Mapping the Current Understanding of Text Input within Virtual and Augmented Reality Environments

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Abstract

Text input is a vital part of how people interact with technology. With the emergence of augmented and virtual reality platforms, we see the adoption of new interaction devices and techniques that move away from traditional tools such as the keyboard and mouse. With the technology being new, we found that there are no clear standards on how to deal with text input. In this study, we used a systematic method to map and classify relevant literature on this topic. We also looked into how text input is handled in current AR/VR applications as well as the alternatives that are available in the current market. The results give an overview of the existing work on this topic and identify gaps for future research.

Keywords

Text input, Text entry, Virtual keyboards, Augmented reality, Virtual reality, Mixed reality.

1.Introduction

1.1 Overall context of the problem, basic definition

Augmented and virtual reality platforms have both increased in popularity in recent years. As companies develop and bring their own versions of these systems to market, many have opted to implement their own way of obtaining user input instead of using traditional hardware such as a mouse and keyboard. For example, VR devices such as the HTC Vive and Oculus Rift, have adopted one-handed wireless motion tracked controllers that allow users to interact with the virtual world. The Microsoft HoloLens, an AR device, combines head tracking and hand gestures to communicate with virtual-holographic items in the environment around a user. These new types of approaches, as well as the expanded capabilities of these platforms, has transformed how common tasks, such as cursor and text input, are performed.

For the past year, the Agile Software Engineering lab at the University of Calgary has been developing software for these technologies, specifically for the HoloLens, HTC Vive, and Oculus Rift. During this development period, a common point of contention among developers and clients was text input. Many found that the text input techniques that were implemented were functional but flawed when it came to usability. Furthermore, the lack of evidence-based consensus on how to properly deal with text input within these environments made properly evaluating alternative solutions challenging.

As the industries around these platforms develop, so does the terminology. Alongside VR and AR, we also see the term mixed reality (MR). However, this term has been used to classify very different devices. For example, the Microsoft Hololens and Samsung HMD Odyssey have both been classified as mixed reality devices. Categorizing these products under the same term can lead to confusion as the Hololens allows users to consume virtual content alongside the real world while the Odyssey occludes the user vision from their surroundings. For the purpose of this study, we will use the following terminology to classify the different technologies. *Virtual reality* allows users to be fully immersed in a computer-generated environment while the real world is occluded when the device is in use. *Augmented reality* allows for information to be superimposed around a user without blinding them to their own surroundings.

1.2 Motivation

Our motivation is to better understand how VR and AR applications should be handling text input. We want to figure out how developers and designers can optimize their applications to provide the best experience. Furthermore, understanding the capabilities of text input is an important piece in understanding the technologies strengths and weaknesses. By recognizing the limits and potentials of each platform and its associated tools/techniques, we can get a better understanding of the types of applications that would thrive.

1.3 Goals

The main objective of the term project was to gain insight into the current understanding of this topic as well as identify areas that require further investigation. We approached this through two major phases. First was to perform a systematic mapping study on the topic of text input within augmented and virtual reality environments. We followed the process laid out in *Systematic Mapping Studies in Software Engineering* [2] from Kai Petersen to perform our study. The second phase was to find non-peer reviewed work by searching relevant search strings through YouTube and the Unity's asset store. We used the same research question and inclusion/exclusion criteria to screen the work and mapped them using the same classification scheme from the first phase.

1.4 Overview

In this report, we will expand on the process and results of our term project. In section 2 we discuss related works. This includes detailing the process that was laid out in Kai Peterson's guide, looking at an example of a systematic mapping study that followed the same guide, and talking about a literature piece on surveying augmented reality technologies. In section 3, we will discuss the systematic mapping study process and results. In section 4 we will talk about how current application is handled and the process of mapping current available options. Then we discuss what we learned from this term project and talk about future works in section 5.

2. Related works

2.1 Research methodology

A systematic mapping study provides a broad overview of the understanding of a given topic. Through sieving large amounts of literature, it can recognize topics with high density areas to direct future systematic reviews on and identify areas for more studies to be conducted. In Kai Petersen's *Systematic Mapping Studies in Software Engineering* [1], he details five major steps that we followed for completing a literature survey.

Definition of Research Questions (Research Scope): The first step was to define a research question that reflect the goals of the study.

Conduct Search for Primary Studies (All Papers): To find primary studies that are related to our research question, a search string was created to find relevant papers, articles, and publications.

Screening of Papers for Inclusion and Exclusion (Relevant Papers): To find which studies are significant to our research question and which to exclude from our study, we created an inclusion and exclusion criteria. All papers from the primary study went through the criteria. We then went through the references and citations of the relevant papers to find new literature that we deem relevant and refine our search string to include those. We returned to step 2 (all papers).

Keywording of Abstracts (Classification Scheme): We identified keywords from the abstracts of relevant papers and combined them to develop a high-level overview. We then used the process shown in figure 1 to develop a classification scheme that was used to sort the articles we found.

Data Extraction and Mapping of Studies (Systematic Map): After all articles were sorted in a scheme, we analyzed the results. The focus was on seeing the frequencies of publications for each category to determine clusters of research that was done in the past as well as areas that requires future research.

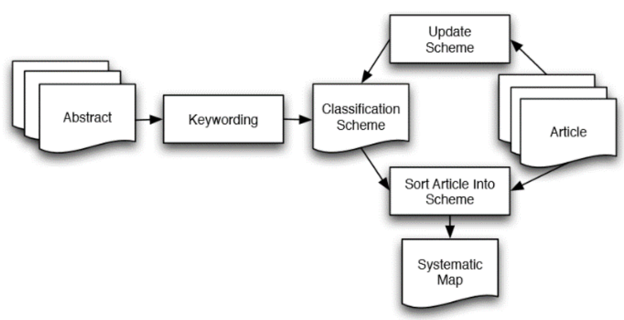


Figure 1

As mentioned before, we used this methodology to complete our systematic mapping study.

2.2 Example of research methodology

In Kai's guide, he often references "*Software Product Line Variability: A Systematic Mapping Study*"[2] as an example to explain his methodology. The papers aimed was to answer, "*what areas in software product line variability have been addressed and how many articles cover the different areas?*" and "*what types of papers are published in the area and in* *particular what type of evaluation and novelty do they constitute?*". The classification scheme that the author came up with included three main facets: variability context, contribution type, and research type. The conclusion reached was the majority of research has been on requirements and architectural variability and with a focus on developing models and methods. Also, there were relatively few papers on processes, tools, and metrics and relating to other variability contexts in comparison to requirements and architecture. Even though our study has very different context, the research questions we are trying to answer were similar. Thus, we utilized this classification scheme as a basis to build ours.

2.3 Other related works

The focus of our study is on text input within AR and VR environments. However, it is important to understand that our topic is part of a larger theme of understanding how we can better interact with these types of platforms. Thus, literature such as "*A Survey of Augmented Reality Technologies, Applications and Limitations*"[3] that provides an overview of the platform will be helpful when it comes to evaluating different text input variations. The paper includes discussion on definitions, ways of distinguishing for AR, VR, and MR; a brief history of the technology, and surveys on the different AR implementation. Furthermore, the paper describes limitations regarding human factors in the use of AR systems that developers will need to overcome.

3. Systematic mapping study

Our aim was to answer the following research question: *What areas are addressed when it comes to text input within augmented and virtual reality, and what types of research has been done in the different areas?*

The chosen academic search engine that we decided to run our study on was the University of Calgary's library online resources. It comprises of 803 different databases, which includes ACM Digital Library, IEEE Xplore, ProQuest, and many more.

We used the following criteria when screening our papers for relevancy.

Inclusion: The abstract explicitly mentions dealing with text input. From the abstract, the researcher is able to deduce that the focus of the paper has relevance to the understanding of text input within augmented and virtual reality environment.

Exclusion: Literature where text input is not part of the contributions of the paper, the terms are only mentioned in the general introductory sentences of the abstract.

3.1 Conduct Search for Primary Studies and Screening of Papers

The initial search string used was built with the intention of keeping the amount of papers around this topic manageable but allowing for enough breadth to cover the research question. The resulting searching string was "*Abstract: ((text AND (input OR entry)) AND (immersive OR augmented OR virtual OR mixed) AND (environment OR reality))*" with filters constricting the search to Conference Proceeding, Dissertation/Thesis, and Journal Article. There were 192 results in total. After the screening process, a total of 18 relevant papers remained.

To increase the number of relevant papers, we went through the references and citations of the papers that were found in the initial search and identified 11 more relevant literature that fit our inclusion criteria. The search string was then changed to accommodate the newly identified papers into the primary search. The resulting searching string was "*Abstract: (((text OR keyboard OR symbolic) AND (input OR entry)) AND (((immersive OR augmented OR virtual OR mixed) AND (environment OR reality)) OR (AR or VR) OR (head AND mounted AND display) OR (HMD) OR (smart AND eyewear)))*" with filters constricting the search for Conference Proceeding, Dissertation/Thesis, and Journal Article. In total, there were 368 results. After the screening process, a total of 34 relevant papers remained.

3.2 Establishing a Classification Scheme

The next step we took was to classify the relevant papers. To do this we followed the process laid out in figure 1. The first step was to look for keywords and concepts that reflect the contributions of the paper. From there these keywords are clustered together to form categories that we used to develop our classification scheme. We develop six different classes each with a set of categories to which our relevant papers can be mapped. As mentioned previously, variability context, research type and contribution types were classes mentioned in "*Software Product Line Variability: A Systematic Mapping Study*"[3]. Our classes are:

Platform explicitly dealt with: Which platform does the literature explicitly deals with?

Variability context: Which topic of text input within VR and AR does the paper focus on?

Research type: What is the novelty level and how the research is characterized?

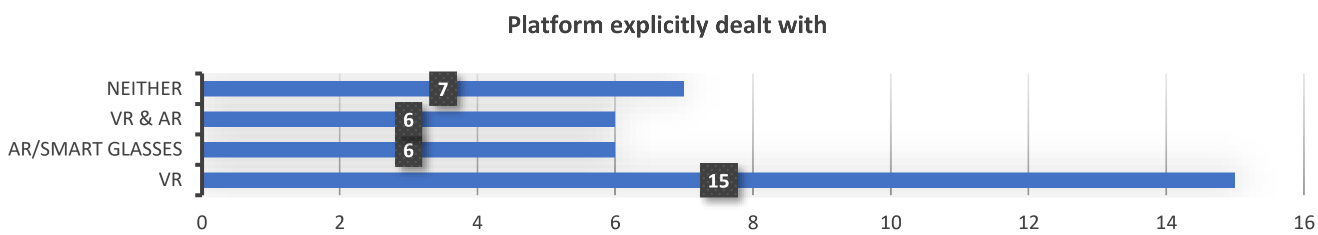
Contribution type: What was developed in order to achieve advances in the focus area?

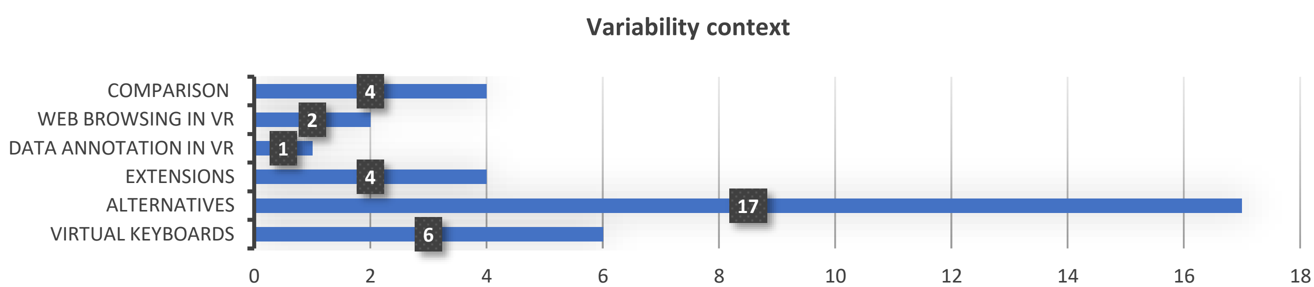
Two of our classes are subclasses of the tools and techniques categories within the contribution type class. They are

Mobility: Is the proposed solution or technique meant for a stationary or mobile environment?

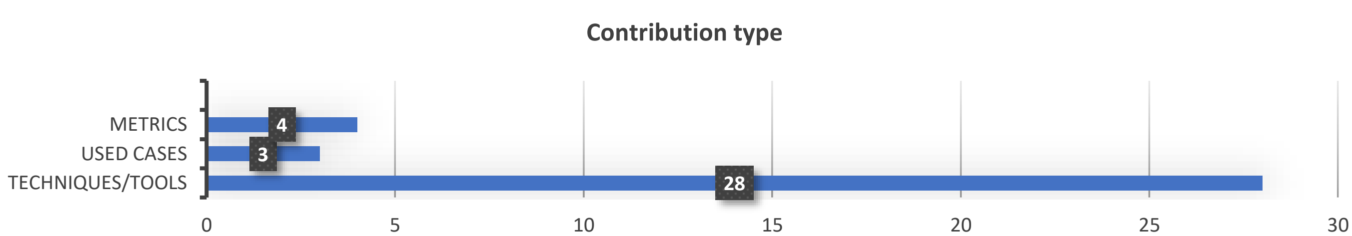
Software or hardware solution: Is the proposed solution software or hardware based.

3.3 Mapping of Studies

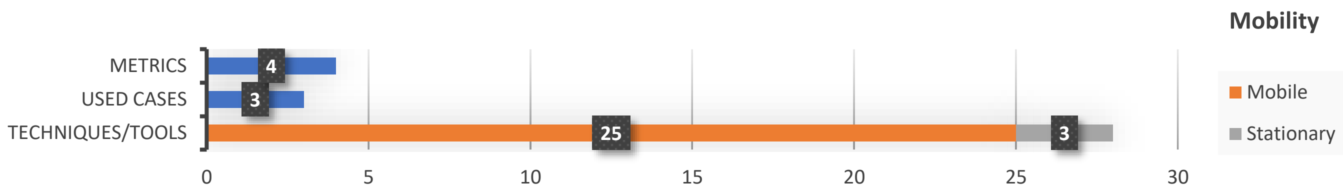




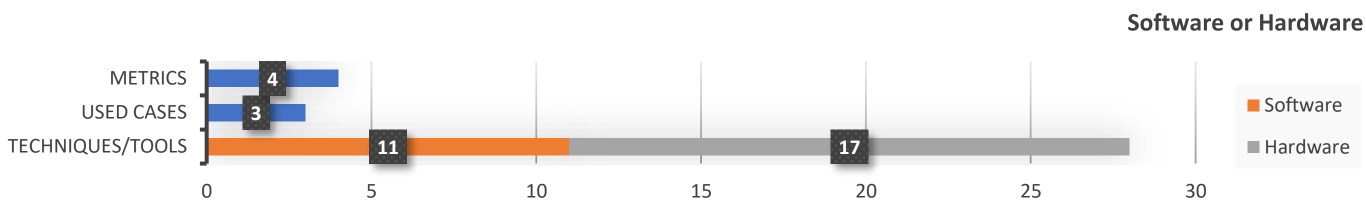
Category	Description
Virtual keyboards	In this category, the context of text input relates to virtual QWERTY keyboards and text input.
Alternatives to Virtual keyboards	In this category, the context of text input relates to techniques not following the standard QWERTY keyboard design but instead offers a new type of solution for text input.
Extensions	In this category, the context of text input relates to techniques that work in conjunction with other text input techniques.
Data annotation	The literature deals with data annotation in VR.
Web browsing	The literature explores web browsing in VR.
Comparison	The literature compares different text input techniques.



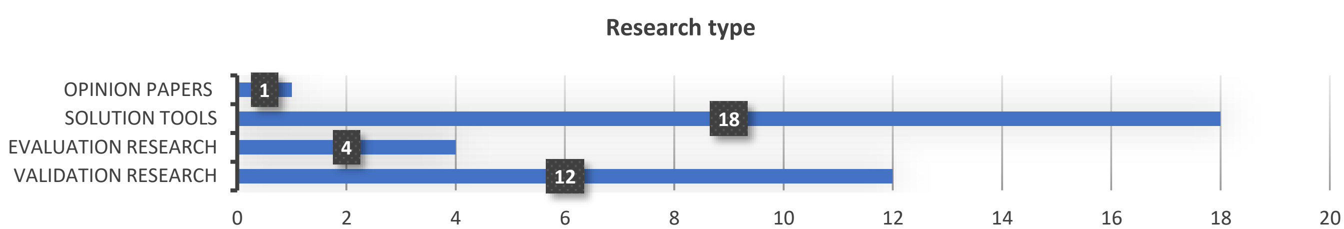
Category	Description
Techniques/tools	Describes a technique or offers a solution for text input
Used cases	The paper provides a used case where text input is greatly involved.
Metrics	The paper provides metrics and measurements around text input.



Category	Description
Mobile	Techniques or solutions could be used in a mobile context.
Stationary	Techniques or solutions provided does not account for the user moving and is meant for a stationary environment.



Category	Description
Software solution	Techniques and solution are software based.
Hardware solutions	Techniques and solution are hardware based.



Category	Description
Validation Research	Techniques investigated are novel and have not yet been implemented in practice.
Evaluation Research	Techniques are implemented in practice and an evaluation of the technique is conducted.
Solution tools	A solution for a problem is proposed, the solution can be either new or significant extension of an existing technique.
Opinion Papers	These papers express the personal opinion of the author, do not mention the use of any research methodologies.

3.4 Evaluation and results

Emphases on VR less on AR: The charts clearly show that more work has been done on VR with 44% compared with AR/Smart glasses at 18% but with 18% of the literature mentioning both. This can be seen as a reflection of the current market as VR is ahead in terms of providing more consumer-ready products. However, as AR technology develops, it is important to see how text input solutions differ from that of VR solutions and what characteristic of the technology contributes to these differences.

Emphasis on creating new solutions: The largest category out of all the classes belong to tools and techniques with 80%. You can see this being reflected in other classes such as variability context where virtual keyboards (17%), alternative text input methods (50%) and extensions (12%) make up a large portion of the literature found.

Few reports on comparisons of solutions: Despite there being a large amount of literature dedicated to exploring and proposing different text input methods, the comparison category within the variability class are few at 11%. It should be noted that some of the abstracts within tools and techniques did mention comparing their method against other solutions; however, it was not the main focus of the paper. It is important for more work to be done on contrasting the advantages and disadvantages of the many different solutions. Not only would it be good in evaluating the solution as a whole but we can identify aspects of particular solutions that can be helpful in developing guides for developers on what makes a good text input solution.

One of our biggest takeaways from the study was that there was a lack of focus on understanding the current market of these platforms. From experience working at the Agile Software Engineering lab, we knew that there were texts input solutions that were not being reflected in the mapping study. To better address our initial research question of *what areas are addressed when it comes to text input within augmented and virtual reality, and what types of research has been done in the different areas,* we felt like we needed to get a better understanding of the current market.

4. Understanding the current market

4.1 Text input in current applications

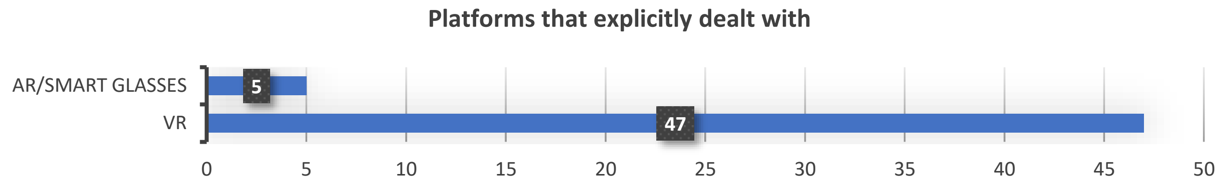
For the second phase of our project, we wanted to go beyond non-academic literature to find out what we can learn about the current state of text input in these environments. The first thing we noted was that text input is not a frequent task within AR and VR applications. However, when text input was required, a common implementation found was the point and click input on a floating virtual keyboard. This can be seen on major platforms such as the Samsung gear, Google Daydream, Microsoft HoloLens, and Steam VR.

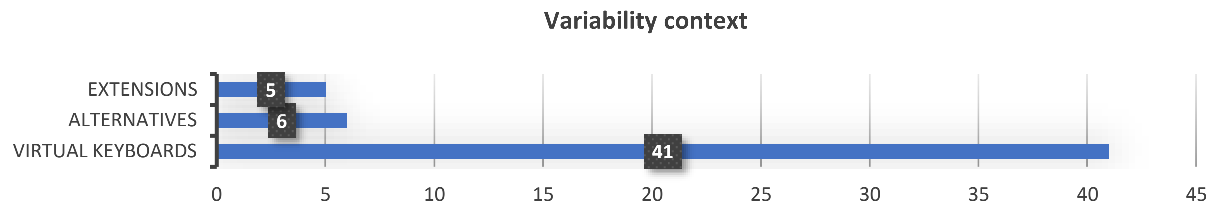
4.2 Conducting search for available options

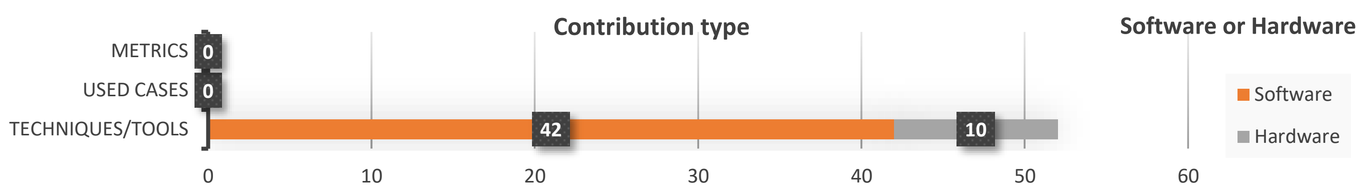
After looking at the common ways text input was being handled, we wanted to look at the available options that existed for these platforms. We decided to conduct a search on two different sites, the Unity asset store, the store for a popular cross-platform engine used to build 3D or 2D application, and YouTube, a video sharing site. For Unity, the search string was "Keyboards VR AR text input" and there were 694 results in total. After using the same criteria as the first phase, but instead of looking at abstract we looked at product description, a total of 10 relevant works remained. For YouTube, we used the following search strings *"text input VR Virtual reality", "keyboards VR Virtual reality", "text input AR Augmented reality", "keyboards AR Augmented reality", "text input MR Mixed reality*", and *"keyboards MR Mixed reality"*, and identified 42 different relevant videos.

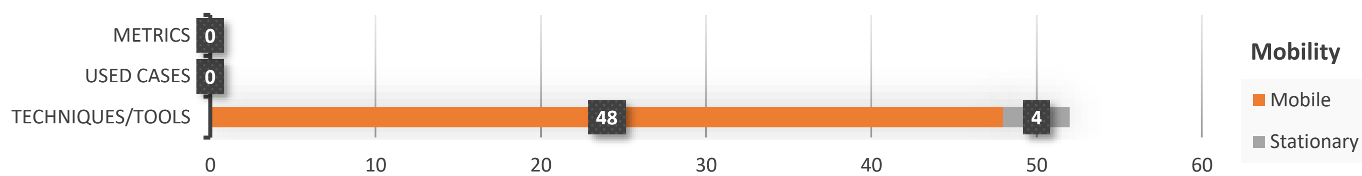
4.3 Mapping search results into our classification scheme

We took the relevant works from our search and tried mapping them to the same classification scheme in our mapping study. The classes that we reused were platforms that explicitly dealt with variability context, contribution type, mobility, and software or hardware.









4.4 Evaluation and results

Confirmed emphasis on VR compared to AR: The results from our search mirrored that from the original mapping study in that there was an emphasis on VR with 91% when compared to 9% with AR. VR devices such as the Oculus Rift and HTC Vive often showed up in videos, while consumer AR devices rarely showed up even in videos about AR. This reinforces the fact that the more consumer ready the products is, the more it encourages work to be done on it.

More emphasis on keyboard solutions vs alternative text input solutions: The variability showed that there was a clear emphasis on virtual keyboards (79%) in comparison to alternative text input solutions (11%). This result is in contrast with that of our original mapping study which showed a higher amount of work was done on alternative solutions (50%) then virtual keyboards (17%).

More emphasis on software solution vs hardware solutions: The variability showed that there was a clear emphasis on software solutions (80%) in comparison to hardware solutions (20%). This result is in contrast with that of our original mapping study which showed a higher amount of work was done on hardware solutions (61%) then software solutions (39%).

5. Conclusion and Future work

The main objective of the term project was to gain insight into the current understanding of text input within virtual and augmented reality environments as well as identify areas that require further investigation. Our systematic mapping study has shown that most of the research done is on creating solutions and techniques. Often these solutions explore different techniques that do not involve QWERTY style keyboards as well as hardware-based solutions. Also, the study has shown that a lot of the work done on this topic has been focused on VR instead of AR. Our second phase results from mapping of works found during our search for available options also showed more worked done was on VR. However, unlike the mapping study, the focus of the majority of the solutions tended to be around virtual QWERTY keyboards and was software based. An area where both studies have shown there is insufficient research is comparing solutions.

The systematic mapping study provided a broad understanding of what has been done on this topic. A good next step would be to perform a systematic literature review on all the works we had identified. By doing this, we hope to find common design philosophies that could be used as a framework for developing evidence-based practices. This can provide a first step in developing a guideline that would make suggestions to an interaction designer on how to deal with text input in AR and VR environments. Another option for future work on this topic would be to run user tests. As mentioned previously, there is insufficient research on comparing solutions. Running studies to see how the different solutions compare in terms of text input speed, errors, user preference, and more can provide useful data. Since these platforms allow users to interact with a 3D environment, identifying types of scenarios where text input may be possible can be important. It would also be interesting to see how the results of these user tests would change in different scenarios.

From the results of this project, we can conclude that there is a lot more that can be done, but there is clear interest in finding a solution for text input in AR and VR environments. Understanding what role these technologies will have in the future will rely on understanding how we can communicate with them. Text input will be an important part of that equation.

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