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The Localization of Software and Video Games: Current State and Future Perspectives

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Abstract: The study of linguistics applied to computer science is a much-discussed topic today. In this area, particularly relevant is the software localization process describing the linguistic and cultural adaptation of software products to a specific market scenario. Software localization is going through a phase of strong development due to the great market demand and the current trend of making the computer more human-like in the way it interacts with the user. This paper focuses on "linguistic" localization by addressing the language translation process from the perspective of translation studies. In particular, the process of translating the language assets in a game and making the game linguistically and culturally appropriate for the target market will be explored. The study provides a systematic literature review of the main localization methods developed over the last four decades, along with the major issues and challenges mainly related to the main linguistic and cultural aspects of videogames. The review results are integrated with the results of a qualitative analysis conducted through a focus group with the participation of both academic and professional experts in software and videogame localization. The results of this study are worthwhile for many academics and industry professionals as they provide an in-depth overview of the localization process in software and videogames as well as potential directions for future research.

Keywords: software localization; videogame localization; systematic literature review; focus group

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1. Introduction

The localization industry originated from the computer industry in the 1980s, due to the increasing demand for multilanguage support in software. As the global market requires fully adapted programs that include nonlinear texts and multimedia content, the simple translation process would not be enough [1]. In fact, localization affects a large variety of other processes and tools involved in software and game development, such as game engines and graphic tools [2].

Since localization addresses the demand of the computer and software industry, it evolves constantly as new electronic contents are created that need to be localized. New dimensions in translation studies are surfacing because of localization practices, requiring further research into this domain.

Game localization can be considered a new industry that came along as a result of the birth of video games. During the 1990s, video game developers began to adopt a specific methodology known as "partial localization", which was concerned with localizing only certain elements, such as in-game text and user interfaces (UI). Bernal-Merino [3] summarizes the phases of game localization as "partial localization", "full localization" and "deep localization". Some developers underlined the necessity to adapt even more elements in order to meet the specific needs of certain markets by releasing digital products showing a "full localization", where all the audiovisual content was properly adapted in the

target languages. Starting in the 2000s, companies began to adopt a new approach known as "deep localization". In this case, software houses pointed out many other elements to transpose in target languages in order to guarantee a high grade of immersion for players.

There are two distinct aspects to take into account when localizing video games. On one hand, there is "linguistic" localization (which mainly refers to the translation process), while on the other hand, "product' localization" consists of adapting a product or service to the culture and language of customers in a specific target market [1,4], even deeply modifying relevant structural and artistic aspects of a product.

In this study, we focus on "linguistic" localization by addressing the language translation process from the perspective of translation studies by taking into account the main languages debated in the literature; among these, English has been identified as the standard reference language in localization projects, while some under-resourced languages (such as Czech, Estonian, Hungarian, Latvian, Lithuanian, and Polish) have been highlighted and analyzed in several studies. Moreover, the study would analyze the way in which linguistic localization would properly meet the cultural background of the destination markets. Also, the adaptation of audiovisual elements related to gameplay experience (that are beyond the domain of translation studies) will be mentioned as part of game studies. Therefore, in this article, a systematic literature review is provided, covering 45 research studies dealing with software and video game localization methods that have been published in prominent journals, conferences, and workshops throughout four decades (1981–2021) and indexed in three major scientific search engines (Scopus, WoS, and Google Scholar). The results of a focus group with several academic and professional specialists in software and game localization are integrated with this systematic review. Therefore, to obtain both quantitative and qualitative proof of the research performed in this sector, a hybrid methodology that combines systematic review and social research methodologies has been used in this work.

To the best of our knowledge, none of the surveys that have been proposed in recent years have specifically focused on the video game localization techniques, despite some surveys that addressed cultural attributes [5] and translation strategies [6] in game localization. In light of this, the results of this review are helpful to several scholars and industry professionals as they provide a comprehensive overview of the localization process in software and video games as well as potential directions for future research.

The remainder of the paper is organized as follows. Section 2 provides a brief overview of the existing definitions and related surveys on game localization. The research method used to carry out the literature search and the qualitative analysis are presented in Section 3. The results of the systematic literature review and focus group are presented in Section 4. In Section 5, a discussion on the key contributions resulting from the quantitative and qualitative analyses. Finally, Section 6 provides some concluding remarks.

2. Background

In *A Practical Guide to Localization*, localization is defined as "taking a product and making it linguistically and culturally appropriate to the target locale (country/region and language) where it will be used and sold" [1]. In the *Localization Industry Primer*, the authors define localization as "the process of adapting and manufacturing a product so that it has the look and feel of a nationally manufactured piece of goods" and "the process of modifying products or services to account for differences in distinct markets" [2]. The study makes a distinction between localizing and translating, underlining all the aspects that define localization as a process that goes beyond linguistic adaptations. In fact, localization has to deal with linguistic issues but should even consider socio-cultural and technological problems, in developing and releasing digital products that would be similar to local ones.

Among the various kinds of software, even video games are the subject of localization processes. In particular, game localization is defined by Chandler and Deming as "the actual process of translating language assets in a game into other languages" [7], saying that the game localization process has three main phases, involving the translation of language assets and other non-translational activities. O'Hagan [8] defines game localization as "a

set of procedures involved in adjusting games technically, linguistically, and culturally to a given market to distribute them in territories other than their countries of origin". In this complex process, translation only appears in two steps out of the fourteen steps described. From these definitions, it is evident that game localization involves more than the lone translation of the language assets.

Video game localization is generally associated with software localization due to the presence of certain kinds of features that are generally implemented in both application software and video games. In fact, video games could be considered specific entertainment software or applications equipped with user interfaces (UI) and other textual elements to localize. In this regard, software and video game localizers have to integrate linguistic adaptation with software integration [6]. In the same way, the main purpose of software and video game localization would be to release suitable and enjoyable products in specific target scenarios, characterized by the presence of gaps between game research and industry game production [9]. However, other major differences between software and video game localization can be identified. As software localization is mainly concerned with the technical features of products, video game localization would take into account the main aspects of gameplay experience in target cultural scenarios that need high degrees of creativeness and project management skills in translation phases. For instance, making a sort of standardization of localization methodologies for software applications generally does not work when dealing with video game localization. In fact, entertainment products can be classified into a high number of genres, like role-playing game (RPG), first-person shooter (FPS), Massively Multiplayer Online Role-Playing Game (MMORPG), real-time strategy (RTS), simulation, action, sports, and racing. This may require different localization approaches for each genre.

As opposed to localization of application software, video game localization would be generally related to audiovisual translation (AVT); audiovisual text would be dubbed or subtitled [6]. Even if AVT and video game localization share similar aspects, the operative methodologies adopted in AVT are not always applicable to video game localization. For instance, in-game subtitles are generally shown at a faster speed with respect to those in movies, causing considerable variations in the average reading speed. Moreover, character limitation management is deeply different between movies and video games. Other than subtitles, further in-game elements, such as UIs, system texts, and error messages, might be shown on-screen along with subtitles. If subtitles in movies are generally characterized by full semantic units, the text present in video games would be shattered due to the match of different text portions [10]. Then, specific variables related to personal gameplay experiences are generally observed in video game text, as a result of the interactive structure of these kinds of products [10].

In the literature, several attempts to describe and define localization from the point of view of industry professionals and scholars have been made [11–13]. Even if these research studies contributed to defining the general understanding of localization approaches, the increasing implementation of new features and devices in video games (e.g., motion sensors, voice recognition systems or virtual reality) shows the need for having up-to-date information in order to keep pace with technological advancement.

Moreover, there are no significant studies involving the relationship between the linguist and the programmer, especially related to the cross-cultural adaptation of video games in order to define peculiar skills for new and existing professional figures.

Moreover, there are no significant literature reviews focusing on video game localization methods. An existing review [5] deals with the role of culture and cultural attributes in game localization and focuses on the importance of culturalization in digital game localization/development, including marketing studies through several case studies of products. Furthermore, the study would explore and discuss some issues tied to all these aspects in relationship with game development research [14].

Finally, even cross-mediality and trans-mediality represent cardinal narrative aspects to take into account in both the internationalization and localization stages of modern

games [15]. This research aims to fill the abovementioned gaps in the current literature on video game localization by gathering objective evidence by combining social research methods with a systematic literature review to provide quantitative data that serve as proof for the results of the focus group's qualitative analysis. Moreover, it investigates several points of view about the way a video game could be ideated and designed starting from the idea of a storyline and how narration could be technically and culturally adapted to different scenarios. Finally, the study focuses on the ways media are related to games by analyzing a possible application of convergence culture theory [16] to them.

3. Materials and Methods

In this study, to gather data on the research impact of software and video game localization methods, a hybrid methodology is applied, which consists of the following two steps;

(1) A systematic literature review of the scientific production of software and video game localization methods in order to determine: (i) current trends and key issues addressed in software and video game localization; (ii) the main open challenges in video game localization; and (iii) the main studies in comparative linguistics and culture related to game localization. This step is detailed in Section 3.1.
(2) A qualitative analysis based on a focus group involving academic and professional experts in software and game localization, in order to support the results obtained from the systematic literature review, as detailed in Section 3.2.

The choice of a mixed-method systematic review has been made for a twofold purpose; on one hand, a focus group-based qualitative analysis can be relevant to confirm the results of the quantitative analysis. On the second hand, as this research field is quite recent and evolves rapidly, the focus group results can help to identify further emergent paths, issues, and challenges in linguistic localization.

Moreover, PRISMA methodology incentivizes the adoption of mixed methods systematic reviews, as they provide a more complete basis for complex decision-making compared to single method reviews, thereby maximizing their usefulness to decision-makers [17–19].

The implementation of each step of the methodology is explained in depth in the next two sub-sections.

3.1. Systematic Literature Review

This section provides a description of the methodology applied for the selection of the research products to be included in the survey. Specifically, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [20] have been followed for conducting the systematic literature search.

The reliability of this methodology has been largely proven and certified by almost all the scientific community, allowing to optimize the overall quality of reporting and making the systematic review process more efficient. This study relies on an adapted version of the PRISMA protocol, which comprises the following steps: (1) identifying the focus of the review; (2) defining the review question(s); (3) selecting studies to include in the review; (4) data extraction and study quality appraisal; (5) synthesizing the findings; and (6) reporting the results.

Regarding the first and second steps of the PRISMA protocol, the following review focus was identified: to analyze and systematize scientific knowledge related to software and video game localization, which is addressed by defining the following review questions:

(1) What are the main localization methods used in software and video game localization?
(2) What are the main issues in software and video game localization?
(3) What are the main open challenges in video game localization?
(4) What are the main studies in comparative linguistics and culture related to video game localization?

The idea upon which these questions were defined is to follow a gradual approach to find out, first, what is the most common way to operate in the localization process and which are the main techniques applied; to this aim, it is particularly relevant to define and compare the main features of these techniques/methodologies, identifying which are the most efficient ones.

Another key point is to recognize the main issues in software and video game localization procedures. In fact, this complex process always involves both technical and human aspects. The focus here is to deeply analyze the relationship between the linguist and the programmer to identify the main issues that could lead to a badly localized product.

The next question would be specific to entertainment software, with the aim to recognize the main open challenges to resolve some of the actual big issues about video game localization, trying to contribute to the creation of useful strategies and solutions.

Finally, the last review question focuses on the main comparative linguistic/case studies in video game text translation and localization. In particular, the main priority here would be to analyze how certain terms and sentences are translated from the source language to the target one. To obtain useful data, a check and analysis of parallel corpora would be made. Also, an outline of low-resource languages would be important to fully comprehend further issues and challenges to investigate.

The third step of the PRISMA guidelines aims at selecting studies to include in the review. In this step, we decided to consider both indexed and not-indexed studies. In particular, the scientific search engines used for retrieving the indexed publications were Web of Science and Scopus, while Google Scholar was used for not-indexed works. In particular, the choice to include also not-indexed works in the survey has many reasons. First, the field of software and videogame localization is relatively new, and many relevant studies are not indexed yet. Moreover, not-indexed works often cover a lot of specific aspects of this research, including several interesting case studies, points of view, and techniques that are very useful for the aim of the survey.

The main keywords used to search relevant references in the three search engines are the following: "Software localization" OR "software localisation" OR "videogame localization" OR "videogame localisation" OR "software localization issues" OR "software localization challenges" OR "software localization case studies" OR "videogame localization issues" OR "videogame localization challenges" OR "videogame localization case studies" NOT "localizer".

During the screening stage, the search results were filtered using the exclusion and inclusion criteria listed in Table 1. The understandability (e1) and availability (e2) exclusion criteria and the relevance (i1) inclusion criterion were applied. Specifically, only studies that are available in full text and in English have been selected. That choice was noticeably made to easily consult each part of the references. The availability and understandability criteria are binary, and all selected studies obtained a score of 1. According to the relevance criterion, only studies that reported a score of 3 points or above have been selected. This choice was made to include only specific works, excluding those that could not answer, even in part, at least one of the four review questions.

Finally, a temporal exclusion criterion was not defined, as this field of study is almost recent, and it barely covers the last two decades.

Therefore, at the end of the third step of the PRISMA protocol, the articles that constitute the final sample are obtained.

The next step consists of data extraction, in which an extraction sheet was prepared and the following information was extracted from the full texts of the articles included in the review:

- Methods used in software and video game localization;
- Main issues that can affect the software and video game localization process;
- Open challenges in video game localization;
- Main studies in comparative linguistics and culture related to video game localization.

This step is necessary for preparing the data to answer the research questions.

The next and last steps of the PRISMA protocol consist of synthesizing the findings and reporting the results. These steps are illustrated in Section 4.1, in which the results of the systematic literature review are reported.

Table 1. Exclusion/inclusion criteria.

	Criterion Description	Scores
Exclusion criteria	(e1) Understandability -articles not written in English	0: references are not written in English 1: references are written in English
	(e2) Availability -articles not accessible in full text	0: references are not available 1: references are available
Inclusion criteria	(i1) Relevance -articles relevant to the review focus, i.e., describing software and videogame localization -articles relevant to answer our research questions, i.e., describing current methods, main issues and open challenges, and/or comparative linguistic and cultural aspects	0: Off-topic study 1–2: study that does not meet the focus of the research or appears to be too generic 3: study that appears coherent with the main topics of the research and matches with one or more review questions' general themes 4–5: study deeply related to the review questions' specific themes, even proposing important and useful case studies

3.2. Qualitative Analysis

To improve the reliability of results by offering updated feedback to the review questions, a qualitative analysis has been integrated into the quantitative analysis described in Section 3.1. Specifically, a focus group has been conducted involving 3 experts working on application software, websites, and game localization. The experts were chosen both in the academic and industry sectors according to the international relevance of their experiences in linguistic localization. Specifically, two experts had both academic and professional profiles; that stimulated the debate on reducing the gap between industry and academia. The focus group, titled "Software and videogame localization: methods, tools and perspectives" was conducted online on the 8 November 2022. The platform adopted was *Microsoft Teams version 24257.205.3165.2029*, and the total length of the event was 1 h and 15 min. The whole conversation has been recorded, in agreement with the participants. Eight questions (provided in the Supplementary File) were asked to the participants to stimulate the debate and to have feedback on the following aspects related to software and video game localization:

(1) Professional aspects: Education, skills, and competencies of software and video game translator/localizer to further explore the relationship between the translator/localizer and the programmer in software and video game development;
(2) Linguistic and socio-semiotic aspects: Languages support, parallel corpora and cultural adaptations software and video game localization;
(3) Technical aspects: main issues and open challenges of current localization techniques (Computer-Assisted Translation Tools, machine learning).

We encouraged the interaction between the participants in each proposed question. In order to extract all the relevant information related to each of the three aspects, qualitative data analysis software has been used. The selected software was *ATLAS.TI* (https://atlasti.com/, accessed on 22 November 2022), which offered several useful tools to properly analyze the focus group transcription file.

The data analysis and extraction processes are composed of the following steps. The first step consists of a manual cleaning phase to reduce repetitions and typos presented in the automatically produced transcription file. Then, the text was codified in its substantive

aspects, each of them related to a specific thematic area; in particular, speakers, questions, and answers were identified and marked. Moreover, several specific keywords and text portions were searched and coded for the co-occurrence analysis, with the main purpose of showing which items (such as issues/challenges and other relevant aspects) could be associated with the review questions.

For each topic, a Sankey diagram showed the specific elements produced by the analysis and related to the three main aspects.

4. Results

This section shows the findings of the quantitative analysis based on *PRISMA* methodology and the qualitative analysis using the focus group, introduced in the previous section.

4.1. Quantitative Analysis Results

By applying the systematic literature review protocol illustrated in Section 3.1, during the search on the three scientific search engines made on 19 December 2021, the total number of retrieved works was 409 (181 from Web of Science, 218 from Scopus, and 10 from Google Scholar).

After removing duplicate records, 386 articles were assessed for the inclusion criteria. At the conclusion of the screening stage, 185 articles were found by applying the relevance criterion to the titles and abstracts of the studies. After removing the 15 articles that did not meet the availability criterion's requirements for full text access,170 articles were kept for a thorough eligibility assessment. These studies are assessed using the scores of the relevance criterion (i1) shown in Figure 1. A total of 45 articles were included in the qualitative synthesis, whereas 125 papers with a score of less than "3" were discarded.

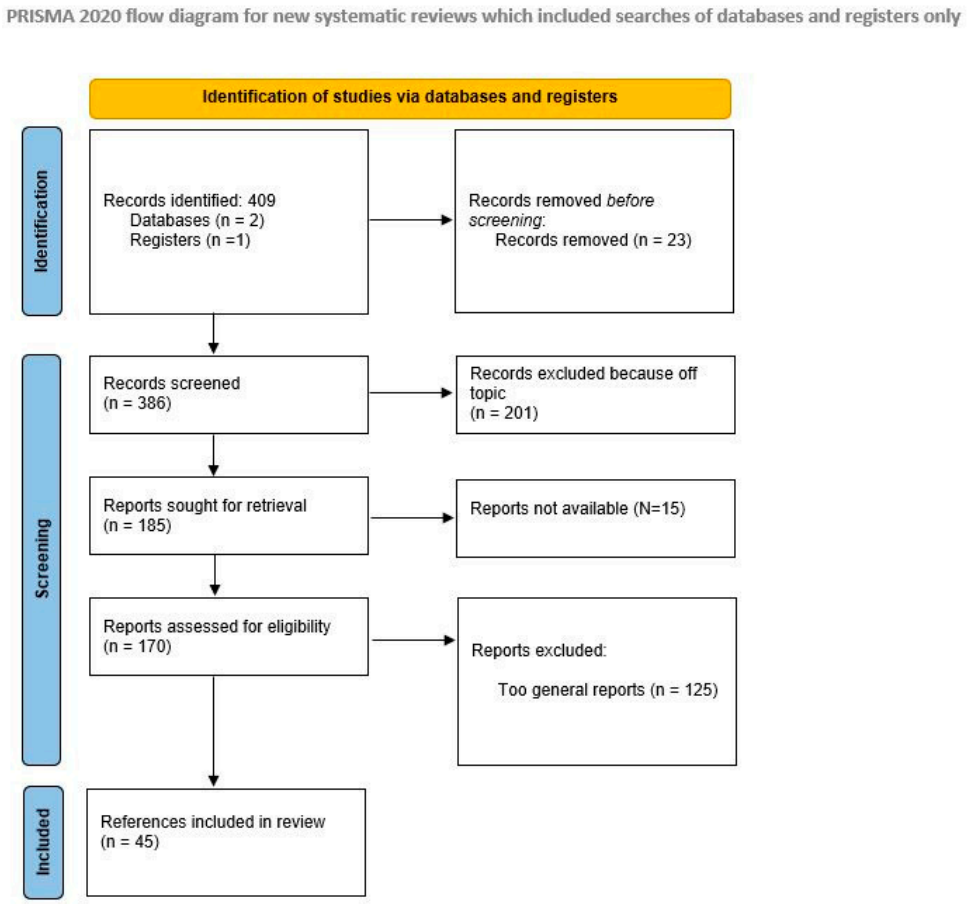

Figure 1. Prisma flow diagram, adapted from [20]. For more information, please visit http://www.prisma-statement.org/, accessed on 22 November 2023.

The following diagram, which is an adaptation of the official PRISMA 2020 flow diagram, shows in detail the whole procedure of this selection.

The temporal distribution of the surveyed studies underscores that the majority of the related indexed studies were mostly published in the last decade, with the scientific community's interest growing from 2014 and 2016, when it reached its highest level (see Figure 2).

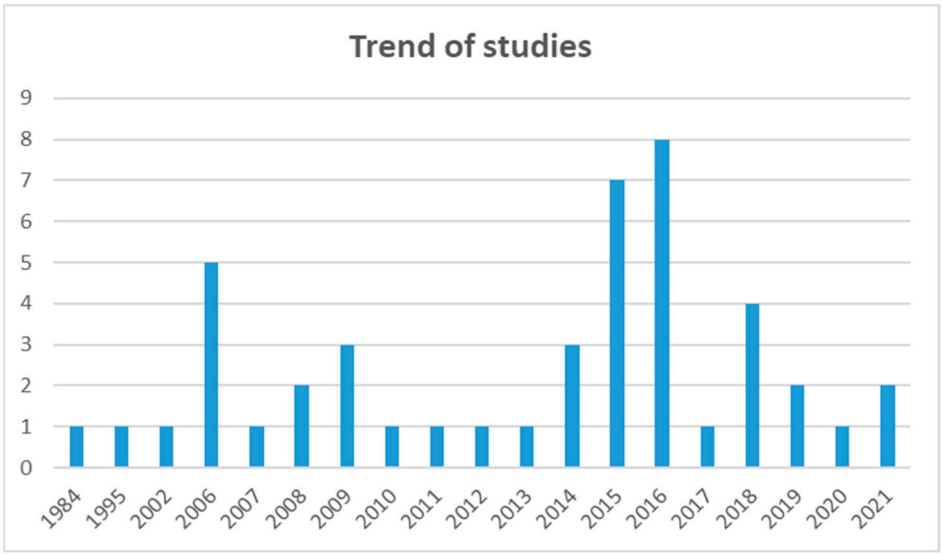

Figure 2. Temporal distribution of selected publications.

The selected publications were mostly released in journals (33%—15 studies), followed by books/book chapters (31%—14 studies), theses (18%—8 studies), conference proceedings (13%—6 studies), and only 2 preprints (4%). Consequently, 22% of the studies are made up of gray literature (theses and preprints), whereas the majority of the research products (78%) are indexed in journals, books, or conference proceedings.

Figure 3 shows the information about the main sources where the studies were published.

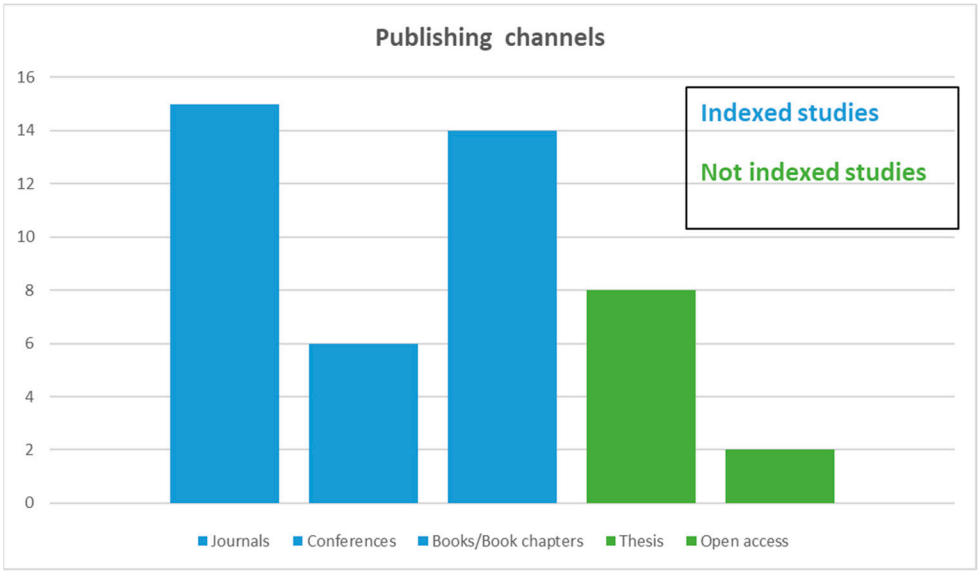

Figure 3. Sources of surveyed studies.

In the following sub-sections, an analysis of how the 45 studies addressed the review questions listed in Section 3.1 is given.

4.1.1. Methods Used in Software and Video Game Localization

The first item that came out of the systematic literature review is about software and video game localization methodologies. In particular, the literature analysis shows that the main used techniques are translation memories, Unicode, and Computer-Assisted Translation Tools (CAT Tools). Less used methods are artificial intelligence-based methods, mainly machine translation and neural networks.

However, the results obtained must be contextualized on a time-proportion basis. Although these results might suggest that AI-based tools have little role in the localization industry, AI technologies are brand new technologies implementing new and relevant tools related to linguistic localization. In this regard, and in reference to Figure 3, the selected studies had been conducted starting in 2016, and their number is set to rise a lot in the near future.

Translation memories, which were conceived in the 1980s, seem to be the most reliable and used solution, even if CAT tools would have more future-proof features, as they use newer technologies, such as the integration of collaboration features, terminology management, or In-Context Editing and Quality Assurance tools. Since the end of the 1990s, CAT Tools began to be widely used for both translation and localization purposes, and they continue to evolve, integrating newer features. Figure 4 shows these results in detail, while Figure 5 reports how localization techniques were used over time.

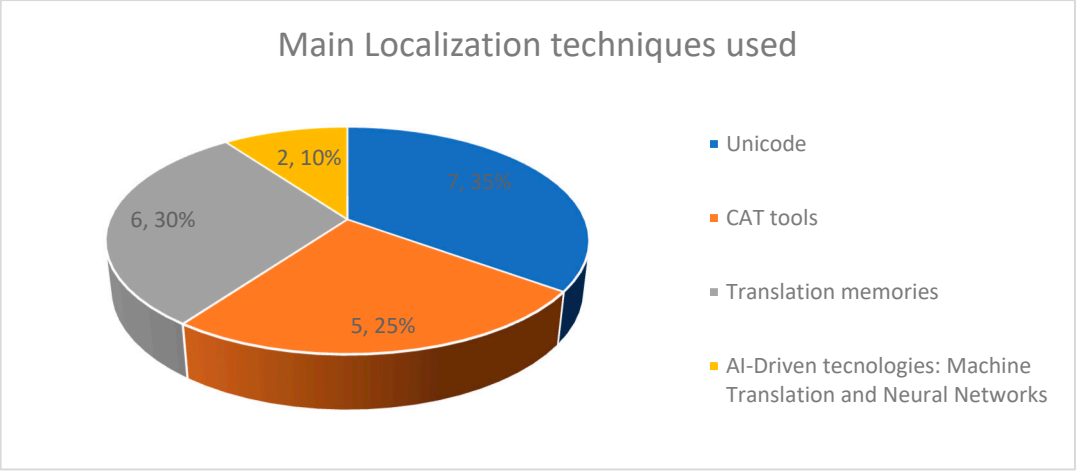

Figure 4. Main localization techniques used in the surveyed studies.

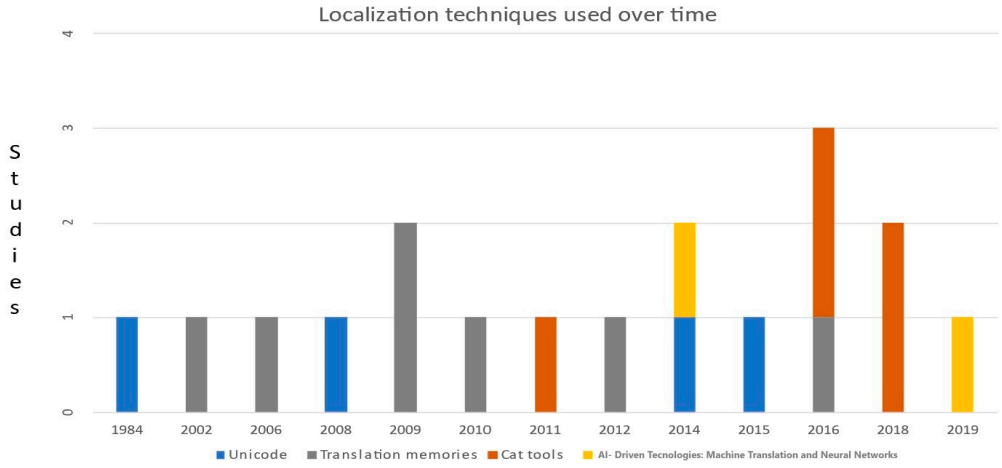

Figure 5. Localization techniques used over time.

Despite this variety of solutions, the choice of the best methodology/technique to use for efficient localization work depends on several considerations. First, a common

issue seems to be related to the internationalization process; in fact, most internationalized products do not perfectly match with a localization tool. A big challenge would be to realize a standardization of the internationalization process, which would also allow to reduce localization costs. This should also be made in relationship with low-resourced languages, where localization plays a crucial role in expanding access to application software and gaming experiences globally. There is still a small percentage of studies on languages with limited linguistic data in the literature, although they are exponentially growing. In particular, they are mainly concerned with the lack of technical terminology and specialized jargon in these languages, other than the cost and expertise constraints and the community engagement and support in these localization projects [21–25].

Moreover, it is important to note that the idea of being able to achieve a quality translation fully automated has given way, in recent years, to a change of perspective: computers do not provide translations, but an aid to translation; in fact, this aid can be more or less accurate and efficient depending on the context, available techniques, etc. Studies talk about computer-aided translation and not more about automatic translation. The translation carried out entirely by the computer and the one carried out by a human being without the slightest help of a computer are only the two abstract extreme points of a continuum where all are possible concrete cases of interaction and collaboration between man and machine.

It is important to note also that in localization the linguistic and technical aspects are interdependent: for a localized program, it is necessary to guarantee at the same time comprehensibility and clarity, as well as correct functioning in the target market [26].

Moreover, the idea of localization related to a particular software can occur in two quite different scenarios. In the first scenario, the focus is on the program: the programmer internationalizes the software and looks for people who are able to localize it in various languages. In this scenario, internationalization represents a goal that the programmer sets to develop a specific program with an interest in facilitating its use in different cultures and with different languages. In the second scenario, the focus is on the language: a software house would be interested in adapting a preexistent working environment (for example, an operating system with its most important applications) to a particular language. In the first scenario, the collaboration with involved programmers could be easier, while greater consistency could be ensured in the second scenario, where terminology would tend to be more accurate.

4.1.2. Main Issues in Software and Video Game Localization

The major issues that can affect the localization process are complex and varied, as summarized in Table 2.

Table 2. Studies about issues in software and game localization.

Issues	Studies
Gap between internationalization and localization	[27]
Localization costs and time constraints	[21,22]
Lack of support for under-resourced languages	[23–25]
Lack of information available for translators	[28]
Fragmentation of nonlinear storytelling	[29,30]

The first issue that emerged from the literature analysis is related to the interaction between internationalization and localization processes, which are both not standardized [27]. Localization techniques need to be compatible with the internationalization process, which refers specifically to the design and development of a product, application, or document content so that it can be localized for target audiences that vary in culture, region, or language. The internationalization process often struggles to adapt and correctly

support the different methodologies used in the localization process, even in relation to the use of a variety of localization tools tied to game engines or other software development structures [14].

This leads to another issue, which is related to localization costs [21], which can be very high, and that does not allow to always have the required expertise available in order to have a good, localized product. The use of computer-assisted translation and AI-based tools can significantly reduce the costs, although the amount of savings varies depending on the specific localization project. Anyway, there is still a need for human intervention to handle words (mainly technical), for which there is no equivalent in some languages, even though translation software and careful preparation of source text minimize translation costs [31].

Anyway, in gaming, where dialogs and other textual and gameplay elements can have varied meanings depending on the context, AI-driven neural machine translation (NMT) has made relevant advancements, mainly due to the analysis of broader textual inputs that allow improving the localization. Also, AI-driven tools can scale rapidly and handle updates in real-time, in particular in the gaming industry, where patches and content expansions are frequent and manual localization can be time-consuming and expensive. Moreover, since video games often use a peculiar lexicon or genre-specific terms that might not translate directly into another language, AI-based tools can be tailored to recognize and adapt to gaming jargon. For instance, the translation of a specific game genre's lexicon (such as fantasy or sci-fi elements) can be automatically preserved during the localization process.

Afterward, another big issue is about *under-resourced languages*. These languages (such as Czech, Estonian, Hungarian, Latvian, Lithuanian, and Polish) do not have much software/data/tools/resources available for computer-aided translation or machine translation, or more specialized human resources for testing phases and Quality Assurance [25]. They also have peculiar text characters that significantly differ from the most commonly used in the world. So, due to the lack of tools that implement them, both internationalization and localization phases would be more articulated and complex for these languages and cultures. Furthermore, an approach to integrating underserved cultural factors in computer applications consists of the investigation of cultural markers, followed by translation or adaptation, implementation, and evaluation by end-users [24]. Even considering building usable machine translation systems for less-resourced languages with complex morphology and syntax is difficult due to a lack of linguistic resources, on the one hand, and the complexity of the language, on the other hand [23].

Moreover, there are specific issues proper in the entertainment software field.

In fact, although video game translation has certain similarities with software localization, dubbing, subtitling, and audio-visual media translation, it has some distinct qualities [10], so there are some specific problems that video game translators may encounter. The first one is about time constraints: game developers frequently have strict deadlines to meet, which may leave translators with less time to work on a game.

Another problem is the lack of information about the project: translators might have to work without the working game, and this could lead to translation errors caused by this lack of context knowledge. Chandler [32] sheds some light on this matter as well, noting that audio, visuals, and even gameplay itself convey a lot of information. As much of the material as feasible should be available to translators (e.g., playable game versions, design documents, cheat codes, glossaries, and any tools the translator might need to use) [32]. This material is crucial, for instance, to better comprehend the character's personality and other important elements, which will lead to a higher quality translation.

Then, there is a large variety of video game genres within the video game industry, such as First-Person Shooters, Role-Playing Games, Puzzle games, Adventure games, Simulation games, etc. These video game genres may require translators to search for information about the context in which they are set to familiarize themselves with its lexicon and style; this can include reading books or watching movies set in the game contexts or themes.

Finally, another issue is text fragmentation proper of nonlinear storytelling [29,30]. In fact, in many video games, the story depends on the players because most game events happen only when a player initiates them. Therefore, tables and spreadsheets can be used by translators to arrange several nonlinear text strips. However, because of the lack of context and chronological order, this job might be problematic for translators who used to translate novels or other media in the past.

4.1.3. Open Challenges in Video Game Localization

The results of the literature analysis reported several open challenges aimed at improving the final quality of localized entertainment products. Table 3 shows five crucial open challenges to face in order to improve and to make video game localization more efficient.

Table 3. Studies about open challenges in video game localization.

Challenges	Studies
Defining proper skills for translators	[11,28,33–35]
Enhancing relationships between translators and programmers	[27,36–38]
Keeping translators informed about the context of the game	[28]
Improving internationalization software	[25,36,39]
Improving CAT tools, machine learning translation and other localization techniques	[33,40–47]

For instance, the major open challenges related to video games (and application software) localization would be to highlight a set of relevant skills for enriching translator's background with additional competencies, in the attempt to bridge the existing gaps between the old and the modern industry operative approaches. In particular, the software companies should find some ways to incentivize the level of cooperation and communication between translators and programmers [38]. In this direction, a relevant step would be a direct involvement of linguists and translators in the internationalization phases [28]. Moreover, companies should keep the translator informed about all the aspects related to the game context, in the attempt to share with him important information about the storyline and the characters, other than further details about the environment or the narrative universes upon which the video game is being designed.

Furthermore, in video game localization management, translators should assure that translated content will be correctly reported on the screen. For example, some languages tend to use a high number of words to express and describe the same concepts in comparison with English. In these cases, there is the need to optimize the internationalization process to support the correct character number that should be displayed on the screen, even calculating any variations in textual dimensions when changing from one language to another. This generally happens even with most Western languages, so it would be relevant to propose valuable solutions also related to low-resourced languages. These approaches could improve the grade of readability of textual content of video games and UIs. In gaming, where dialogs, quests, and item descriptions can have multiple meanings depending on the context, AI-driven technologies can better identify linguistic variations by analyzing broader textual inputs. For example, Neural Machine Translation models adopt context-awareness to improve translation quality by ensuring—in-game terms—that character abilities or story-driven conversations would be properly adapted in target languages without losing the intended meaning.

Moreover, in order to make a video game usable for customers in different regions, it is not enough to simply translate the text. In particular, localization professionals must deal with peculiarities in formatting and conventions operations related to specific elements, such as dates, time, numbers, addresses, or local currencies. As these regional aspects are also tied to game development processes [48], it is important to implement them into

the internationalization phase, so that the translator can easily adapt them to the target country/culture. In this direction, AI-driven systems can be trained on region-specific data to understand how certain idiomatic expressions, symbols, or actions might be interpreted in different markets and cultures.

In addition, in the attempt to fix issues and bugs or implement new features, digital products generally receive various kinds of patches and updates. Usually, patches and updates would present even more items that should be localized. This would require a sort of "continuous localization" related to both large and small localization adjustments, requiring constant work. In order to properly deal with these needs, even new translation-specific tools would be developed to make these operations quicker.

Eventually, further relevant challenges would be aimed at improving new technical instruments, such as CAT tools and machine learning translation [40,42]. These technologies are relatively new and require the implementation of constant updates of features and functions. In other words, CAT tools could represent valuable assisting tools when dealing with both localization and internationalization processes; furthermore, modern innovations of machine learning and other AI-driven technologies would set promising scenarios for the future of software and video game localization. In this regard, two main specific CAT tools are currently used in software and game localization; in particular, SDL Passolo is the most common tool adopted for application software localization projects, while MemoQ is the reference tool for game localization, although it has not been designed for this specific purpose.

4.1.4. Reference Studies in Comparative Linguistics and Culture Related to Video Game Localization

Localized video games would not be enjoyable to play if they used direct translations. In fact, word-for-word translation has its place in certain fields, but interactive entertainment is not one of them. Localizing video games calls for a freer, more creative approach to translation, and that is where transcreation makes its mark.

Rather than merely substituting one word for another, the localization process allows translators to transfer the meaning and purpose of the source content into their own creations. Localization aims to effectively scrap the original and insert a specific text that creates almost the same emotions and responses in players as the original. The intent, tone, and context of the text have to recreate the experience of users in the source language while adapting to the needs of the target language and culture.

The results of the systematic literature review reported three peculiar case studies about comparative linguistics related to video game localization and corpora. Table 4 shows the results with the related specific description.

Table 4. Studies about comparative linguistics and culture in game localization.

Description	Studies
Categorization of the values of term similarity in a parallel corpus of technical texts (English and Spanish)	[49]
Diatopic variants in sci-tech written language	[50]
Parallel corpus analysis of two video games	[29]

By comparing the old and new translations on parallel corpora, two of the surveyed studies aim to see if and how translation choices have changed over time [29,49]. In particular, parallel corpora occur when texts are available for two or more languages that are systematically the translation of each other. The studies are specific for written language, even if they analyzed particular communicative aspects, such as irony related to video game dialogs, and various audiovisual modalities of games that can have an impact on localization. One of the selected works deals with a particular communication form, known as Sci-tech communication [50]. This represents a sub-code proper of the ICT environment,

where the translation is a key issue; as science and technology attempt to unify very different linguistic communities and cultures under one single language, non-native users of that language need a translation both for terms and neologism with related new cultural aspects [51].

4.2. Qualitative Analysis Results

The answers collected during the focus group involving three experts on localization have been analyzed, and the results of this qualitative analysis have been classified into three main groups related to the professional, linguistic/socio-semiotic, and technical aspects of software and video game localization, as introduced in Section 3.2.

The results related to the professional aspects (education, skills, and competencies of software and video game translator/localizer) showed some relevant items in the development of the professional profile of the localizer, as depicted in Figure 6.

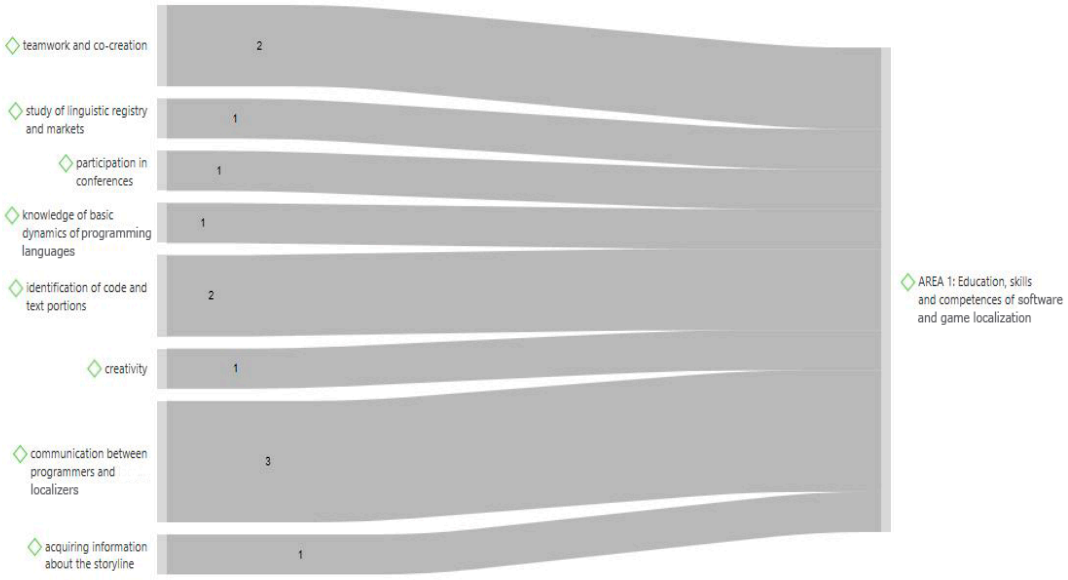

Figure 6. Sankey diagram about professional aspects in software and video game localization. The numbers represent the number of answers collected on the topic.

In particular, participants in the focus group highlighted the importance of efficient communication between programmers and localizers [27,36–38], in line with the open challenge that emerged from the systematic literature review (see Table 2, second row). Also, localizers should know the basic dynamics of programming languages, with the final purpose of distinguishing text portions by code.

Another relevant skill to acquire would be a proper use of creativity, especially in a shared working environment, other than regular participation in specific conferences to keep up to date about the latest trends and methodologies [30].

The results related to linguistic and socio-semiotic aspects in software and video game localization are reported in detail in Figure 7.

Specifically, the analysis reported several aspects that are deeply involved in the localization process. First of all, creativeness is deeply tied to the definition of transcreation, in the attempt to properly transpose audiovisual content to a target market [30]. In addition, cross-mediality and transmedia storytelling should be considered in software and video game localization because of their deep bond with a large variety of media forms and channels. Furthermore, the importance of properly supporting under-resourced languages has been mentioned by participants, who underscored crowdsourcing campaigns as a possible solution. In this case, the involvement of native translators is necessary, as the use of CAT tools and machine translation technologies related to under-resourced languages

can lead to localization issues caused by missing characters and errors in translation tags [23].

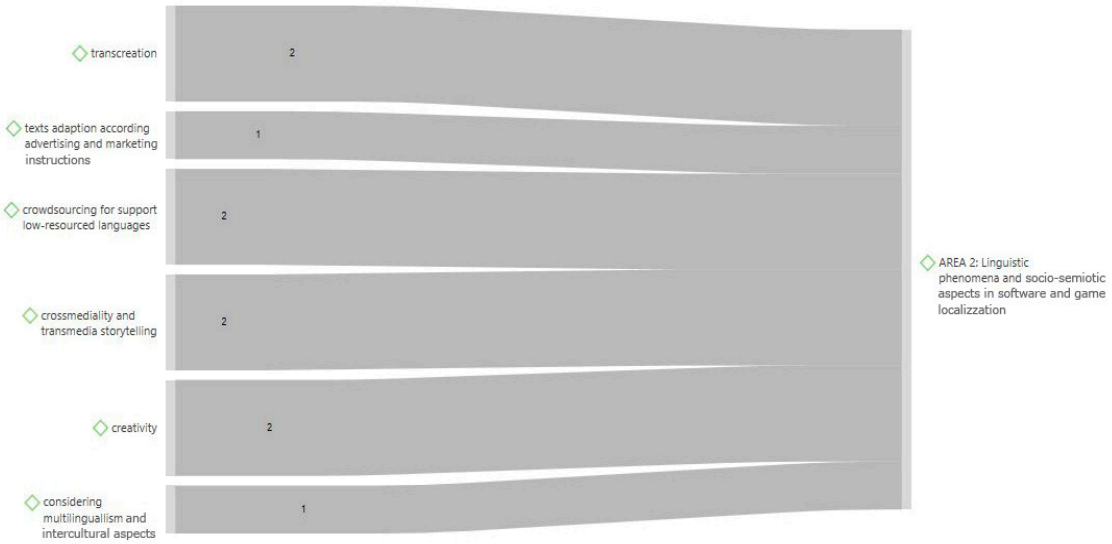

Figure 7. Sankey diagram about linguistic and socio-semiotic aspects in software and video game localization. The numbers represent the number of answers collected on the topic.

The results related to the technical aspects outlined the major issues and challenges in software and video game localization shown in Figure 8.

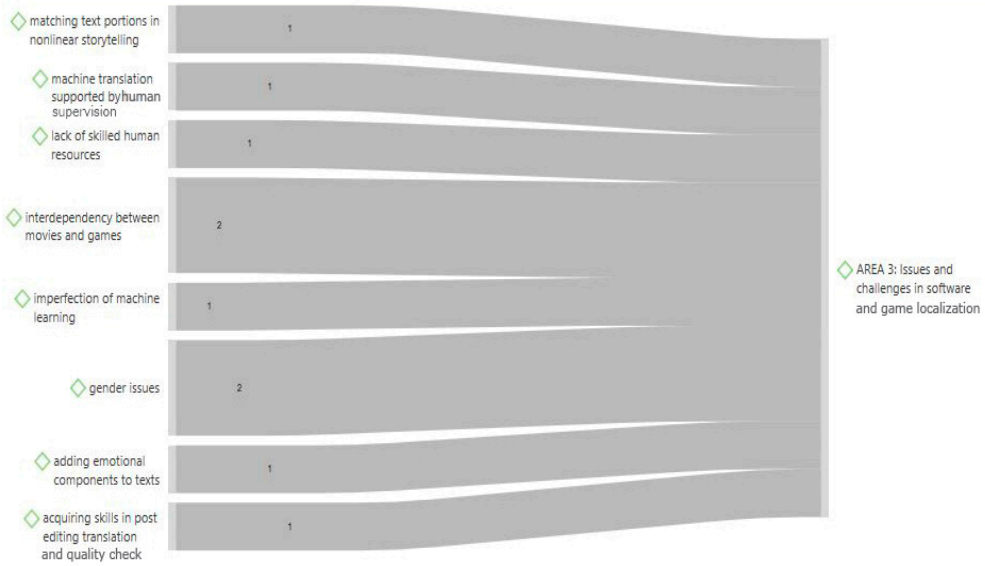

Figure 8. Sankey diagram about technical aspects in software and video game localization. The numbers represent the number of answers collected on the topic.

The main relevant issues that emerged from the qualitative analysis are focused on the lack of skilled human resources and the difficulty in adapting and translating nonlinear text portions. That confirms the results of the literature review (see Table 2, first row) that highlighted the need to define proper skills for translators incorporating additional competencies to their curricula [11]. Localizers would also be able to acquire skills in post-editing translation other than adding emotional components to texts [30,34].

Moreover, further important challenges, which are specific to our times, are related to the gender dimension and the interdependency between movies and games. Considering the former, the participants suggested that the localizers should build stories or user

interfaces around the user profile; while for the latter, they highlighted that nowadays games tend to offer stories and experiences similar to films, also considering that movies are implementing interactive features, often related to new storytelling methodologies, such as branching narrative [52].

5. Discussion of Key Findings

The key findings resulting from the quantitative and qualitative analyses can be summarized as follows.

The localization process could be compared to that of the simple translation; however, it differs from it for several reasons.

In the first place, to implement the localization process, the software must be specifically "enabled" for it; in other words, it must be "internationalized". For instance, while it is technically possible to translate a novel even without the collaboration of its author, this does not apply to software localization, for which there must be a collaboration between the parties involved, the programmer/developer on the one hand, and the translator on the other. The selected studies reported how both internationalization and localization phases are linked to each other; in particular, bad internationalization deeply affects the localization stage. Consequently, localizers often have to deal with bad software optimizations, which can lead to several issues, such as the lack of support for some characters or languages.

Then, the localization process takes place in specific technological contexts: it follows that the translator must know, at least in principle, the infrastructure that allows the operation of the localized versions of programs in different linguistic and cultural contexts (known as local); and, to ensure the proper functioning of the produced localization, he must use some particular programs that allow checking what is written (first with the control of some characteristics of the texts, and subsequently through the compilation of source files). It should not be forgotten that the programs are in continuous evolution, and therefore, the translator has to be able to "recycle" the work already carried out for other locations, using peculiar localization tools that allow archives of recognizable and even reusable text segments.

The selected studies reported how CAT tools are today the most common technique used in software and video game localization, nearly followed by the Unicode standard. However, newer technologies such as neural networks and Artificial Intelligence are evolving rapidly. Even if they are still in the early development stage, their use in both software and video game localization has already shown its first advantages. In these surroundings, game developers are increasingly leveraging AI technologies to enhance various aspects of gameplay and user experience. Specifically, AI technologies can help game developers, especially in context awareness, content adaptation, game design support, and speed and translation quality improvement. The use of AI can help to understand the context in order to translate more accurately the content, including idioms, slang, and common sayings typical of specific cultures. Some AI tools can support the adaptation of the content by suggesting alternative translations that better suit local cultural norms. In addition, AI-powered analytics can help developers understand player behavior and preferences, enabling them to tailor content and mechanics properly. Furthermore, AI algorithms are employed in game design for tasks such as generating realistic environments, creating interactive non-player characters (NPCs) with dynamic behaviors, optimizing game difficulty levels based on player skill, and personalizing gaming experiences through adaptive narratives. Moreover, even though the quality of the AI-based translation deeply depends on the availability of training data, for high-use languages (like English), the AI-based translation performs very well, allowing to obtain initial translated dialogs more quickly and to save localization costs and resources. The leveraging of AI technologies by game developers has also been promoted during the last editions of *The Game Developers Conference* (GDC). In his dedicated video platform (GDC Vault), GDC provides a large number of recorded events available to industry professionals, with the purpose of encouraging them

to exchange insights on utilizing AI for specific gameplay elements, even tied to localization and interactive digital storytelling. Through the integration of AI, game developers strive to deliver more immersive, engaging, and challenging gaming experiences to players.

However, as localization is not limited to translation, there may be technical needs related to many kinds of issues (for example, font size, icons, colors, etc.).

Also, the localization work should be divided into linguistic and cultural contexts; in particular, localization professionals should try to preserve the proper stylistic and lexical coherence [48] in relationship with the overall user interface managed by users. In this way, localization projects can make proper use of glossaries and style guides. Also, when dealing with video games, localization professionals should be able to recognize programming source code reflecting also on costs of production, development, and location.

As for the main related linguistic aspects, the studies reported some peculiarities of a particular sub-code proper of information technology. It is well known how numerous neologisms can be found in it, reflecting the dizzying pace with which new technologies are presented on the market. From a diachronic perspective, the studies analyzed on the one hand how many of these neologisms were born in their original Anglo-American form and on the other hand how the Italian language reacted. From a synchronic perspective, the studies analyzed the two classical typologies of linguistic interference (loanwords and calques), highlighting how often some motivations can be shared, or at least understandable, even pragmatic from one point of view, due to the choices made by speakers.

6. Conclusions

This study examined software and video game localization techniques and practices through a systematic literature review of the scientific knowledge retrieved from formally published and gray literature and qualitative research performed using a focus group involving academic and professional experts.

The results of the systematic literature review showed a gap in the studies related to the lack of a definition of the skills and competencies that should be acquired by the modern translator, confirmed also by the experts of the focus group. A new and flexible professional profile should be identified, able to communicate effectively with programmers and comprehend the basis of the most common programming languages. In fact, localizers have to distinguish texts from code in order to fix possible bugs that can occur due to occasional overlaps between them. In this way, localizers should be able to contribute even to the internationalization phase, with the advantage of better optimization of products.

Moreover, a relevant challenge is the involvement of video game localizers in the game context. This implies that localizers should be informed about several narrative aspects of a video game, such as game characters and narrative universes composed of a variable number of storylines, proper of different medial forms (for example, the meta-analysis reported a strong interdependency between movies and video games). Achieving this goal is complex, mainly because the concept of license has become multifaceted, and the same authorship has become even more complex and distinct in each case. However, video games are often characterized by nonlinear stories, which are written and designed with the aim to give a feeling of control to the player [48]. Consequently, localizers have to deal with nonlinear text portions, with the difficult task of using a certain grade of creativity in writing and matching them.

Finally, from the analysis, it emerged that there are no studies aimed at defining specific educational paths for software and game localization. Consequently, a future research direction would aim to reduce the research gap to contribute to better defining this new professional profile.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/info15100648/s1, Triggering questions of the focus group.

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