Human-computer interaction patterns of design for multilingualism

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Abstract. Introduction*: The increased access to computing devices and the greater connectivity among the general population, especially in developing countries, has caused the diversity of software users to expand considerably. In this context, aspects related to accessibility, cultural diversity, and multilingualism gain strength as research interests in Human-Computer Interaction (HCI). Despite that, few studies have been carried out that analyze the impact of multilingualism on interaction design strategies.* ***Objective:*** *In this doctoral thesis, an approach based on design patterns is adopted to analyze current design strategies aimed at the multilingualism of software users. Multilingualism is taken into consideration here in both its social form (the linguistic diversity of the user base) and its individual form (the ability of each user to understand and express themselves in different languages).* ***Methodology or Steps:*** *Based on a systematic literature mapping, this thesis initially proposes a framework for the development of HCI design patterns. Next, a pattern language developed using this same framework is presented and validated through two studies with professionals in the field.* ***Results:*** *Both the development framework and the language itself represent advances in knowledge in the area of HCI, which are useful to researchers and professionals in the field. The framework can be useful to researchers who want to discover new patterns and develop new HCI pattern languages. The proposed pattern language may be of interest to researchers who wish to study the intersections between HCI, multilingualism, and cross-cultural design.*

Keywords *Bilingual, Multilingualism, Pattern Language, Design Patterns, Human-Computer Interaction, Interaction Design, Cross-Cultural Design.*

1. Identification

This paper presents a summary of the doctoral thesis entitled "Human-computer interaction patterns of design for multilingualism", presented as a requirement for the completion of the doctoral course in the Graduate Program in Computer Science (PPGCC) of the Pontifical Catholic University of Rio Grande do Sul (PUCRS)[1]. The work was authored by me (Diego Moreira da Rosa) and supervised by Prof. Milene Selbach Silveira, PhD. The doctoral course took place between 2020 and 2023, and the thesis was

[1]In Portuguese: Programa de Pós-Graduação em Ciência da Computação da Pontifícia Universidade Católica do Rio Grande do Sul.

approved by the evaluation committee on 22 March 2024. In addition to the supervising professor, the following professors participated in the committee: Luciana Cardoso de Castro Salgado, PhD (DCC - UFF[2]); Roberto Pereira, PhD (DInf - UFPR[3]); and Afonso Henrique Corrêa de Sales, PhD (PPGCC - PUCRS).

The thesis presents the perspective that multilingualism can and should be an important focus of interaction design. In a present scenario of increased cultural exchanges, wider visibility of multilingualism, and growing concerns about the future of the world's linguistic diversity, an improvement of Human-Computer Interaction (HCI) design is expected with the adoption of such perspective. The methodology involves proposing and discussing a pattern language based on solutions for user interfaces designed towards multilingualism and found in current computer systems. The discovery of these patterns was supported by a new framework, which is also described in this work and is the direct result of a systematic literature mapping. The framework proposal is one of the main contributions of this thesis. The pattern language is another main contribution and, at the same time, a validation for the framework.

2. Research problem

Although the intersections of multilingualism and Human-Computer Interaction (HCI) have been the subject of recent scientific work, very few of these studies investigate the design strategies that are impacted by users' multilingualism, and none of them do so in a way that is both broad and in-depth. User interface solutions that might be impacted by the different levels of multilingualism include: language settings configuration, content presentation in multiple languages, data entry in multiple languages, collaborative online help, collaborative translations, among others. Preliminary studies conducted by the author of the thesis (published before the doctorate) showed the immaturity of some of these solutions and a great diversity of the adopted design strategies [Da Rosa 2017, Da Rosa e Pons 2017, Pons e Da Rosa 2017].

Considering the aforementioned context, there are indications of a new form of interaction design being applied in current multilingual-aware software systems, but it is also evident the lack of a set of best practices, such as a pattern language for the design of these solutions. This leads us to the research questions (RQs) that will guide the remaining of the thesis:

- **RQ1:** How are patterns developed in the context of HCI?
- **RQ2:** What patterns better represent current design solutions that embrace multilingualism?
- **RQ3:** How can a pattern language assist designers in developing software interfaces adapted for multilingual individuals and multilingual situations?

3. Produced solution

To answer the research questions, a two-part main objective was defined: to describe a framework for HCI patterns development and, using this framework, propose a pattern

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language based on the observation of current software solutions adapted for multilingual users. We argue that the proposed framework can assist HCI specialists in developing new HCI pattern languages in a structured and practical way. The pattern language, in turn, can assist designers in developing interfaces that improve the experience of multilingual users without harming the experience of monolingual ones. The adopted methodologies, obtained results, and discussion of the contributions are discussed in the following sections.

4. Research plan and methods

As expected for a doctoral research, several studies were conducted to arrive at the final result of the thesis. This section discusses the research plan and the methods used in the main studies.

4.1. Research plan

The plan to achieve the established objectives and answer the research questions started with a systematic literature mapping on human-computer interaction patterns. It was followed by two iterations of the pattern language development. Fig. 1 summarizes the plan and methods used during the research.

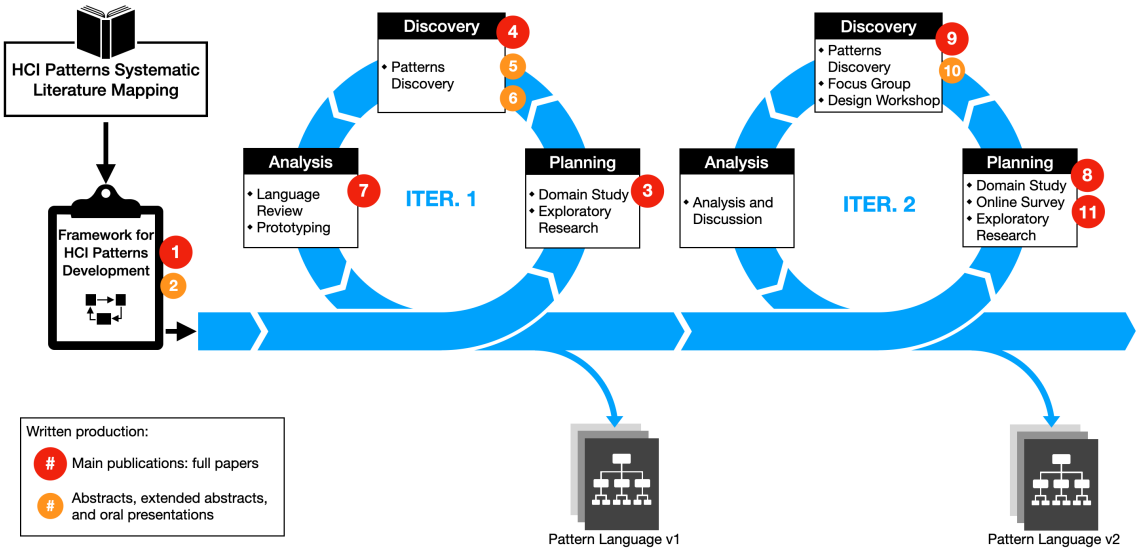


Figura 1. The research plan shows the two iterations of the development process and includes methods, outcomes, and written production.

Fig. 1 also displays the written production (papers, abstracts, and extended abstracts) published and/or presented during the research. The most important works (full papers) are indicated by the red circles, and less relevant publications are indicated by the smaller orange circles. The circles are displayed close to the activities to which they are related. Table 1 shows more details of the publications.

Findings of the systematic mapping yielded the proposal of a framework for HCI patterns development which grounded the subsequent activities. The proposed framework defines three phases for developing a new pattern language: Planning, Discovery, and Post-Discovery (depicted as Analysis in Fig. 1). It also defines an iterative process through

Tabela 1. Papers and abstracts published during the research.

No.	Year	Venue[a] — Track	Type	Reference
1	2022	IxD&A Journal N. 54	Full paper	[Da Rosa e Silveira 2022a]
2	2023	IHC — International Articles	Ext. Abstr.[b]	[Da Rosa e Silveira 2023]
3	2021	IHC — Innovative Ideas and Emergent Results	Full paper	[Da Rosa et al. 2021]
4	2022	EuroPLoP	Full paper	[Da Rosa et al. 2022c]
5	2022	IHC — Workshop of Theses and Dissertations	Ext. Abstr.	[Da Rosa e Silveira 2022b]
6	2022	PLoP — Writers' Group	Full paper[c]	[Da Rosa et al. 2022b]
7	2022	SugarLoaf PLoP	Full paper	[Da Rosa et al. 2022a]
8	2023	HCII — Late Breaking Work	Full paper	[Da Rosa et al. 2023a]
9	2023	EuroPLoP	Full paper	[Da Rosa et al. 2023c]
10	2023	PUCRS Conexão Pós	Abstract[d]	[Da Rosa et al. 2023b]
11	2024	IHC — Innovative Ideas and Emergent Results[e]	Full paper	[Da Rosa et al. 2023b]

[a]Venues in order of appearance: Interaction Design & Architecture(s) Journal (IxD&A), Brazilian Symposium on Human Factors in Computing Systems (IHC), European Conference on Pattern Languages of Programs (EuroPLoP), Conference on Pattern Languages of Programs (PLoP), Latin American PLoP (SugarLoaf PLoP), International Conference on Human-Computer Interaction (HCII).
[b]Extended Abstract
[c]Presented at the Writer's Group of the PLoP'22 but not accepted for publication.
[d]Submitted as abstract and presented in pitch format — five minutes (works not published to date).
[e]Awarded with Honorable Mention in the best paper contest.

which patterns can be repeatedly reviewed and improved. Detailed descriptions of the systematic mapping and the framework were published in the Autumn 2022 edition of the Interaction Design & Architecture(s) Journal (IxD&A N. 54) [Da Rosa e Silveira 2022a] (a summarized version of this work translated to Portuguese was published and presented at the International Articles track of the XXII Brazilian Symposium on Human Factors in Computing Systems (IHC'23) [Da Rosa e Silveira 2023]).

Two iterations of the pattern language development are displayed in Fig. 1. The planning phase of the first iteration started with a study on the presentation of multilingual user reviews in accommodation websites followed by the proposal of a few proto-patterns[4] (results published and presented at the IHC'21 Innovative Ideas and Emergent Results track [Da Rosa et al. 2021]). Next, exploratory research expanded the number of systems selected for analysis in preparation for the discovery phase. The next phase consisted of applying pattern identification techniques to discover the first version of the pattern language. Results of this first cycle of patterns discovery were published at the 27th European Conference on Pattern Languages of Programs (EuroPLoP'22) [Da Rosa et al. 2022c] and at the Workshop of Theses and Dissertations of IHC'22. Some patterns of the language were described in a full paper which was presented at the Writers' Group of the Conference on Pattern Languages of

[4]Early conventions in a specific domain that still need to mature to become proper patterns.

Programs (PLoP'22) [Da Rosa et al. 2022b] (works in this group were not included in the conference proceedings). The first iteration was closed with a period of analysis of the results, adjustments to the pattern language, and the development of prototypes to test the patterns in practice. Observations from the first iteration regarding the presentation of pattern languages were published at the Latin American Conference on Pattern Languages of Programs (SugarLoaf PLoP'22) [Da Rosa et al. 2022a].

The second half of this doctorate was marked by a period of six months as a visiting researcher (*doutorado sanduíche*) at the Università della Svizzera italiana (USI) under the supervision of professor Monica Landoni, PhD. Working in cooperation with the team from USI's Laboratory of User Experience, Interaction & Accessibility (LUXIA), the second iteration started with further studies on the roles of languages in HCI, with results published as Late-Breaking Work at the 25th International Conference on Human-Computer Interaction (HCII) [Da Rosa et al. 2023a]. To deepen our knowledge of users' behavior regarding multilingual interactions, an online survey was conducted with students from USI (Switzerland) and PUCRS (Brazil). The results of this survey were published at the IHC'24 Innovative Ideas and Emergent Results track [Da Rosa et al. 2024]). Closing the planning phase of the second iteration, the list of selected systems was again expanded for the second round of patterns discovery. Besides a new stage of patterns identification, the discovery phase includes a validation stage comprised of two user studies: a focus group and a design workshop. A subset of the newly discovered patterns was published at EuroPLoP'23 [Da Rosa et al. 2023c]. A summary of this second version of the pattern language was presented in an internal seminar called *Conexão Pós* organized by PUCRS. Finally, a final phase of analysis and discussion closed the studies for this thesis.

4.2. Methods

As previously mentioned, the research consisted of several studies. In this section, the methods used in the six main studies that comprised this research will be briefly described. Further details of the studies and the methodology applied in each of them can be found in the final text of the thesis or in the corresponding publications.

4.3. Study 1 method: Systematic literature mapping

To understand how patterns and pattern languages are being developed and used in HCI contexts, we conducted a systematic literature mapping, a particular type of systematic literature review. We performed the mapping considering the guidelines provided in the work of [Kitchenham et al. 2015] and [Petersen et al. 2015]. This methodology was chosen to obtain a broad view of design patterns in the context of HCI primary studies. In systematic mappings, research questions are broader and more numerous than in systematic reviews because the focus is to provide an overview of a research area [Kitchenham et al. 2015]. The direct product of the systematic mapping is the framework for HCI patterns development which summarizes the mapping discoveries.

4.4. Study 2 method: Online survey

To explore language-related issues of human-computer interaction in different contexts of multilingualism, an online survey was conducted with the academic communities of the two universities where this doctorate took place: Università della Svizzera italiana

(USI), in Switzerland, and Pontifical Catholic University of Rio Grande do Sul (PUCRS), in Brazil. The two universities were chosen for convenience, since the survey was planned and partly executed during the period in which the author was at USI as a visiting researcher. Furthermore, Switzerland and Brazil are very distinct countries, which allowed the examination of users' behavior in diverse cultural and linguistic contexts[5]. The study was planned and conducted following typical guidelines for surveys in Human-Computer Interaction research [Lazar et al. 2017]. The questionnaire was built on the Qualtrics platform, and the answers were stored on a secure server. The survey was mostly self-selected and used convenience non-probability sampling. Participants were recruited through instant messaging groups (WhatsApp), social network groups (Facebook), institutional email, and direct in person invitations.

4.5. Study 3 method: Patterns identification and organization

As evidenced by the research plan, the entire process of discovering patterns and organizing the pattern language was guided by the framework proposed at the beginning of this doctorate [Da Rosa e Silveira 2022a]. This process involved several steps, all based on good practices extracted from the literature.

4.6. Study 4 method: Patterns validation—Focus group

To validate the language from the point of view of experienced professionals, a focus group was planned and conducted. The procedure was adapted from the guidelines for interviews and focus groups in the context of HCI as described by Lazar et al. [Lazar et al. 2017]. In this setting, the typical focus group structure was combined with elements of a design workshop, which was the most common form of validation found in our literature mapping about HCI patterns. Participants were recruited among students from the PUCRS graduate program who had a minimum of 4 years of professional experience in computing, design, or related areas.

4.7. Study 5 method: Patterns validation—Design workshop

A second study was planned to validate the language from the point of view of beginner developers. This activity was structured as a design workshop. Design workshops or design sessions were techniques frequently mentioned in the literature mapping that had been carried out. The procedure described by Sauppé and Mutlu, who conducted design sessions to validate their pattern language for human-robot interactions [Sauppé e Mutlu 2014], was used as a reference. Participants were recruited among PUCRS undergraduate computing students with little or no professional experience.

4.8. Study 6 method: Patterns application—Prototyping

To analyze the applicability of the developed patterns, a design intervention to a website was started with the help of the research team at PUCRS. The website chosen for the intervention was the Plants For A Future (PFAF) (`pfaf.org`), an information database on edible plants. The decision to carry out an intervention on an existing website (instead of creating a new one from scratch) aimed to simplify the process, allowing us to focus on

[5]Switzerland and, in particular, the city of Lugano are places with a long tradition of multilingualism. Brazil, on the other hand, is generally considered a monolingual country.

applying the patterns. A design intervention was planned for the website. The idea was to draw new wireframes using the Figma (`www.figma.com`) tool for interface design. The basic look and feel of the website would be kept on the new screens, allowing the team to focus on new functionalities. The main motivation of the alternative design was to allow international visitors to create and manage user accounts, becoming active contributors to translations and new content. To achieve this, the patterns of design for multilingualism should be applied whenever possible to validate the patterns' feasibility.

5. Results and discussion

This section presents the main results obtained during the doctorate and reported in the thesis. Once again, the section is organized taking into account the six main studies conducted. The two main products of the thesis, the HCI patterns development framework and the developed pattern language, are presented in Sections 5.1 and 5.3 respectively.

5.1. Study 1 results: Systematic literature mapping

The results of the systematic literature mapping, such as terminology and research methods, grounded the construction of the framework. Analyzing the selected papers also allowed the identification of the main stages that make up the process. Furthermore, these results were contrasted with established literature on pattern methodology (mentioned previously in this section), uncovering each approach's positive and negative aspects. The analysis allowed us to identify stages and outcomes typical to the patterns development process in HCI. The organization of these stages in a pattern life cycle form the basis of the proposed framework seen in Fig. 2.

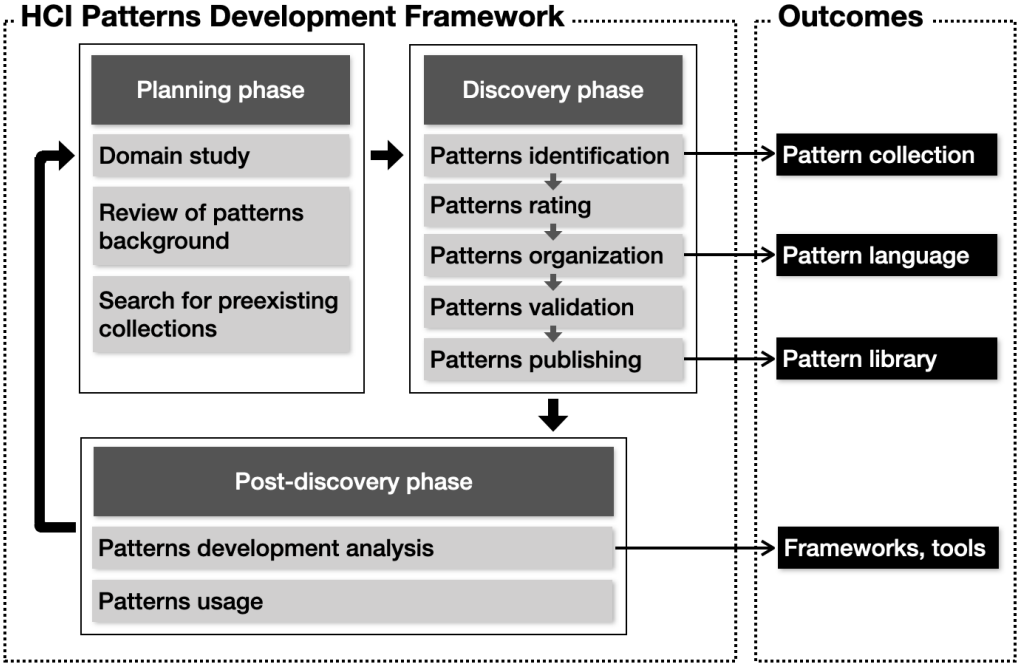


Figura 2. A framework for design patterns development in HCI.

Stages of the framework were grouped into three main phases, namely: *Planning Phase*, *Discovery Phase*, and *Post-discovery Phase*. The iterative configuration of

the framework expresses the notion that a pattern language is not always static. On the contrary, it will probably constantly evolve whenever the language elicited in the Discovery phase is practical and alive. Living pattern languages should be continuously updated so that the observations from the Post-discovery phase feed the Planning phase, initiating a new development cycle. The framework also describes typical outcomes of certain stages. The result of the Patterns identification stage is a collection of patterns. When these patterns are organized and related to each other, the collection turns into a pattern language (outcome of the Patterns organization stage). After the Patterns publishing stage, the pattern language is made available to other developers resulting in a pattern library. Analysis of the patterns and patterns development process often result in new frameworks and/or tools aimed at facilitating a specific design strategy.

5.2. Study 2 results: Online survey

The online survey conducted with students from the two universities presented results consistent with the highest level of multilingualism in Switzerland. Fig. 3 shows the reported frequency of engagement in digital activities involving multiple languages. In turn, Table 2 shows a heatmap of the issues related to multilingual activities faced by participants from both universities. Open questions allowed participants to detail their responses and report issues not mentioned in the survey questionnaire.

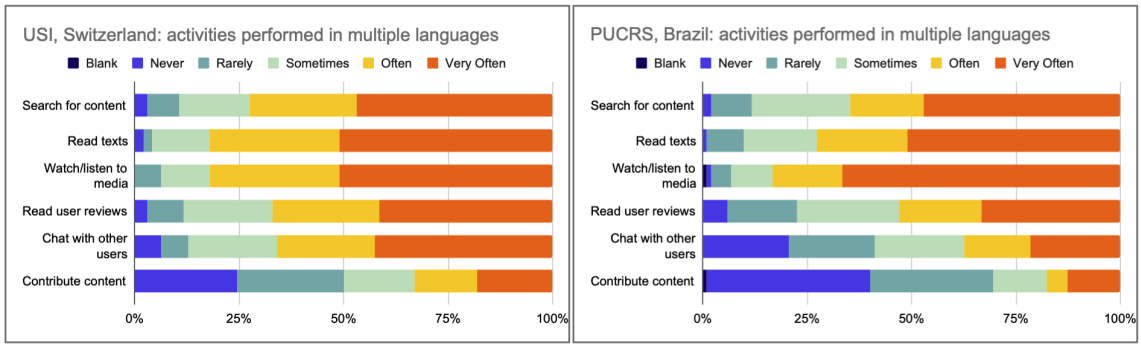


Figura 3. Frequency of engagement in digital activities involving multiple languages by participants from both universities.

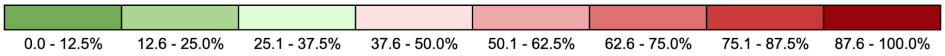
The survey results are coherent with previous language-related assumptions, such as the high levels of multilingualism, societal multilingualism implying individual multilingualism, and multilingualism being transposed into the digital world. Differences between the responses of the two universities also indicate that different linguistic societies/communities face different difficulties when interacting with digital systems. Common problems related to HCI and multilingualism were identified, some more specific to the USI environment.

5.3. Study 3 results: Patterns identification and organization

The final result of the patterns identification and organization is the pattern language represented by the network diagram shown in Fig. 4. The discovered patterns were grouped into five categories according to each pattern's main function or area of application. The classification and the names of the categories were inspired by the organization of two well-known user interface pattern libraries: Welie.com and UI Patterns.

Tabela 2. Issues related to multilingual activities faced by participants from both universities.

Category	Issue	USI (Switzerland) %	PUCRS (Brazil) %
Configuration	Your preferred language was not available for selection in a specific system.	29.8	31.4
	It was difficult to find/identify the desired language from the selection list.	16.0	13.7
	Automatic detection of your region from the Internet connection led to undesirable settings.	60.6	35.3
	Other settings related to language (currency, date format, etc.) inconsistent with your preferences.	39.4	31.4
Reading	Badly translated software interface or web content.	75.5	73.5
	Content in different languages was hidden or difficult to access.	39.4	27.5
	Advertisements being displayed in languages that you do not understand.	69.1	25.5
	It was difficult to read/comprehend content in different languages.	31.9	23.5
	It was difficult to interact/chat with other users in different languages.	18.1	9.8
Input / Typing	Autocorrection feature incorrectly changing words when typing texts in different languages.	84.0	73.5
	Spell check incorrectly highlighting words when typing texts in different languages.	70.2	69.6
	Physical keyboard not adapted to type texts in one of your preferred languages.	63.8	26.5
	Problems to select/use the most appropriate virtual keyboard on a mobile device.	22.3	14.7
	Voice interfaces not recognizing speech in different languages.	31.9	26.5
Search	It was difficult to search content/websites in many languages using a single search.	40.4	37.3
	It was difficult to identify the language of the returned results.	6.4	10.8
	Most relevant results not appearing on top of the result list.	36.2	34.3



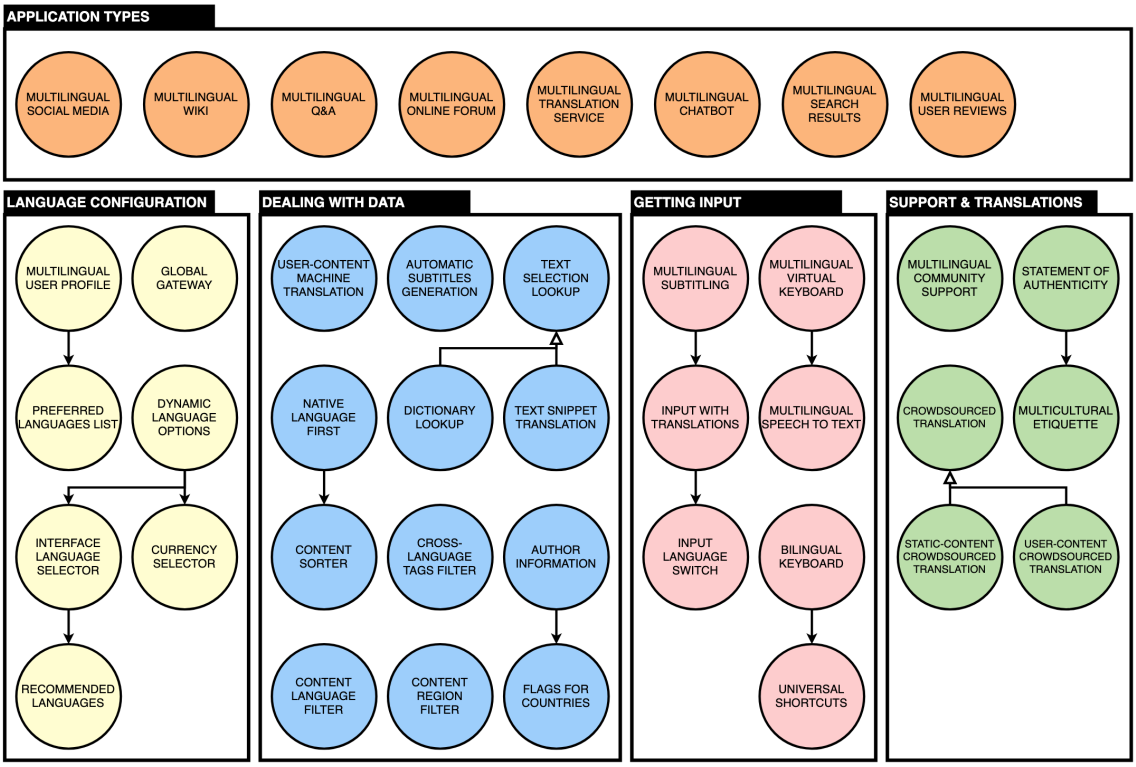


Figura 4. Pattern language of design for multilingualism: diagram after patterns organization.

Full descriptions for all the patterns are present in one of the thesis appendices and had been published on a website for public access[6]. The description of pattern PREFERRED LANGUAGES LIST is presented as an example of the identification and writing process. This pattern describes a widget commonly used to configure language preferences in user profiles. Fig. 5 shows an illustration of this pattern as seen in the system settings of macOS.

PREFERRED LANGUAGES LIST

Allow users to manage a list of preferred languages.

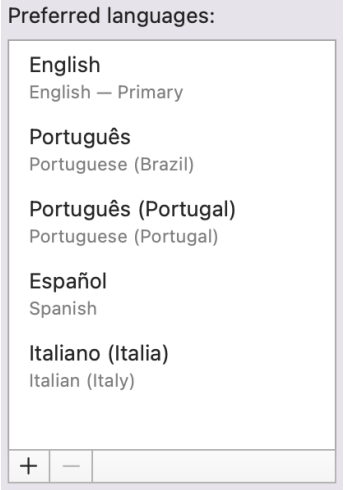


Figura 5. Illustration of PREFERRED LANGUAGES LIST as seen in the macOS 12.7.3.

Context: You are designing the interface of a MULTILINGUAL USER PROFILE to allow the management of user account settings in a website, application, platform, or operating system designed for multilingualism.

Problem: You want to enable users to inform their complete language abilities without being restricted to a single preferred language.

Solution: *Provide a compound widget that enables users to create and manage a list of preferred languages.* The languages in the list are organized in descending order, meaning that the most important languages will be displayed first or on top. The order of the languages reflects the user's preference regarding the languages used to view content and interact with the system.

As a result, the first language will be the user's favorite language. It will be the interface language, i.e., the language used to display static content within the interface. It is recommended to highlight the first language in the widget, indicating that it will be the interface language. In some situations, the order of the languages will correspond to the user's level of proficiency in each one of them, but this is not a requirement, as there are different motivations for setting language preferences.

The development team defines the list available language options, which typically

[6]The website was available at the time of the doctorate committee, but is currently down. We are working to restore access to the website.

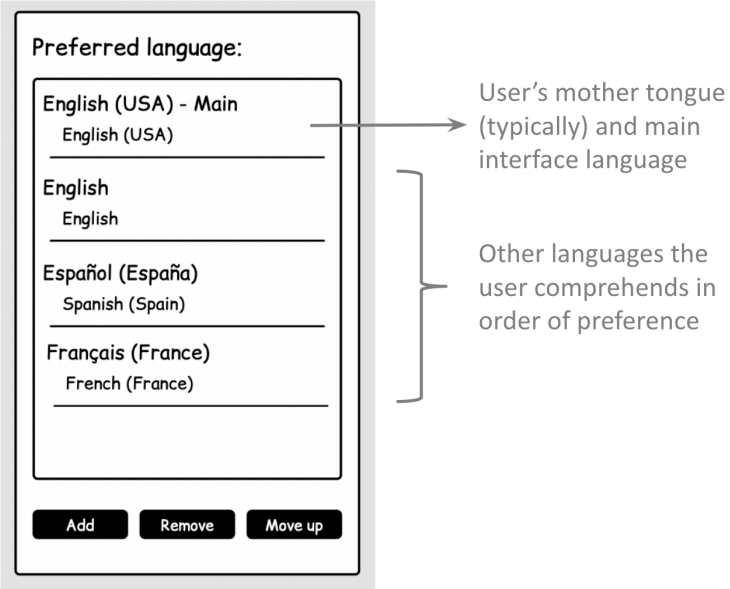


Figura 6. Diagram of PREFERRED LANGUAGES LIST.

represents the languages supported by the system. When multiple dialects of the same language are offered to the user, the widget should clearly distinguish between the dialects or locale variations. For example, differentiating between *English* (international English), *English (UK)* (British English), and *English (US)* (American English).

Language names should be displayed in the current interface language and in their original language (spelling and script), facilitating the recovery if a user changes the interface language to a language they do not understand. The widget should allow users to add new languages, change the position of added languages, and remove languages from the list.

Confidence rating: ☆☆☆

Related patterns: To add a new language to the list, the system can provide an INTERFACE LANGUAGE SELECTOR. Once the user correctly fills in their preferred languages, the system can make varied use of this information besides setting the interface language. Operating systems can use this profile to configure language-related functions, such as DICTIONARY LOOKUP and MULTILINGUAL VIRTUAL KEYBOARD. Most web browsers will pass on this information on HTTP headers to load websites with the best language configuration. Web platforms can use these preferences to determine which content is best suited for MULTILINGUAL SOCIAL MEDIA and MULTILINGUAL SEARCH RESULTS.

5.4. Study 4 results: Patterns validation—Focus group

After activities and group discussion, the participants of the focus group filled a final evaluation questionnaire. The answers can be seen in Table 3. All five participants agreed or strongly agreed that **the patterns were easy to find** within the language (Question 1). Regarding the quality of the patterns (Question 2), all participants evaluated that **the pattern descriptions were of good or excellent quality**. The last question was an open question in which users could provide their impressions on the potential of the pattern

language (Question 3). All professionals praised the **potential of practical application** observed for the patterns, using words such as *"viable"*, *"useful"*, and *"relevant"*

Tabela 3. Evaluation of the pattern language by participants of the focus group.

Part.	**Question 1:** Whenever necessary, it was easy to find patterns within the language.[a]	**Question 2:** How do you evaluate the quality of the pattern descriptions?[b]	**Question 3:** How do you assess the potential for these patterns to be applied in practice?
PFG1	Strongly agree	Good quality	*"Lots of potential for use within the proposed context."*
PFG2	Strongly agree	Excellent quality	*"They can be very useful in building a website/system, as a guide in application development."*
PFG3	Agree	Excellent quality	*"Highly relevant."*
PFG4	Strongly agree	Excellent quality	*"Very relevant (as seen by someone who had no prior knowledge)."*
PFG5	Agree	Excellent quality	*"Totally viable."*

[a] 5-level traditional Likert scale.
[b] 5-level scale. The options were: terrible, bad, fair, good, and excellent quality.

Tabela 4. Assessment of the pattern language by participants of the design workshop: responses to questions 4 and 5 of the evaluation questionnaire.

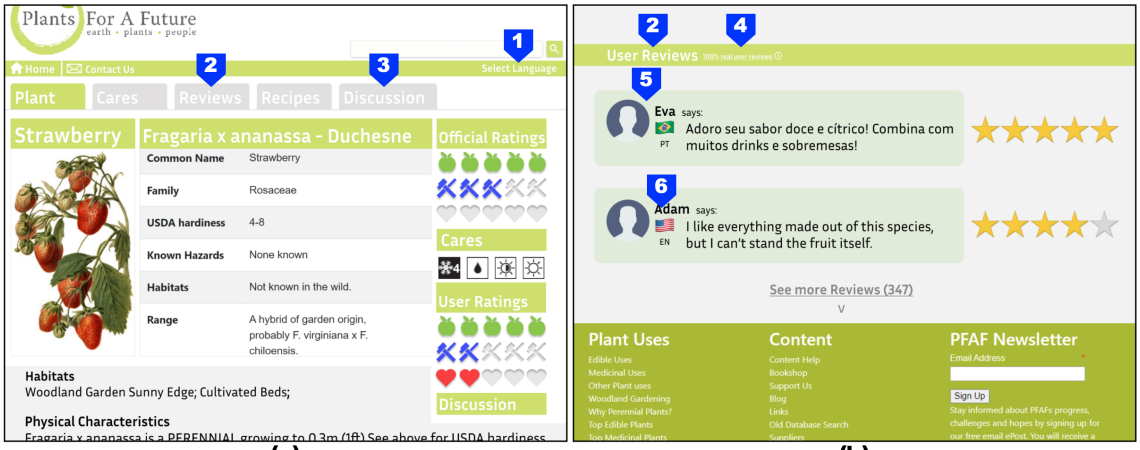
Question	**Response**	**N. Part.**	**%**
Question 4: Whenever necessary, it was easy to find the patterns within the language.	Strongly agree	8	27.6%
	Agree	17	58.6%
	Neutral / Undecided	4	13.8%
	Disagree	0	00.0%
	Totally disagree	0	00.0%
Question 5: How do you evaluate the quality of the patterns descriptions (accuracy, completeness, consistency, comprehensibility, etc.)?	Excellent quality	11	37.9%
	Good quality	14	48.3%
	Average quality	4	13.8%
	Bad quality	0	00.0%
	Terrible quality	0	00.0%

5.5. Study 5 results: Patterns validation—Design workshop

Participants of the design workshop were divided in groups and received design tasks to be performed with the help of pattern cards. Table 4 summarizes the responses for questions 4 and 5 of a final evaluation questionnaire. In general, participants evaluated the patterns positively. Regarding the task of finding patterns within the language during the design activity (Question 4), 86.2% of participants agreed or strongly agreed that **the patterns were easy to find**. The same number of participants approved the quality of the patterns (Question 5), evaluating that the pattern **descriptions were of good or excellent quality**.

5.6. Study 6 results: Patterns application—Prototyping

A few wireframes were designed for the website. Although some of the wireframes are still incomplete, they give a sample of what the website could look like with the new proposal. Fig. 7 shows the page for plant information with the added functionalities of user reviews and collaborative discussion (question & answers).



(a) (b)

Figura 7. Proposed intervention in the PFAF website: the page for an edible plant (a) and a summary of the user reviews on the plant page (b). Patterns in these images: INTERFACE LANGUAGE SELECTOR (1), MULTILINGUAL USER REVIEWS (2), MULTILINGUAL Q&A (3), STATEMENT OF AUTHENTICITY (4), AUTHOR INFORMATION (5), and FLAGS FOR COUNTRIES (6).

Although the prototype is incipient, the positive aspects of using the pattern language could be observed. The patterns were used as a catalog of successful solutions and as a rationale for design decisions. During the research team's meetings, the patterns were frequently used as technical vocabulary. The prototype still needs to be more detailed, especially in relation to ways of translating and generating content in various languages. Evaluations by experts and potential users are also envisioned.

5.7. Discussion: principles of the design for multilingualism

Analyzing the rationale behind each pattern allowed us to identify some principles that appear to have guided these design solutions. By grouping patterns that aim for similar objectives, it was possible to list the following principles.

- **Favor language configuration over guessing.**
  - *Rationale:* Most analyzed systems favor language configuration through MULTILINGUAL USER PROFILE and DYNAMIC LANGUAGE OPTIONS over automatic detection techniques such as IP geolocation.
  - *Description:* Trying to guess the user's language preferences is a difficult task that often leads to mistakes. No guessing strategy will ever be more efficient than asking to the users themselves.
- **Decouple country from language.**
  - *Rationale:* The implementations found for patterns MULTILINGUAL USER PROFILE, INTERFACE LANGUAGE SELECTOR, and CURRENCY SELECTOR indicate that country and language selection should be treated separately.

  - *Description:* A country can have multiple languages, and a language can spread across multiple countries. On certain occasions, it may be useful and even necessary to find out the user's country, but this information should not be coupled with language preferences. Likewise, the user's chosen language should not imply the country or other language-related preferences, such as currency, date/time format, units of measurement, etc.
- **Facilitate the exploration of multilingual data with filters and sorting.**
  - *Rationale:* The patterns NATIVE LANGUAGE FIRST, CONTENT SORTER, CROSS-LANGUAGE TAGS FILTER, CONTENT LANGUAGE FILTER, and CONTENT REGION FILTER assist users by helping them extract the most useful information from the available multilingual data.
  - *Description:* Displaying multilingual content can increase the amount and diversity of data offered for the user to explore. Adding filtering and sorting options become more critical when presenting this type of content. In particular, filtering by language and/or region is key to facilitate the exploration of multilingual data.
- **Assist non-fluent users.**
  - *Rationale:* Assistance in the form of USER CONTENT MACHINE TRANSLATION, AUTOMATIC SUBTITLES GENERATION, DICTIONARY LOOKUP, and TEXT SNIPPET TRANSLATION ensure access to information for non-fluent users.
  - *Description:* Acknowledging multilingual users should not imply treating them as fluent in multiple languages, nor should it harm the experience of monolingual users. Offering reading assistance is a good way to guarantee multilingual accessibility and might also be helpful for the low-literate, people with intellectual disabilities, and other categories of people with special needs.
- **Facilitate typing through multilingual keyboards.**
  - *Rationale:* BILINGUAL KEYBOARD and MULTILINGUAL VIRTUAL KEYBOARD facilitate text input in many languages.
  - *Description:* Full support for multilinguals is only ensured when users are allowed not only to consume multilingual content, but also to produce content in multiple languages. Multilingual keyboards are essential for easy text entry.
- **Foster language accessibility through multimodal input/output.**
  - *Rationale:* Patterns such as MULTILINGUAL SPEECH-TO-TEXT and screen readers can favor the digital inclusion of users who find listening/speaking easier than reading/writing.
  - *Description:* Some multilingual users can find it easier to listen/speak in a certain second language rather than to read and write. Multimodal input/output, through audio for example, guarantee the digital accessibility for those users.
- **Balance human-made translations and machine translations.**
  - *Rationale:* The proposed patterns allow for both human-made (INPUT WITH TRANSLATIONS, MULTILINGUAL SUBTITLING, CROWDSOURCED TRANSLATION) and machine translation (MULTILINGUAL TRANSLATION SERVICE, USER CONTENT MACHINE TRANSLATION, AUTOMATIC

SUBTITLES GENERATION), indicating that a balance should be sought between the two.
  - *Description:* The availability of translations ensure that users can read the content even if they are not fluent in the original language. The discovered patterns suggest a balance between human-made and machine translations. Good quality human-made translations tend to be more accurate than machine translations, especially when the text contains jargon language, cultural references, and code-mixing. Machine translations are useful when there are no human-made translations available.
- **Trust the power of the multilingual community.**
  - *Rationale:* When a software system has a large enough user base, patterns such as MULTILINGUAL COMMUNITY SUPPORT and CROWDSOURCED TRANSLATION can be used to provide services that would otherwise be unaffordable.
  - *Description:* Many users are willing to help in their own languages. Support and translations provided by users themselves can be cheap and of good quality as long as the platform has a loyal and large enough user base.

6. Contributions to the field of HCI

The doctoral thesis presents a new perspective on interaction design in which multilingualism becomes one of the focuses of the design process. Designing for multilingualism is an important step towards more accessible and sustainable software system design. Although multilingualism-aware solutions can be observed in practice in current systems, they are losing space with the advancement of artificial intelligence (AI) and the increasing personalization of web systems, which can lead to linguistic and intellectual isolation.

In the initial stages of this research, a proposal is presented of a new framework for the development of HCI pattern languages. Through the application of the framework, an HCI pattern language was developed. The patterns describe the main design solutions towards multilingualism that are currently adopted in software systems. This pattern language was later validated with beginners and experienced professionals and through the construction of a prototype.

The main contributions of this research are the framework for developing HCI patterns and the pattern language aimed at multilingualism created through this framework. The following are these contributions in light of the research questions.

RQ1: How are patterns developed in the context of HCI? To answer this question, a systematic literature mapping was carried out. The main findings of this mapping gave rise to a framework for developing HCI patterns (see Section 5.1). Based on the analysis of previous HCI patterns research, the framework defines an iterative process organized into phases and stages. Furthermore, the framework also details aspects of the process, such as the procedures for pattern identification, validation, and rating. The proposed framework was subsequently used to develop a pattern language of design for multilingualism (see Section 5.3), which was later validated by professionals and used in a prototype design. The development of the pattern language is evidence of the framework's

effectiveness. The framework can be used by researchers and professionals in HCI, UX, web design, and related areas to develop pattern languages in a structured and effective way. With the adoption of the framework, new HCI pattern languages are expected to be created, published, and used in real projects. The framework can also serve as a reference in future research on the pattern development process.

RQ2: What patterns better represent current design solutions that embrace multilingualism? Section 5.3 describes the discovery process of the 40 patterns of design for multilingualism. These patterns represent successful design solutions found in current software systems that have been designed considering a multilingual audience. They are also organized in a pattern language that expresses the relationships between the patterns and facilitates their understanding and application. The discovery process was carried out rigorously and with the assistance of experts in rounds of shepherding and writers' workshops. All patterns are published on a website for public access so that they can be studied, used, and improved.

RQ3: How can a pattern language assist designers in developing software interfaces adapted for multilingual individuals and multilingual situations? The proposed pattern language was successfully used by professionals to debate design tasks and support design decisions during the validation studies. Experienced professionals discussed the language in a focus group and produced sketches of an interface for displaying user reviews on an e-commerce website. Beginner professionals engaged in discussions on the design of a social network using cards that contained information about the patterns. The language also proved useful when the research team prototyped a redesign for PFAF, a website containing information about edible plants. In summary, the pattern language served as a specialist technical lexicon, enabled beginner and experienced professionals to engage in the design process, and provided rationale for design decisions. All these qualities of the patterns can assist in developing websites and applications that take into account the issues of multilingualism and linguistic diversity. Software interfaces fully adapted to multilingualism tend to ensure a more accessible and culturally sustainable HCI design.

7. Ethical considerations

All studies that involved participation of humans (namely, the online survey, the focus group, and the design workshop) followed ethical standards. The project description, informed consent forms, and questionnaires were submitted to the research ethics committees of both USI and PUCRS and analyzed between March and July 2023. At USI, the application was submitted on 28 March 2023 and the approval was issued as Decision CE 2023-6 issued on 26 April 2023. At PUCRS, the project was registered in the *Plataforma Brasil*, the national Brazilian system, as CAAE 65338122.9.0000.5336 (amendment E1) and approved on 01 July 2023.

8. Conclusion

This paper presented an overview of the doctoral thesis on HCI design patterns focused on multilingualism. The research questions, methods, main results and a summary of the contributions to the field of HCI were presented. Further details can be found in the resulting publications and in the text of the thesis attached to this work.

As previously stated, not many works were found dealing with the issues of multilingualism in HCI. Research of this scope is expected to give rise to several future works. We believe that the proposed pattern language is the first step in a process of reinforcing human language as an important aspect of HCI design. Principles elicited from the discussion can be matured and expanded, becoming a set of good practice guidelines. These guidelines could assist in the development of more accessible and sustainable software systems that respect users from all cultures and from the most varied linguistic backgrounds.

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[7] https://www.overleaf.com/
[8] https://www.google.com/
[9] https://translate.google.com/

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