVID-19 pandemic, Marques Correa *et al.* [2022] report the necessary adaptations and lessons learned related to the experiences of carrying out investigations remotely.

Campos [2021] describes the challenges and lessons learned in the design and evaluation of interactive systems carried out during social confinement. Campos [2021] describes the risks, challenges and lessons learned, as well as the techniques used to overcome limitations.

Although we identified some practices and strategies related to interaction design and user involvement in DSD projects, the identified studies present few details about how users were involved in interaction design in the context of DSD.

3 Methodology

The methodology of this research is composed of three phases: i) *Literature review*, ii) *Empirical investigation*, and iii) *Results consolidation*. This research began with the initial definitions, in which we identified the research problem and defined the objectives and methodological steps. After that, we carried out the *Literature review* phase, which consisted of understanding the problem through two systematic mappings of the literature and, from that, making inferences based on fundamentals and concepts of HCI and interaction design. The *Empirical investigation* phase consisted of an

empirical investigation conducted with DSD professionals. These two phases generated knowledge resulting from the exploratory investigation and we conceived, in the *Results consolidation* phase, a set of recommendations for interaction design in DSD. The *Literature review*, *Empirical investigation*, and *Results consolidation* phases were conducted from the perspective of the methodeutics of Peirce's semiotics.

3.1 Methodological Orientations

This research is based on methodeutics proposed by Charles Sanders Peirce (1839 - 1914). In his pragmatic and phenomenological philosophy, an important extension made by Charles S. Peirce from his earlier views involving abduction, deduction, and induction was to integrate the three forms of argument into his view of a systematic procedure for seeking truth, which he called "scientific method" [Burch, 2017] or methodeutics [Santaella, 2008]. Since deduction, induction, and abduction are integrated, they are not simply forms of argument: they are three phases of the methodology of science [Burch, 2017].

Santaella and Vieira [2008] present the logical sequence of the three phases of scientific research according to the Semiotics of Charles S. Peirce. The authors state that "Abduction concerns the generation and selection of an explanatory hypothesis. Two moments are distinguished there: the generative and the selective" [Santaella and Vieira, 2008, p. 117, Our translation]. On the other hand, deductive reasoning "[...] is the mode of reasoning by which one determines what must necessarily or probably be the case, if a hypothesis is true" and corresponds, in the syntax of the methods that constitute the method of science , to the second phase of scientific research [Santaella and Vieira, 2008, p. 122, Our translation]. Deduction consists in the logical analysis of the hypothesis, in order to generate all kinds of necessary or probable experiential consequences that follow from it. After that, the scientific method moves on to the induction or confirmation stage, which has the role of confirming or falsifying the hypothesis [Santaella and Vieira, 2008].

Thus, this research was conducted under the methodeutics of Peircean semiotics. Abduction, deduction, and induction, in an integrated way (methodeutics), were necessary during all phases of this research, contributing mainly to the understanding and explanation of the research problem through the generation and selection of hypotheses and the creation of a new idea, namely: the proposition of a set of recommendations for interaction design in DSD.

Regarding investigative procedures, the methods defined for this research were: bibliographic research [Wohlin *et al.*, 2012; Kitchenham and Charters, 2007] and mixed methods research [Creswell, 2010].

3.2 Work method

The working method of this research was elaborated based on the methodeutics of Peirce's semiotics [Santaella and Vieira, 2008; Peirce, 1914] and considering the objectives to be achieved with the development of this research. The working method of this research, shown in Figure 1, consisted of 3 phases and 10 steps.

This research started from abductive inferences, in which explanatory hypotheses were generated and selected about how interaction design occurs in DSD projects and its main challenges and difficulties. After that, through deductive inferences, mainly based on the results of *Phase I - Literature Review* and on fundamentals and concepts of HCI and interaction design, we obtained evidence and conclusions about how interaction design occurs in projects of DSD. Based on this evidence and conclusions, we planned *Phase II - Empirical Investigation* and elaborated data collection instruments. Finally, in the *Empirical Investigation* and *Results consolidation* phases, induction was used to verify how true the hypotheses were, through empirical investigation in the real context of DSD and, consequently, contributed to the conclusions obtained and in the conception of the recommendations for the interaction design in DSD.

As previously mentioned, this research began with the initial definitions, in which two steps were conducted: *problem identification* and *definition of objectives and methodology*.
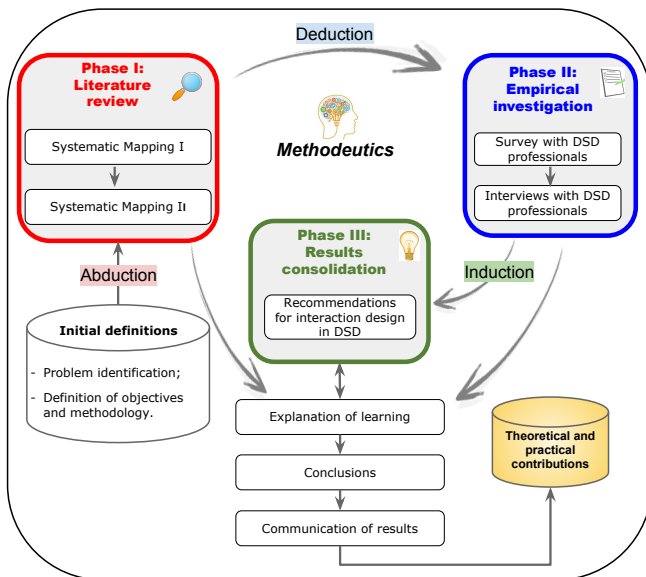

Figure 1. Research work method

In *Phase I: Literature Review*, we investigated interaction design in DSD from both research and practice perspectives. This phase aimed to identify research efforts related to interaction design in DSD. Phase I consisted of the following steps: *Systematic mapping I* and *Systematic mapping II*. The systematic mapping studies were planned and conducted following the guidelines proposed by Petersen *et al.* [2008] and Petersen *et al.* [2015]. We also used the protocol model described by Wohlin *et al.* [2012] and the recommendations provided by Kitchenham and Charters [2007]. Details of the working methods for conducting these systematic mapping studies are available at: Alves [2022], Alves and Matos [2017c], and Alves *et al.* [2023].

In *Phase II: Empirical investigation*, we conducted an empirical investigation to understand how interaction design occurs in DSD projects. The explanatory sequential mixed methods research [Creswell, 2010] was used as a methodological strategy to plan and conduct the empirical investigation. Therefore, the empirical investigation was carried

out in two distinct steps, namely: *Survey with DSD professionals* and *Interviews with DSD professionals*. The *Survey with DSD professionals* step was planned and conducted following the process proposed by Kasunic [2005]. This step involved data collection through an online questionnaire and quantitative data analysis using the descriptive statistics method and association tests. In order to obtain a detailed and in-depth understanding of the quantitative results of the *Survey with DSD professionals* step, a second step (*Interview with DSD professionals)* was conducted, which involved the collection of qualitative data through the interview technique. For the analysis and systematization of qualitative data, the thematic analysis [Braun and Clarke, 2006] was used. Details of the working methods for conducting Phase II: Empirical investigation are available at: Alves and Matos [2019], Alves [2022], and Alves and Matos [2022].

In *Phase III: Results consolidation*, we conceived a set of recommendations for interaction design in DSD, based on the consolidation of the results of Phases I and II, and based on concepts of HCI and interaction design. This phase consisted of a single step, namely *Recommendations for interaction design in DSD*, which referred to the development of a set of recommendations for interaction design in DSD.

Finally, the research proceeded to the last three steps: *Explanation of learning*, *Conclusions*, and *Communication of results*.

We believe that understanding practice through methodeutics has the potential to contribute to identifying aspects that must be taken into account when conceiving/developing technologies and can advance the state of practice in Computer Science. Thus, encouraging and valuing the investigation of practice can contribute to the state of the art and to the enrichment of the process of building legitimate knowledge in Computer Science, enhancing the human factor as a source of knowledge.

4 Results and discussion

In this section, we present the main results obtained in this research, as well as a discussion of these results and their implications for theory and practice related to interaction design in DSD.

4.1 Interaction design in FLOSS development

The *Systematic Mapping I* step presents the results of a systematic mapping about methods, techniques, tools, strategies, and approaches (MTTSA) of interaction design that have been proposed or used by researchers in the context of FLOSS development. Eleven primary papers were selected in this systematic mapping that were classified into four main categories: method, technique, tool, and strategy/approach.

The main findings of this mapping are the following:

- there are few studies on MTTSA of interaction design proposed or used for/in FLOSS development;
- methods of interaction design proposed specifically for the development of FLOSS were not found; the studies found used existing methods of interaction design in the context of FLOSS;

- techniques of interaction design, proposed specifically for the development of FLOSS, were not found; one of the selected papers, Lichtner *et al.* [2009], used pre-existing techniques and did not consider the distributed development environment of FLOSS;
- the principal interest of the selected studies is in the activities of prototyping and evaluating; few studies have addressed the activities of establishing requirements and designing alternatives;
- the majority of the selected studies do not present any type of validation through empirical studies.

This systematic mapping identified few studies that proposed/used MTTSA of interaction design in the context of FLOSS. Despite this fact, the selected studies were successful and brought important contributions by applying MTTSA of interaction design in the development of FLOSS.

The results of this mapping showed that there are few studies involving interaction design and development of FLOSS. Furthermore, the results suggested the need for research efforts in the field of interaction design for the context of distributed software development. With that, due to the result of an abductive process that pointed to interaction design problems and challenges in any software development project carried out with geographically distributed stakeholders (and not just in FLOSS development), we chose to broaden the scope of this research, that went from interaction design in FLOSS development to interaction design in DSD. Once the scope of the research was expanded, a new systematic mapping was necessary.

The detailed results, data analysis and discussions of the *Systematic Mapping I* step are available at: Alves and Matos [2017c] and Alves [2022].

4.2   Interaction design in DSD

In the *Systematic Mapping II* step, we presented a systematic mapping that was conducted to identify, synthesize and analyze papers related to interaction design in DSD. We obtained an overview of different ways in which the literature has discussed interaction design in DSD, identified gaps, and present future research directions on interaction design in DSD. A total of 1,287 studies were identified (during the search process) and 32 papers were included. The analysis of these 32 included papers demonstrated that interaction design in the DSD context is not widely covered in the scientific literature. This study also pointed out that interaction design in distributed software development has been little explored, mapped, or structured in the scientific literature. Overall, the results of this study suggest that the HCI community support DSD projects through research efforts in interaction design, considering the specific characteristics of these projects.

Through the analysis of the included papers, this systematic mapping provides an overview of existing studies of interaction design in the context of DSD.

In this systematic mapping, we identified a taxonomy of six research topics. Based on this, we carried out the classification of the included papers through two classification schemes: research topics and research types. This classification of the included papers provided an overview of studies on interaction design in DSD. These topics were useful in identifying research gaps and directing future work. This systematic mapping also identified the main characteristics of interaction design in DSD, such as the level of dispersion of stakeholders, the solutions adopted (approaches, methods, techniques, tools), the involvement of users, and the performance of designers and HCI specialists.

The data extraction from the 32 included papers shows that interaction design in DSD is a topic which is infrequently discussed in the scientific literature. The papers included were mostly published in conferences and during the last 10 years (2008 - 2017). Thus, there is evidence that interaction design in the DSD context is a recent topic and is not widely studied.

The classification by type of research shows that the most frequent research types are "Evaluation Research" (43.8%); "Solution Proposal" (25%); and "Experience Papers" (21.9%). However, no papers have been classified as philosophical or opinion papers. The classification by type of research indicates that there is a need for "Validation Research" to be able to certify if the proposed solutions of interaction design in DSD are valid. There is also a need for "Evaluation Research" to implement the solutions in practice (only two studies have implemented interaction design solutions in practice) since most of the proposed solutions have been classified as "Solution Proposal".

The classification by topic of research showed how the literature has been discussing the theme and reflects the frequency of publication in each category. The results show discussions about the theme in the following categories: (i) Interaction Design Processes and Approaches, (ii) Systems, Tools, and Techniques, (iii) Users' and/or designers' involvement, (iv) Coordination, (v) Communication and (vi) Miscellaneous Issues. The results show that "Systems, Tools, and Techniques"; "Interaction Design Processes and Approaches"; and "Users' and/or designers' involvement" were the topics with the highest number of papers included. "Coordination"; "Communication" and "Miscellaneous Issues" were the topics with the lowest number of papers included. Given the topics identified, future studies may consider gaps and trends in scientific research.

We verified that there is a growing effort to facilitate the implementation of traditional interaction design practices in the DSD context with the development/adaptation of solutions. The results showed that 34.4% of the included papers present solutions for interaction design in DSD. However, most of these papers (54.5%) were classified as "Solution Proposal", 27.3% as "Validation Research" and 18.2% as "Evaluation Research". This shows that most interaction design solutions in DSD have not been validated and few have been implemented in practice. Among these studies, some present results of the interaction design process (or a process step) and/or initial phases of the proposed solution development [Lazarin and Almeida, 2016; Walsh *et al.*, 2012; Heintz *et al.*, 2014; Koehne and Redmiles, 2012; Mentler and Herczeg, 2015]; other studies present solutions without validation and/or implementation in practice [Ebenreuter, 2009; Hosseini-Khayat *et al.*, 2010; Koehne and Redmiles, 2012]. Only two studies [Llerena *et al.*, 2016; Lisowska Masson *et al.*, 2017] present solutions for interaction design in DSD which have been implemented in practice. Although

the included papers contribute to the discussions and identify the need for new interaction design solutions for the DSD context, most of the solutions presented are not yet ready/available for use in the practice of interaction design in DSD.

Most of the studies that present solutions to interaction design in DSD focused on tools to support interaction design activities in DSD. There is evidence that this is justified because of the immediate need for solutions to support interaction design activities in the DSD context.

The results of this systematic mapping also showed that interaction design experiences in DSD have not been widely published through scientific papers. Given this, there is a need for initiatives to promote the publication of these experiences. There is also a need for empirical studies to analyze how interaction design activities have been conducted in DSD projects and for more approximation and dialogue between researchers and industry professionals.

We highlight that several included papers, mainly papers classified as "Evaluation Research", were conducted in the context of FLOSS projects and communities. We know that the objectives, processes, policy, and philosophy of FLOSS projects and communities may be different from most proprietary software development projects. We believe that easy access to the information and artifacts of FLOSS projects and the form of collaborative work, in which team members are generally distributed globally, facilitate and enable the conduct of investigations in these projects. Thus, 44% of the included papers were conducted in the context of FLOSS projects.

The results of this mapping are important for understanding the characteristics of interaction design in DSD projects. We found that, although DSD projects are developed with geographically distributed stakeholders, interaction design is not always conducted with participants also geographically distributed. However, all the projects described in the studies classified as research topic "Interaction Design Processes and Approaches" were mentioned interaction design activities with geographically dispersed participants.

Regarding the results of question "How interaction design has been conducted in DSD projects?", we have identified the following findings:

- a considerable part of the DSD projects conducted interaction design with geographically distributed participants and using the participatory design/codesign or user centered design approaches;
- the level of global dispersion in DSD projects was the most pointed out in the studies;
- most studies report that there were designers and/or specialists in HCI in DSD projects;
- in all studies there was the participation of users in the design and/or development of the software and, in some studies, users actively participated in interaction design activities and in decision making;
- we identified practices and strategies related to interaction design and user involvement in DSD projects. This result indicates that in a considerable part of the projects there was a concern to involve users in the design and development of software. In addition, the results indi-

cate that in these DSD projects there was a concern in relation to good practices of interaction design. However, there is evidence that part of the DSD projects did not adopt good interaction design practices, for example, some studies did not report the involvement of designers or HCI specialists;
- we found several methods/techniques that were used to conduct interaction design in DSD projects. There are also several software tools used to support the interaction design in these projects;
- we highlight that the number of studies that pointed out the use/application of participatory methods or techniques in interaction design is relatively low. This result indicates that (1) it is necessary to develop (or adapt) and disseminate solutions for the involvement of users taking into account the context of DSD; and (2) it is necessary to support and encourage the adoption of participatory practices in DSD projects.
- we found that several of the studies did not report details on how the interaction design process occurred, for example, the activities carried out; the methods, techniques and tools used; among other details that are important to understand the interaction design process in DSD projects. This result suggests that future works report complete and rich empirical context.

The results of this systematic mapping have allowed us to obtain an overview of a relatively new topic. The fact that no new model, method, framework or studies related to the type of research "Philosophical Papers" and "Opinion Papers" has been found, suggest that there is a requirement for studies to theorize the practice of interaction design in the DSD context. There is also a need for solutions that can support the interaction design process in DSD projects, for example, models, methods, techniques, and tools. We have identified the following findings according to the analysis of the information extracted from the included papers:

- there are few studies on interaction design in DSD;
- no methods, models, and frameworks were found for interaction design in DSD;
- the main interest of most of the papers included is the development of interaction design solutions for the DSD context, mostly tools;
- few studies validated the proposed solutions and/or implemented the solutions in practice. Thus, interaction design solutions must be validated and/or evaluated empirically;
- there is a need for studies to base and theorize the practice of interaction design in the DSD context;
- there is a need for new solutions (or adaptations of existing solutions) of interaction design for the DSD context; we found only one modified technique to be used in DSD and few tools to support interaction design in the distributed context. This shows that the solutions identified do not completely cover the process of designing interactive systems in DSD. In addition, there are challenges and problems related to interaction design in DSD;
- there is a need for more research on the identified research topics, in particular "Coordination" and "Com-

munication", as few studies have been conducted and, mostly, through the analysis of one or more specific cases and/or proposed interaction design solutions in the DSD context. The evidence shows that researchers in the HCI area have performed few studies involving interaction design and DSD. Thus, there is a need for studies to improve interaction design in DSD;

- there is a need for studies to understand and describe the interaction design processes in DSD in more detail. The included papers addressed the conduct of interaction design in DSD projects and approaches used but failed to present the processes, roles of participants, the planning of activities and the description of the solutions used in DSD environments.

The detailed results, data analysis and discussions of the *Systematic Mapping II* step are available at: Alves *et al.* [2023] and Alves [2022].

4.3 Investigating how interaction design has been implemented in DSD

In the *Survey with DSD professionals* step, we conducted the planning and application of an online questionnaire. Thus, this subsection presents an overview of the results and analysis of the data obtained through the application of this questionnaire. Upon completion of data collection, 63 completed questionnaires were obtained, all of which were considered valid. We performed descriptive data analysis, crossing of variables of interest, and association tests, which are presented below.

4.3.1 Characterization of participants

In general, we sought to characterize the profile of the participants in the first section of the questionnaire. The questionnaire was answered by 63 participants, of which 55 resided in Brazil, 3 in Portugal and 5 resided in other countries (Czech Republic, United Kingdom, United States, Canada, and Denmark). The results revealed that most participants were from the Brazil (87.3%). Portugal (4.7%), Czech Republic (1.6%), United Kingdom (1.6%), United States (1.6%), Canada (1.6%) and Denmark (1.6%) had a lower concentration of participants.

Analyzing Figure 2, we observe that most participants (82.5%) were men, while 15.9% were women. Only one participant chose not to report gender. This result highlights the low number of women working on DSD projects.
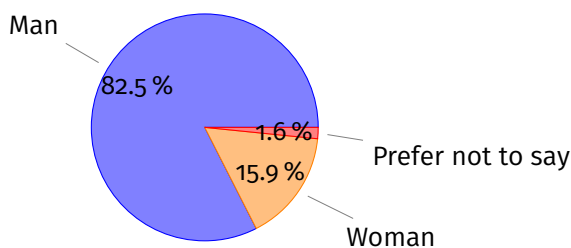

Figure 2. Gender of participants.

We observed that the age groups with the highest number of participants were in the range of 35–39 years and 40–49

years, for 27% and 25.4% of participants, respectively, followed by the age group 30-34 years, with 17.5% of participants, as shown in Figure 3. We noted a low frequency of participants aged under 25 and over 50 years.
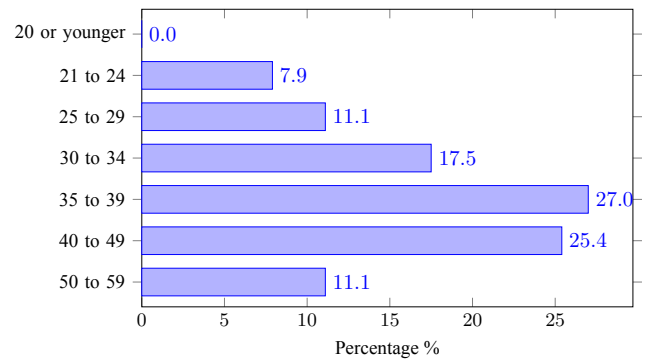

Figure 3. Age range of participants.

In relation to the level of academic training, illustrated in Figure 4, the results revealed that 47.6% of the participants had graduated as the highest level of education. Participants who had a master's degree as the highest level of education represented 25.4% of respondents, followed by participants whose highest level of education was a doctorate, which represented 23.8% of respondents. Only 3.2% of the participants indicated that they had secondary education as their highest level of education. We conclude that most of the participants had high levels of education, with a postgraduate degree *stricto sensu*.
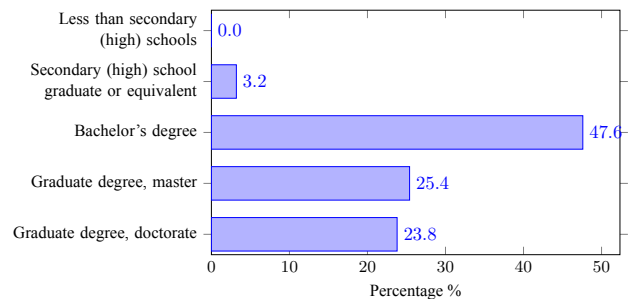

Figure 4. level of formal education of the participants.

Regarding experience in DSD projects, most participants (25.4%) had three to five years of experience, as can be seen in Figure 5. However, when adding the number of participants who had "6 to 10 years" and "more than 10 years" of experience, that is, 6 years or more of experience in DSD projects, the number of participants corresponds to 42,8%; 19% of participants responded that they had less than one year of DSD project experience. This result indicates that, despite the participation of individuals with little experience in DSD projects, most participants still had 6 (six) years of experience.

Regarding the number of DSD projects in which the participants worked, most participants (34.9%) worked on three to five projects, as illustrated in Figure 6: 19% of participants responded that they had worked on more than 10 DSD projects; 17.5% had worked on only 1 DSD project; 15.9% on 2 DSD projects; and 12.7% had worked on 6-10 DSD projects. This result indicates that most participants had worked on three or more ($\geq$ 3) DSD projects.
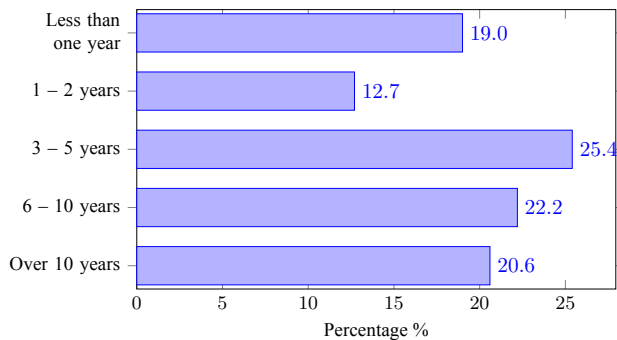
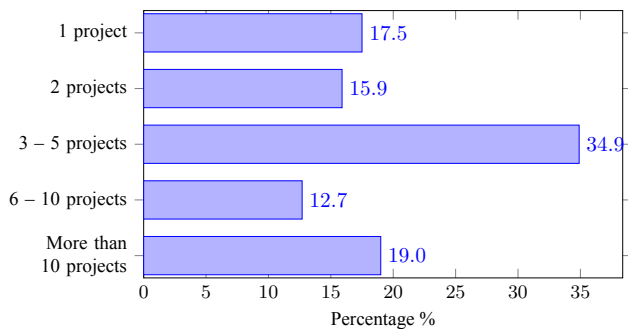**Figure 5.** Experience time of participants in DSD projects.

Figure 6. Number of DSD projects in which the participants worked.

Looking back at the data presented, we observe that most participants were men, aged between 35 and 49, had 6 years or more of professional experience in DSD projects, worked on 3 or more DSD projects, and had high levels of academic background.

We must take into account the low participation of women and individuals under the age of 25 and over 49 in this survey. This evidence suggests that women and older people may not be involved in DSD projects. Thus, there must be greater dissemination and encouragement so that more women, young people, and people over the age of 49 (including the elderly) participate in DSD projects.

4.3.2 Overview of how interaction design is implemented in DSD projects

The results indicated that in a considerable part of the DSD projects, the interaction design was conducted with geographically distributed participants providing us with an overview of how interaction design is implemented in DSD projects considering the solutions used, the influence of the designer and HCI specialist in the adoption of good interaction design practices, and the difficulties and challenges of interaction design in the context of DSD.

The participants' responses were important for understanding the interaction design characteristics of DSD projects. We found that although DSD projects are developed with geographically distributed stakeholders, interaction design is not always conducted with geographically distributed participants. However, most DSD projects conduct interaction design activities with geographically dispersed participants according to the analyzed sample.

We have identified some important characteristics related to interaction design, namely the performance of designers/HCI specialists, end-user involvement, and consideration of quality of use criteria. The results indicated that in most

DSD projects there was mention of the performance of designers and/or HCI specialists, with the User Experience (UX) designer being the most mentioned by the participants. Another characteristic is the use of practices and strategies for user engagement, as pointed out by the majority of participants. We found that usability and user experience were mentioned by most participants, but the results showed that accessibility and communicability were not considered in most DSD projects.

The results provide an overview of how interaction design is implemented in DSD projects. We identified the main characteristics (physical distance, approach, methods, techniques, and tools used/adopted, the main interaction design activities, and the role of end-users) related to interaction design in DSD projects. We also identified the main difficulties and challenges of interaction design in DSD projects. The results can be useful to professionals in academia and the software industry to help clarify the practices, techniques, approaches, and tools that can be used to support distributed interaction design. In addition, the results can be useful in supporting user involvement in projects with geographically dispersed participants.

We found statistically significant results related to the influence of the designer and/or HCI specialist in the adoption of interaction design practices in DSD projects. The results showed a greater tendency of considering interaction design practices (consideration of accessibility, usability, user experience, and communicability, user engagement strategies, and use of interaction design approaches) when designers/HCI specialists were involved in DSD projects. Based on this, we conclude that designers and HCI specialists are key elements in the interaction design process and the main agents responsible for the effective application of good interaction design practices in DSD projects.

The results of this survey, in addition to providing an overview of interaction design in DSD projects, also highlighted the strengths and weaknesses related to interaction design in these projects. From the data analysis, we highlight the following results:

- most participants reported that DSD projects were conducted with team members distributed at the national level;
- usability and user experience were considered in most DSD projects. However, the number of respondents who indicated that the DSD projects considered accessibility and/or communicability is low;
- a considerable part of the DSD projects conducted the interaction design with geographically distributed participants and using the approaches of user-centered design and/or user experience design;
- the number of participants who indicated the use/application of participatory design approaches, methods, and/or techniques in DSD projects is low;
- the number of participants who indicated the performance of an accessibility assessment is low;
- most participants reported that there was a designer and/or HCI specialist in the DSD project(s) in which they worked;
- we found that there was greater consideration of quality

of use criteria (usability, accessibility, user experience, communicability) when designers and/or HCI specialists worked on DSD projects. We confirm a statistically significant relationship between the consideration of usability, accessibility and user experience and the performance of designers and/or HCI specialists in DSD projects. We also confirm that there is an association between communicability and the performance of HCI specialists in DSD projects;

- there is proportionately a greater tendency to adopt strategies/practices to engage end-users when designers and/or HCI specialists work on DSD projects. Thus, we confirm that there is an association between the adoption of strategy/practice for user engagement and the performance of designer and/or HCI specialist in DSD projects;
- there is an association between approaches used in interaction design (user-centered design and user experience design) and the performance of designer and/or HCI specialist in DSD projects;
- there is a proportionally greater probability of using the prototyping technique; conducting the activities of creating design alternatives and building interactive versions of design (prototyping); and the use of video conferencing and web conferencing tools when designers and/or HCI specialists work on the DSD project;

From these results, we identified some research gaps related to interaction design in DSD projects, namely:

- The results of this survey indicated that there is a need to develop (or adapt) interaction design solutions taking into account the DSD context;
- further research is needed to explore and understand in detail the interaction design process in DSD projects;
- there is a need to develop/improve practices and strategies to support end-user engagement in DSD projects; and
- there is a need for studies to investigate how to lessen the difficulties and mitigate the challenges of interaction design in DSD.

The detailed results, data analysis and discussions of the *Survey with DSD professionals* step are available at: Alves and Matos [2019] and Alves [2022].

4.4 Understanding interaction design practices in DSD

In the *Interviews with DSD professionals* step, we carried out the planning and interviews with 20 professionals who work on DSD projects. Data were analyzed based on the thematic analysis method [Braun and Clarke, 2006]. The results of this study provide a detailed view of how interaction design occurs in DSD projects, presenting the perception of professionals involved in DSD projects about interaction design, as well as the main characteristics and practices related to interaction design in these projects. Four themes emerged from the data analysis, namely: "Interaction design activities", "Technology", "Collaboration", and "Users".

4.4.1 Characterization of participants

This study involved 20 participants who worked (or had worked) on DSD projects. Of these participants, 18 live in Brazil, one in the United Kingdom and one in Portugal. Most of the participants (80%) are men, while 20% are women. Table 1 presents the demographic profile of the participants in this study.

Regarding participation in DSD projects, most participants worked (or had worked) in DSD projects in the context of a private software development company (10 participants). The second segment in which there were more participants was a teaching/research institution (4 participants), and two of these participants reported that there were partnerships with private companies/organizations. Three participants worked (or had worked) in DSD projects carried out in a government agency, and another 3 (three) participants worked (or had worked) in other organizations (Non-Governmental Organization, Civil Society Organization of Public Interest, and FLOSS Community).

Table 1. Demographic profile of participants.

P#	Gender	Academic formation	DSD experience[1]	Role in DSD
P1	Woman	Master	1 − 2	Requirements engineer
P2	Woman	Bachelor's degree	1 − 2	Back-end developer
P3	Man	Bachelor's degree	> 10	Development analyst
P4	Man	Master	6 − 10	Designer
P5	Man	Bachelor's degree	3 − 5	Front-end team leader
P6	Man	Doctorate	6 − 10	UX Designer e UX leader
P7	Woman	Master	6 − 10	Designer
P8	Man	Doctorate	> 10	Designer and developer
P9	Man	Bachelor's degree	1 − 2	Web developer
P10	Man	Master	3 − 5	Developer
P11	Man	Doctorate	> 10	Consultant and Team coordinator
P12	Man	Bachelor's degree	1 − 2	Front-end Developer
P13	Man	Master	3 − 5	Web developer
P14	Man	Bachelor's degree	3 − 5	Web developer
P15	Man	Doctorate	3 − 5	Development leader
P16	Man	Doctorate	1 − 2	Programmer
P17	Man	Doctorate	1 − 2	UX Researcher
P18	Man	Doctorate	6 − 10	HCI specialist
P19	Man	Bachelor's degree	3 − 5	Team manager
P20	Woman	Master	6 − 10	UX Designer

[1]in years.

4.4.2 Interaction design activities

The theme "Interaction design activities" refers to the activities carried out in DSD projects related to the design of interactive systems. These activities were usually conducted by HCI specialists and/or designers with the participation of co-located and/or geographically distributed team members and users. With the analysis of the data, four subthemes related to the activities of interaction design in DSD projects were identified, namely: "Establishment of requirements", "Creation of design alternatives", "Prototyping", and "Design evaluation".

Regarding the subtheme "Establishment of requirements", we identified that the establishment of requirements refers to the elicitation, specification and validation of software requirements in DSD projects. We also identified that the establishment of requirements aims to understand the problem/demand and the needs of users by understanding who the users are, their activities and the context of these activities. In requirements elicitation, designers and/or HCI specialists (in some cases systems analyst, contract manager, product team or developers) used techniques (field visit, meeting, interview, focus group, brainstorming, braindraw, participatory workshop , participatory practices or computational tools) to elicit requirements and, therefore, understand the demand/problem and user needs. Regarding the requirements specification, the results showed that the requirements were specified through reports and requirements specification documents. In some cases, requirements specification was carried out through visual representation, for example, use case diagram, conceptual map and prototypes. Collaborative tools were used to support the requirements specification, for example, word processor, spreadsheet, activity/project management tools, collaborative development environment and version control system. Regarding requirements validation, the specified requirements were validated with customers and/or users. Generally, requirements validation occurred through meetings (in person or remotely) with the participation of customers and/or users. Of the participants who reported on requirements validation, the majority stated that requirements were validated with customers and/or users.

The activity of "Creation of design alternatives" was carried out with the aim of generating ideas and proposals for solutions to satisfy users' needs and meet established requirements. Some participants stated that users actively participated in the creation of design alternatives. However, most participants (those who reported on the creation of design alternatives) reported that users were only consulted or did not participate in the activity of creating design alternatives. Another characteristic of the activity of creating design alternatives is the geographic dispersion of interaction design participants, in which the execution of this activity occurred with co-located (mainly when applying participatory practices) and/or geographically distributed participants. We highlight the use of software tools (web conferencing, collaborative design environment, online forums, online whiteboard, email) to support the creation of design alternatives in the interaction design in DSD projects, especially when participants were geographically distributed. We also highlight the use of

the following methods and techniques to support the creation of design alternatives in DSD projects: braindraw, brainstorming, Design Sprint, Design Studio, Semio-Participatory Interaction Design Process (SPIDe) and participatory workshop.

We identified that prototyping is the activity that involves building prototypes for evaluating the software design by team members, clients and/or users. The results showed that prototyping has been carried out with co-located and/or geographically dispersed participants in DSD projects. Furthermore, we highlight the use of collaborative tools to support the construction of prototypes and their availability to team members, customers and users. We also highlight that the majority of participants reported the participation of users in the prototyping activity. In most projects, users participated by providing feedback and/or evaluating the prototype. We emphasize that two participants reported the use of participatory practices with the involvement of users in the construction of prototypes and decision-making.

Regarding the subtheme "Design evaluation", we verified that evaluation is an interaction design activity that aims to guarantee the quality of the user's interaction with the software and validate whether a design artifact (usually prototype) and/or preliminary/final version of the software meets user needs and established requirements. We highlight that the design evaluation in DSD occurred with co-located and/or geographically distributed participants. When co-located, these participants (generally users) traveled to the organization/institution developing the software to carry out the software design evaluation. There have been situations in which team members have conducted design evaluations in the work/living environment of users. When participants were geographically distributed, we highlighted the availability of prototypes and preliminary/final versions of the software for validation and/or providing feedback by team members, customers and users. To this end, some participants pointed out the use of collaborative tools to support the provision and evaluation of prototypes. In addition, remote meetings were held via web conference with customers/users to present, obtain feedback and/or validate the prototype or preliminary/final version of the software.

4.4.3 Collaboration

The theme "Collaboration" addressed how designers, HCI specialists, users, and other team members collaborated to perform activities related to interaction design in DSD projects. The results showed that collaboration has been mediated by computational tools and resources. The tools and computational resources supported the communication between stakeholders, the coordination of tasks, and the cooperation of the team(s) members for the execution of interaction design activities in the DSD projects. We identified that some aspects interfered with the collaboration, for example, language, time zone, and culture. In addition, we identify practices and some challenges and difficulties related to DSD collaboration. Among the practices related to collaboration in interaction design in DSD projects identified in this study, we highlight the ones most mentioned by interviewees:

- definition of a main language for communicating and

sharing information and artifacts in projects involving stakeholders from different languages;

- prioritization of asynchronous communication when the time difference of geographically dispersed stakeholders makes it difficult to hold synchronous meetings and/or events;
- use of email for formal communication with project stakeholders. Email was used to: i) schedule meetings with team members and/or clients; ii) schedule interviews and usability tests with customers and/or users; iii) formalize customer demands and/or requests; iv) submit interaction design artifacts, e.g. prototype link and requirements documents;
- use of instant messaging tools for immediate and quick communication between stakeholders;
- creation of instant messaging groups for communication between team members and/or customers/users;
- use of web conferencing tools to hold meetings between team members on software design and development activities. Web conferencing tools were also used to: i) conduct interviews and/or meetings to elicit requirements; ii) meet with customers and/or users to understand the problem; iii) interview and/or meet with domain experts to understand the problem; iv) hold daily meetings between team members;
- use of a cloud storage service for storing, organizing and making available project and product artifacts;
- use of collaborative tools for storing and sharing prototypes with team members, clients and/or users;
- organization and monitoring of tasks related to interaction design using collaborative tools, for example, Trello, GitLab, online spreadsheet and Kanban;
- holding short daily meetings (generally 15 minutes) in person or remotely (via web conference) between team members to check the progress of activities, identify impediments and plan the work day;
- holding periodic face-to-face or remote meetings (via web conference) between team members to plan and monitor tasks, for example, weekly, fortnightly or monthly meetings;
- holding face-to-face meetings and events between project team members to establish trust, training and/or strengthening personal connections, for example, a biannual event, exchange between geographically distributed team members, training, social interaction event.

4.4.4 Technology

The theme "Technology" refers to the set of approaches, methods, techniques, and computational resources used to support interaction design in DSD projects. Thus, the results of this theme present the technologies that have been used in interaction design in DSD projects. We believe that the results of this theme will help DSD professionals in identifying approaches, methods, techniques, tools, and practices that can be used in interaction design in DSD projects.

We emphasize that part of the methods and techniques were used with co-located participants, especially when user participation was active, for example, in participatory work-

shops and in the use of methods/techniques such as focus groups, braindraw, usability testing, brainstorming, card sorting, design sprint, and design studio. On the other hand, we observed more frequently the participation of geographically distributed users when these users were consulted to provide information and respond to questionnaires, for example, using methods/techniques such as interviews, online questionnaires, and meetings. This result shows that there is a need to investigate the feasibility of applying these methods and techniques (traditionally used with co-located participants) in the context in which users are geographically distributed.

From the results of this theme, we identified the following technologies used in interaction design in DSD projects:

- approaches used in interaction design, for example, User Experience Design, Participatory Design, Codesign, Design Thinking, User-Centered Design, Free Design, Open Design, Design for All, Socially Aware Design;
- methods and techniques for eliciting requirements, for example, meeting, interview, questionnaire, prototyping, ethnographic research, focus groups, document analysis, usage scenario, direct observation, brainstorming and benchmarking;
- methods and techniques to support ideation and creation of design alternatives, for example, focus groups, brainstorming, braindraw and questionnaire;
- techniques to support the construction of prototypes, for example, prototyping and braindraw;
- methods and techniques to support design evaluation, for example, usability testing, meeting, interview, questionnaire, focus groups and brainstorming;
- methods for executing interaction design activities with the participation of project team members, users and/or clients, e.g. co-creation workshop, participatory workshop, Design Sprint, SPIDe and Design Studio;
- tools for communicating and sharing information, e.g. email, mailing list, web conferencing (Skype©, Appear©, Google Hangouts©, GoToMeeting©, Zoom©, Cisco Webex©, Jitsi©), instant message (Slack©, Mattermost©, WhatsApp©, Skype©, Discord©, Messenger©, Google Hangouts©, Jabber©, IRC©, Telegram©), online forum (Consider.it©), *Wiki* (DokuWiki©), social networks (Twitter©, Mastodon©, Facebook©), blog, project website and Short Message Service (SMS);
- collaborative systems to support the conduct of interaction design activities, e.g. collaborative design environment (DSC Platform and Corais Platform), collaborative development environment (GitHub©, GitLab©, SourceForge©), whiteboard tool (Miro©), prototyping (MOQUPS©, InVision©, Marvel App©, Cacoo©, Figma©, Adobe XD©), and remote usability testing (UserZoom©);
- tools for storing and sharing interaction design artifacts, e.g. collaborative development environment (GitHub©, GitLab©, SourceForge©), cloud storage services (Onedrive©, Google Drive©), and tool for sharing and organizing visual design artifacts (Zeplin©);
- tools for organizing interaction design tasks (Trello©,

GitLab©, Redmine©, Kanban©);
• Office application software for creating and sharing interaction design artifacts, for example, interaction design documents (Google Docs©); electronic spreadsheets for recording demands, feedback, suggestions and complaints from customers/users (Google Sheets©, Microsoft Excel online©), and presentations of the results of interaction design activities (Google Slides©).

4.4.5 Users

The theme "Users" approached the participation of users in interaction design activities in DSD projects. We identified some characteristics related to the participation of users in DSD projects, such as the way in which users were selected, the level of geographic dispersion and the role of users. We also found that users have participated in interaction design in DSD projects, mainly in requirements establishment and evaluation activities. In some DSD projects, users actively participated in interaction design activities and decision-making.

The results showed that the application of participatory practices in interaction design in DSD projects generally occurred with co-located participants. We found that users have participated in interaction design activities in DSD, but there are challenges and difficulties in involving them in these projects, especially when they are geographically distributed. Thus, the results showed that the involvement of users in DSD is a challenge. We observed that the number of participants who reported carrying out interaction design activities with the participation of co-located users was greater than those who stated carrying out interaction design activities with geographically distributed users. Generally, there was a need for face-to-face meetings to involve users in interaction design activities, mainly in the application of participatory practices. There was also a need for members of the team(s) to visit the users' living/work environment to carry out interaction design activities.

The results of this study pointed out three main roles that users played in interaction design in DSD projects: (a) informant, (b) tester, and/or (c) co-designer. Users were also represented by intermediaries (clients and/or team members), who played the roles of informant and/or tester. Users in the role of *informant* were observed in their daily activities, mainly in activities carried out to elicit requirements. Users also provided information about their context, as well as their characteristics, needs, and daily activities. In this role, users mainly participated in requirements establishment activities. The involvement of users as informants occurred to understand the problem/demand, the users' context, and their needs. In the role of *tester*, users provided feedback on design alternatives, prototypes and/or developed solutions. Users also performed tests on prototypes (usually an interactive version), preliminary versions, and/or final version of the software. In the role of *co-designer*, users actively collaborated on the design of the solution with other project stakeholders. In this role, users were primarily engaged in the activities of creating design alternatives and prototyping. In addition, users contributed to understanding the problem/demand and making design decisions for the solution under development.

Intermediaries represented users in interaction design in DSD projects, usually in the role of informant and/or tester. We emphasize that the intermediary was an alternative in DSD projects to supply the geographic distribution of users since the interaction between team members and users can be more difficult due to geographic dispersion. Despite Iivari [2011] pointing out the importance of intermediaries in DSD projects, some participants reported difficulties in understanding demands reported by intermediaries and the need to interact directly with users. Thus, there is evidence that the practice of an intermediary to represent users in interaction design may not be the best alternative, as there are reports of difficulties with intermediaries and the need to involve users in projects where there was an intermediary.

The detailed results, data analysis and discussions of the *Interviews with DSD professionals* step are available at: Alves [2022], Alves and Matos [2022], and Alves and Matos [2024].

4.5 Proposed Recommendations for Interaction Design in DSD

The results of *Phase I: Literature review* and *Phase II: Empirical investigation* of this research provided empirical bases for the conception of a set of recommendations for interaction design in DSD projects. Thus, in *Phase III: Results consolidation* of this research, a set of recommendations for interaction design in DSD was conceived, based on the consolidation of the results of Phases I and II and based on concepts of HCI and interaction design.

The consolidation of the results occurred through a recursive process of synthesis of the practices identified through the methodeutics of Peirce's semiotics. In an integrated way, abduction (problematization), deduction (literature review), and induction (empirical investigation) were necessary during all phases of this research and contributed to the consolidation of results.

From this, we decided to consolidate these results and conceived a set of recommendations for interaction design in DSD, in order to support DSD professionals in the planning and implementation of interaction design practices in DSD projects. The main reason for this set of recommendations is to have elements that support the implementation of good interaction design practices in DSD projects.

Therefore, in *Phase III: Results consolidation* of this research, we propose a set of recommendations for interaction design in DSD. The set of recommendations is available in Alves [2022].

To create the recommendations, we followed a recursive process with 3 (three) steps: i) identification of practices; ii) categorization and review of practices; and iii) development and review of recommendations. With the conduction of this process, a set of 21 recommendations was conceived, organized into 4 categories, namely: "Interaction design activities", "Technology", "Collaboration" and "Users".

We highlight that the adoption of good interaction design practices in DSD projects can provide tangible benefits, such as economic and social benefits to users and organizations/companies. Among the benefits, we highlight: im-

proved user satisfaction; increased user productivity and operational efficiency of organizations; development of accessible, easy, efficient interactive systems and, consequently, reduction in costs related to training and support; reduction of barriers and improvements related to accessibility; and reduction of negative aspects of the user experience (e.g., discomfort and stress) [Barbosa and Silva, 2010; DIS, 2009; Preece *et al.*, 2015], as well as broader benefits, such as enhanced collaboration among distributed teams and greater innovation.

We believe that the proposed recommendations could bring the following contributions:

- improvement in the interaction design process in DSD projects;
- support in planning interaction design in DSD - the set of recommendations can support DSD professionals (project managers, team leader, designers, HCI specialists) in planning and defining activities, methods, techniques, tools and practices to be used in interaction design in DSD projects in their companies/organizations;
- favoring user involvement in DSD projects;
- integration and enhancement of interaction design in DSD projects.

4.6 Discussion

In *Phase I: Literature review*, we found that the number of studies that pointed to the use of participatory methods or techniques in interaction design is relatively low. We also found that participatory practices have been conducted with co-located participants. This result highlighted the need to (i) develop (or adapt) and disseminate solutions for user engagement taking into account the DSD context; and (ii) support and encourage the adoption of participatory practices in DSD projects.

In *Phase II: Empirical investigation*, the results indicated that interaction design activities have been performed with co-located and/or geographically distributed participants in DSD projects. The results provided a detailed insight into how interaction design is implemented in DSD projects and the identification of interaction design practices in the context of DSD. We also identified challenges and difficulties related to interaction design in DSD projects. There were indications that the application of participatory practices in interaction design in DSD projects generally occurred with co-located participants. We found that users have participated in interaction design activities in DSD projects, but there are several challenges and difficulties when involving them in these projects, especially when they are geographically distributed. Thus, the results show that the involvement of users in DSD projects is a challenge.

With the literature review and empirical investigation with DSD professionals, we obtained a detailed view on how interaction design occurs in DSD projects. We identify practices, challenges, and difficulties in interaction design in the context of DSD. The results of this research indicate the main characteristics (physical distance; approach, methods, techniques, and tools used; performance of designers and involvement of users) related to interaction design in DSD

projects. We also identified the different practices and strategies used in interaction design in DSD projects. The results of the empirical investigation complemented the results of the literature review since most of the papers included in the systematic mappings did not detail interaction design activities. Thus, the results of this research can be useful for researchers and software industry professionals to understand the practices, techniques, approaches, and tools that can be used to support distributed interaction design. Furthermore, the results can be useful to support user engagement in projects with geographically dispersed participants.

We present below the answers to the secondary research questions, which provide a detail of the answer to the main research question (RQ. How is interaction design practiced in DSD projects?), and present a discussion of these answers.

4.6.1 SQ1. What interaction design solutions (models, methods, techniques, tools) have been proposed for the DSD context?

In the *Systematic mapping I* step, we identified some tools, strategies, and approaches proposed to support the interaction design activities in the development of FLOSS, mainly in the prototyping and evaluation activities. However, the results showed that there are few studies proposing interaction design solutions for the development of FLOSS and we did not identify methods and techniques specifically proposed for interaction design in the context of FLOSS. Thus, the results of this mapping pointed out research gaps and the lack of studies involving interaction design and development of FLOSS. Despite this, the selected studies were successful and showed important contributions when applying interaction design solutions in FLOSS development. We conclude that there is a need for broad support for FLOSS projects and communities by the HCI community, through research efforts in interaction design for the availability of methods, techniques, tools, strategies, and approaches for interaction design considering the characteristics of the development of FLOSS.

In the *Systematic Mapping II* step, we identify proposed interaction design solutions for the DSD context, mainly computational tools to support interaction design activities. However, we did not identify interaction design method, approach, process, or process model proposals for the DSD context. We conclude that there is a need for new interaction design solutions (or adaptations of existing solutions) for the DSD context. We identified only one modified technique to be used in DSD and few tools to support interaction design in the distributed context. This shows that the identified solutions do not completely cover the design process of interactive systems in DSD.

In both systematic mappings, we identified few studies that validated the proposed solutions and/or implemented the solutions in practice. Added to this, the results showed that although the papers included contribute to the discussions and identify the need for new interaction design solutions for the DSD context, most of the solutions presented are not yet ready/available for use in the practice of interaction design in DSD.

4.6.2 SQ2. What are the main interaction design activities in DSD projects?

The results of this research showed that the main interaction design activities in DSD projects are: establishing requirements, creating design alternatives, prototyping, and design evaluation.

In *Phase I: Literature review*, the results of the *Systematic mapping I* step indicated that the main interest of the selected studies was in prototyping and evaluation activities. On the other hand, few studies have addressed the activities of establishing requirements and creating design alternatives. In the *Systematic mapping II* step, the main activities addressed in the papers included were establishing requirements, prototyping, and evaluation. Few papers address creating design alternatives.

In *Phase II: Empirical investigation*, the interaction design activities most mentioned by survey participants were: "Establishment of requirements" (63.5%) and "Prototyping" (50.8%). Other activities pointed out by a smaller percentage of participants were: "Creation of design alternatives" (41.3%) and "Design evaluation" (39.7%). In the interview study, we identified four sub-themes related to interaction design activities in DSD projects, namely: "Establishment of requirements", "Creation of design alternatives", "Prototyping" and "Design evaluation".

4.6.3 SQ3. What approaches, methods, techniques, and tools have been used in interaction design in DSD projects? What are the interaction design practices in DSD projects?

In the *Literature review* and *Empirical investigation* phases, we identified several approaches, methods, techniques, and tools used in interaction design in DSD projects.

Regarding the use of interaction design approaches in DSD projects, in the *Systematic mapping II* step, participatory design/co-design was used in 5 of the 11 included studies; User-centered design was used in 3 studies and 1 study described the use of user experience design. In *Phase II: Empirical investigation*, survey participants were asked about the use of interaction design approaches in DSD projects. As a result, we observed that the most cited approaches were user-centered design (41.3%) and user experience design (38.1%). The participatory design and co-design approaches were mentioned, respectively, by 20.6% and 6.3% of the participants. The design thinking approach was answered by 19% of the participants. In the interview study, the approaches most cited by the participants were: user experience design (3 participants), participatory design (3 participants), and design thinking (3 participants).

Regarding the methods and techniques used in interaction design in DSD projects, in the *Systematic mapping II* step, we observed that the most used methods/techniques in interaction design in DSD projects were prototyping (8 studies), interview (4 studies), usability testing (4 studies) and survey (3 studies). We note that the frequency of studies that report the use of participatory methods and techniques

is low, namely: brainstorming, cooperative inquiry, focus groups, and workshop (each cited in 2 studies). In the *Phase II: Empirical investigation*, the survey results showed that most participants pointed to the use of prototyping (52.4%) and interview (50.8%) techniques. Other techniques cited by a considerable number of participants were usability testing (41.3%), questionnaire (36.5%), brainstorming (36.5%), and storyboarding (23.8%). However, the percentage of those who use participatory methods, techniques, and practices is low, namely: contextual inquiry (17.5%), focus group (14.3%), workshop (12.7%), think-aloud (7.9%), brainwriting (4.8%) and braindraw (3.2%). In the interview study, the methods/techniques most cited by the participants were: prototyping (18 out of 20 participants), meeting (13 participants), interview (12 participants), usability testing (10 participants), and questionnaire (8 participants).

Regarding the tools used to support interaction design in DSD projects, the results of the *Systematic mapping II* step pointed to the most cited tools: e-mail/mailing list (6 studies) and web conference (4 studies). In the *Survey with DSD professionals* step, the tools most cited by participants were e-mail (68.3%), mailing list (38.1%), and chat (36.5%). Other tools used in DSD projects were instant messaging (34.9%), voice-over IP software (34.9%), collaborative development environment (33.3%), project management software (31.8%), video conferencing (30.2%), web conferencing (30.2%), telephone (25.4%), and prototyping tool (25.4%). In the *Interviews with DSD professionals* step, the computational tools most cited by the participants were: web conferencing (19 out of 20 participants), e-mail (18 participants), instant messaging (16 participants), collaborative development environment (8 participants), and prototyping (8 participants),

This result can be useful to project managers, designers, and HCI specialists as they plan which approaches, methods, techniques, and/or tools to employ in interaction design in DSD environments. However, we highlight the need for an (online) technological collaborative design environment that integrates and brings together the main tools to support distributed interaction design, since the use of several computational tools can make collaborative work and user participation difficult.

4.6.4 SQ4. What is the geographic distance of interaction design participants in DSD projects?

In the *Systematic mapping II* step, when analyzing the physical distance of participants in interaction design in DSD projects, the global distance was identified in 4 studies. Continental and national distances were identified in 2 and 1 study(ies), respectively. In 4 studies, the level of dispersion of interaction design participants was not reported, but it was identified in these studies that some interaction design activities were carried out with co-located participants and others with geographically dispersed participants.

In the *Survey with DSD professionals* step, when asked about the physical distance of the participants in the interaction design of the project, the national distance was indicated by 47.6% of the participants, followed by the same physi-

cal location (44.4%). The global and continental distances were answered, respectively, by 27% and 15.9% of the participants.

In the *Interviews with DSD professionals* step, participants reported that DSD projects were developed with geographically distributed stakeholders at national and/or global distances. The national distance was reported by 12 (twelve) participants. The global distance was reported by 11 (eleven) participants. We observed that 3 (three) of these participants worked on DSD projects at the national and global levels. Despite the geographical dispersion of team members and other stakeholders in software development, the results showed that interaction design activities were generally conducted by designers/HCI specialists with the participation of team members and users co-located and/or geographically distributed.

We conclude, therefore, that interaction design has been carried out both with co-located and geographically distributed participants in DSD projects.

4.6.5   SQ5.   Have designers and HCI specialists been working on DSD projects? Is there an association between the adoption of good interaction design practices and the performance of a designer and HCI specialist in DSD projects?

In the *Systematic mapping II* step, one of the results pointed out that designers and/or HCI specialists have worked on DSD projects, but in some analyzed studies (4 of the 11 papers included) it was not possible to identify whether designers or HCI specialists worked on the project.

In the *Survey with DSD professionals* step, participants were asked about the existence of HCI specialists and designers in DSD projects. Most participants (60.3%) responded that their project(s) had a user experience designer. Interaction designer and HCI specialist were selected, respectively, by 28.6% and 23.8% of the participants. We observed that 22.2% of the participants answered "None", that is, designers and/or HCI specialists did not work on the project. This result pointed to the predominance of user experience designers in DSD projects. However, in some projects, there was no involvement of designers or HCI specialists.

In the *Interviews with DSD professionals* step, participants reported the performance of HCI specialists and/or designers in conducting interaction design activities in DSD projects. Only 3 of the 20 participants reported the lack of an HCI specialist and/or designer in the DSD projects they worked on.

Regarding the question "Is there an association between the adoption of good interaction design practices and the performance of a designer and HCI specialist in DSD projects?", the survey results showed that there is a proportionally greater tendency to consider some interaction design practices when designers and/or HCI specialists work on DSD projects. We conclude, therefore, that there is some relationship between the adoption of some interaction design practices (for example, consideration of quality of use criteria, use of strategies/practices to engage users, use of user-centered design and user experience design approaches) and

the work of designers and/or HCI specialists in DSD projects. The results showed the influence and importance of the designer and/or HCI specialist in the adoption of interaction design practices in DSD projects.

We conclude that designers and/or HCI specialists have acted in most DSD projects, according to the results of the literature review and empirical investigation. There is also evidence that designers and HCI specialists are key elements in the interaction design process, being the main agents responsible for the effective application of good interaction design practices in DSD projects.

4.6.6   SQ6.   Have users participated in interaction design activities in DSD projects?   What are the strategies and practices for involving users in DSD projects? What are the roles of these users?

Regarding the participation of users in interaction design activities in DSD projects, in the *Systematic mapping II* step, we verified that there was the participation of users in at least one interaction design activity in all studies that described the conduction of interaction design activities. The results also showed that different practices and strategies were adopted for the participation of users in DSD projects, with users co-located and/or geographically distributed.

In the *Survey with DSD professionals* step, participants were asked about the role of users in interaction design activities in the DSD project(s). Most participants (49.2%) indicated "User (users participate as subjects of observation)". Almost half of the respondents, 47.6%, stated that users play the role of "Tester (users can be observed and provide feedback on predefined solutions, e.g. prototype testing)" and 36.5% indicated "Informant (users can be observed, provide information and feedback during the design process)". Only 14.3% of respondents indicated "Design partner (similar to informant role, but users directly and effectively participate in design activities)" and 15.9% of respondents indicated that users did not participate in interaction design activities in the DSD project(s). We also asked participants about practices and/or strategies for engaging users in DSD projects. Most participants (50.8%) responded that there were practices and/or strategies to involve users in the DSD project. This result indicated the need to develop/improve practices and strategies to support user involvement in DSD projects.

In the *Interviews with DSD professionals* step, one of the themes that emerged from the data analysis was "Users". The theme "Users" is related to the participation of users in interaction design activities in DSD projects. We identified some characteristics related to the participation of users in DSD projects, such as the way in which users were selected, the level of geographic dispersion, and the role of users. We also identified some strategies and practices used to involve users in DSD projects. Of the 20 participants in the interview study, 19 reported that users participated in interaction design activities. The results of this study pointed out three main roles that users played in interaction design in DSD projects: (a) informant, (b) tester, and/or (c) co-designer. Users were also represented by intermediaries (clients and/or team members), who played the roles of informant and/or

tester.

The results showed that the application of participatory practices in interaction design in DSD projects generally occurred with co-located participants. We found that users have participated in interaction design activities in DSD projects, but there are challenges and difficulties in involving them in these projects, especially when they are geographically distributed. Thus, the results showed that the involvement of users in DSD projects is a challenge. We observed that the number of participants who reported carrying out interaction design activities with the participation of co-located users was greater than those who stated carrying out interaction design activities with geographically distributed users.

5 Contributions to the HCI area

In this research, we approach interaction design in DSD from two perspectives: i) research: refers to the investigation of scientific efforts related to interaction design in DSD, and ii) practice: refers to the investigation of how interaction design occurs in DSD projects.

We hope that the results pointed out by this research contribute to the body of knowledge about interaction design at the research frontier between HCI and DSD by (i) providing an overview of research efforts on interaction design in DSD, (ii) providing an overview of the practice of interaction design in DSD, (iii) identify research gaps and discuss future research directions, and (iv) conceiving a set of recommendations for interaction design in DSD.

From a research perspective, we provide the scientific community with information that can contribute to conducting new research and developing (or adapting) methods, techniques, tools, and approaches to interaction design for the DSD context. In this way, we hope to contribute to the consolidation of actions and research in the areas of Software Engineering, Collaborative Systems, and HCI, encouraging the adoption and participatory construction of software, seeking to contribute to the development of interactive software and offer the scientific community elements that contribute to overcoming of the research challenges in Computer Science defined by the Brazilian Computer Society, regarding the participatory and universal access of Brazilian citizens to knowledge.

From a practice perspective, we believe this research is an initial effort towards improving interaction design processes in DSD. In addition, we hope that the set of recommendations supports the application of interaction design practices in DSD projects and, thus, contributes to the developed product meeting the expectations and objectives of the users.

The results of this research can be useful for professionals in academia and the software industry to understand the practices, techniques, approaches, and tools that can be used to support distributed interaction design. With the identification of the main technologies used in interaction design in DSD projects, the results of this study can support practitioners in their search for technologies to be used in interaction design in DSD projects. In addition, the results can be useful to support user involvement in projects with geographically dispersed participants.

We advanced in the state of the art and in the effectiveness of a proposed artifact for guiding interaction design activities as a strategy to benefit distributed software development.

The main potential contributions of this research are summarized in Figure 7 and described below:

- providing an overview of studies addressing interaction design in DSD and research trends;
- providing the scientific community with evidence on difficulties, challenges, and research opportunities related to interaction design in DSD;
- providing recommendations for interaction design in DSD;
- contributing so that researchers and practitioners have a better understanding of interaction design practice in DSD;
- presenting a set of interaction design practices in DSD;
- presenting the main characteristics (physical distance; approach, methods, techniques, and tools used/adopted; performance of designers; user involvement; practices and strategies) related to interaction design in DSD projects;
- supporting the planning and implementation of good interaction design practices in DSD projects;
- presenting solutions (approaches, methods, techniques, tools) used in interaction design in DSD projects;
- showing the importance of the designer and/or HCI specialist for the adoption of good interaction design practices in DSD.
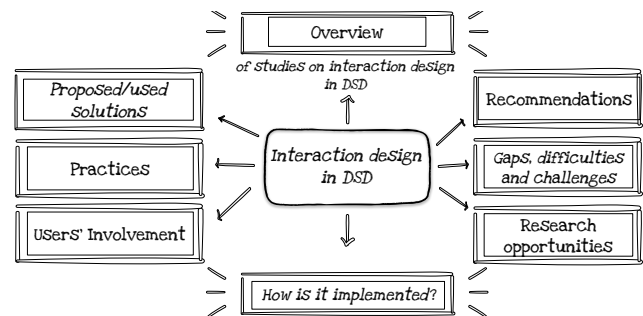

Figure 7. Overview of main research contributions.

We believe that understanding how interaction design has been implemented in DSD projects is essential to identify which aspects should be taken into account when developing interaction design solutions for the DSD context. As HCI researchers, we have the opportunity to understand this topic and identify solutions to problems and challenges in DSD, incorporating the ideals of our field. To provide effective support in the interaction design process in DSD and support the implementation of good interaction design practices and the involvement of users in DSD projects, we conceived, at the end of the research, a set of recommendations for interaction design in DSD. We hope that the set of recommendations will support DSD practitioners in planning and implementing interaction design practices in DSD projects. With this, we also hope to contribute to improving the quality of the interaction design process in DSD and, consequently, of the developed product.

In addition to the previously described contributions, we publish and/or present the results of this research in journals, conference proceedings, and scientific events. These scientific productions are listed in the References section, as follows: [Alves, 2022], [Alves and Matos, 2017c], [Alves and Matos, 2017b], [Alves and Matos, 2017a], [Alves and Matos, 2018], [Alves and Matos, 2018], [Alves and Matos, 2019], [Alves *et al*., 2023], [Alves and Matos, 2022], [Rosa *et al*., 2018], and [Rosa *et al*., 2019].

The first author of this paper has participated in the Brazilian Symposium on Human Factors in Computational Systems (IHC), with papers published in conference proceedings and oral presentations of the results of this research, for example, in the Research Articles track [Alves and Matos, 2017c, 2019, 2022], Theses and Dissertations Workshops [Alves and Matos, 2018] and Research Groups Forum [Matos *et al*., 2017].

6   Research Ethics Aspects

Since the subject of this research is human beings, the responsible researcher took all precautions throughout the steps of this research, clarifying the rights, responsibilities, risks, and benefits involved. Throughout the research, the researchers carried out the project in line with the norms and resolutions that guide research involving human beings in Brazil, in particular Resolution CNS 466/12 [de Saúde, 2012] and its complementary. This research was registered in Plataforma Brasil ³ under the Certificate of Presentation for Ethical Appreciation (CAAE) nº 16534619.3.0000.8055 and approved by the Research Ethics Committee of the Federal Institute of Education, Science, and Technology of Mato Grosso (IFMT), according to opinion number: 3.549.992.

The confidentiality and privacy of the information provided by the participants were guaranteed. The personal data obtained in the context of this research are confidential and will not be distributed or disclosed individually, in order to ensure the confidentiality of the participants. At the end of the research, all material will be kept on file for at least 5 years, according to CNS Resolution 466/12.

Participants were informed that their participation in this research could expose them to minimize risks such as embarrassment (for example, when remembering highly stressful situations) when answering a question; the embarrassment of interacting with strangers; taking time to participate in the study; fear of eventual repercussions and stigmatization. Participants were also informed that, if this occurred, they would be instructed to stop participating in the study, if they so desired, and return later. The researcher took the appropriate measures to mitigate these risks.

Research participants had no direct benefit. However, the indirect benefits related to collaboration in this research are: offering subsidies for future research and actions to support the definition, evaluation, and improvement of interaction design processes in DSD projects; providing the scientific community with evidence on problems, challenges, and solutions of interaction design in DSD; and providing an overview of how interaction design has been conducted in DSD projects.

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³http://plataformabrasil.saude.gov.br/

We hope that in the future the results of this scientific research will be used for the benefit of professionals working on DSD projects, based on the development of a set of recommendations for interaction design in DSD. In addition, access to the results of this research will be allowed through scientific papers and/or the doctoral thesis.

Participants signed a Free and Informed Consent Form (FICF). In all publications in this research, an anonymous identifier (P#) was used for each of the participants. The responsible researcher adopted good privacy and information security practices, as well as made use of available protection mechanisms, kept his computer updated and free of malicious codes, and used data collection and storage services that offer security and privacy, such as encryption in the transfer of data, protection of data from unauthorized access and accidental or illegal situations of destruction, loss, alteration, communication or any form of inappropriate or illegal treatment.

7   Limitations and threats to validity

In guarantee an impartial selection process, all the steps of the systematic mappings process were followed according to the protocol. During the studies selection and data extraction steps, some threats such as researcher biases and misunderstandings could appear. To remove these threats, the first author of this study consulted with his advisor and negotiated regarding disagreements and doubts. A common limitation of systematic mappings is finding all existing relevant papers. Due to the limited number of digital libraries and the search string used, it is possible that relevant studies have not been included. To minimize this problem, the digital libraries used include most of the main journals and conferences in the area of Computer Science. Furthermore, for the definition of the search string, the first and second authors carried out several discussions and tests of strings in the defined digital libraries. Due to resource and time constraints to complete this study, we did not conduct forward and backward search of bibliographic references of included papers.

During the *Survey with DSD professionals* step, some actions were taken to mitigate threats to the validity of the research. First, we conducted a poll to identify the individuals who had worked on DSD projects to prevent those who had never worked on a DSD project from answering the survey questionnaire, thus mitigating a threat. In addition, we followed a systematic process to conduct this survey. As the target audience of this survey is composed of professionals from different domains of computing, some terms related to interaction design might not have been familiar to the participants. This can also be considered a threat to the validity. To mitigate this risk, definitions of interaction design and DSD were introduced at the beginning of the questionnaire. In addition, in some questions of the questionnaire, we described some terms that might not have been familiar to the participants. The limited number of participants in this survey can be considered another threat to validity. There was participation from a considerable number of professionals who had worked on DSD projects, but greater participation from other countries would have been desirable. The questionnaires

were prepared in English and Portuguese, but there was little participation from professionals from other countries. However, the use of non-probabilistic sampling reduces this threat to validity. We did not use probability sampling because of the difficulty in determining the entire population studied. Despite this, we believe that the study is representative, as it included participants from Brazil, Portugal, Czech Republic, United Kingdom, United States, Canada, and Denmark, albeit not to the desired extent. Thus, the results can be used to generalize the conclusions of this study in a limited manner.

During the *Interviews with DSD professionals* step, some actions were also taken to mitigate threats to validity. First, a survey was applied to identify professionals who worked (or had worked) on DSD projects to prevent those who had never worked on a DSD project from being invited to the interview, thus mitigating a threat. Second, we followed a systematic process to conduct this study. In addition, to promote diversity, we also conducted interviews with participants playing different roles in DSD projects. Another threat to validity is that respondents might not understand the questions in the interview script. To mitigate this threat, we conducted a pilot interview study with a researcher who worked on DSD projects. Thus, the questions in the interview script were reformulated as necessary. To mitigate the threat of participants not discussing the difficulties, problems, and other issues of their current practice, we explain in the Free and Informed Consent Form (FICF) and explain during the interviews about the data privacy and anonymity of the participants.

Due to limited time to complete this research, we did not evaluate the proposed set of recommendations. Thus, future work can be conducted to evaluate the set of recommendations.

8 Final considerations

In this research, we investigated how interaction design is practiced in DSD projects, seeking to understand its practices, challenges, and difficulties. For this, we rely methodologically on the methodeutics proposed by Charles S. Peirce. The bibliographical research method was used to investigate the state of knowledge and the mixed methods research to investigate the state of practice. Thus, in the end, this research provides a detailed view on how interaction design is practiced in DSD projects, describing its main characteristics, as well as its challenges and difficulties. With the consolidation of the main results of this research, we conceived a set of recommendations for interaction design in DSD.

We emphasize the relevance of the methodeutics proposed by Charles S. Peirce to investigate how interaction design is practiced in DSD projects. The use of Semiotics beyond the linguistic and communicative proposal, but fundamentally methodological, can provide a potential contribution to conducting scientific research. We understand that a paradigm shift is necessary by also considering the pragmatic approach for the advancement of science, especially when there is a need to understand phenomena and their relationships, according to the pragmaticism of Charles S. Peirce. Charles

S. Peirce's pragmaticism and methodeutics can contribute to advancing the state of practice in several areas of knowledge, especially when considering the practice as a source of knowledge. Thus, we believe that Semiotics has much more to offer to the academic and scientific community.

With a detailed view of the state of knowledge and practice of interaction design in DSD projects, as well as the gaps, difficulties, and challenges identified, the results of this research suggest that the research community makes an effort to investigate and develop solutions to provide a solid foundation for interaction design in DSD. We propose below a challenge and research agenda to foster future research and the development of new theories and solutions for interaction design in DSD.

We propose the following challenge: **Distributed Collaborative Interaction Design (Co-design): development of methods, techniques, and computational resources for distributed co-design**. The main contribution of this challenge proposal is to encourage future research and the development of new theories and solutions for interaction design in DSD, on the research frontier between Human-Computer Interaction and Collaborative Systems.

To contribute to this challenge, a research agenda is proposed considering three perspectives to address and encourage research related to distributed interaction design: i) *Theoretical-methodological*: it is necessary to investigate how to solve difficulties and challenges in distributed interaction design because we still have a limited understanding of how distributed interaction design works. Concomitant with this, it is necessary to investigate and develop new theories and solutions for the involvement of users in distributed interaction design. In addition, it is necessary to research how to consider traditional processes, methods, techniques, practices, approaches, and models of interaction design in a distributed context; ii) *Technical*: it is necessary to develop new technologies (or adapt existing technologies) in order to solve the difficulties and mitigate the challenges of the distributed interaction design; iii) *Social*: it is necessary to investigate the impact of distributed interaction design solutions on people's behavior and lives [Baranauskas *et al.*, 2015], mainly with regard to designers, HCI specialists, and users.

These perspectives can be realized with the following actions: formation of study and research groups, partnerships between academia and the software industry, incentives from funding agencies, insertion of topics of interest in event calls along with holding events addressing this topic, and insertion of topics related to this theme in undergraduate and graduate curricula.

Future work can be carried out to better understand the state of interaction design practice in DSD, for example, systematic mapping to identify methods, techniques, systems, and computational tools used in the interaction design in DSD, including the gray literature (blogs, FLOSS communities/projects); virtual ethnography to understand the state of practice of interaction design in FLOSS projects/communities and/or in virtual software development communities.

Declarations

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