SHREWS: A Game with Augmented Reality for Training Computational Thinking

Francisco Saraiva
Centro ALGORITMI, Departamento de Informática,
University of Minho, Campus Gualtar, Braga, Portugal

Lázaro V. O. Lima
Centro ALGORITMI, Departamento de Informática,
University of Minho, Campus Gualtar, Braga, Portugal

Cristiana Araújo
Centro ALGORITMI, Departamento de Informática,
University of Minho, Campus Gualtar, Braga, Portugal

Luis Gonzaga Magalhães
Centro ALGORITMI, Departamento de Informática,
University of Minho, Campus Gualtar, Braga, Portugal

Pedro Rangel Henriques
Centro ALGORITMI, Departamento de Informática,
University of Minho, Campus Gualtar, Braga, Portugal

Abstract

This paper proposes a game to help young students training Computational Thinking (CT) skills to aid in solving problems. CT is a problem-solving approach based on picking a complex problem, understand what the problem is, and develop solutions in a way that a computer or human could solve. To help in this task, Augmented Reality(AR) will provide a more engaging visual way of interaction to keep students motivated while they search for solving problems. This benefit is a consequence of the AR capability of providing a visual and dynamic representation of abstract concepts. This work investigates AR and CT concepts and the best way of combining them for training student's skills to understand software and its effects. Thus, these concepts will be explored for the construction of learning activities to explain and create analogies to understand complex concepts related to computer programs. So the focus of the paper is the introduction of Shrews, the game created in this context. The principle and the proposed architecture are detailed. At the end, there is a description of how the game works and the current state of the prototype. We believe that the immersive experience using AR and CT concepts is one of the important aspects of the game to maintain a motivational approach to students. An exploratory prototype is created to explore the topic of teaching CT skills via playing a video game.

2012 ACM Subject Classification Computing methodologies → Mixed / augmented reality; Social and professional topics → Computational thinking

Keywords and phrases Augmented Reality, Computational Thinking, Learning Activity, Game

Digital Object Identifier 10.4230/OASIcs.ICPEC.2021.14

Category Short Paper

Funding This work has been supported by FCT – Fundação para a Ciência e Tecnologia within the R&D Units Project Scope: UIDB/00319/2020.

1 Introduction

Computational Thinking, is the action of "thinking like a computer" [15], but in detail refers to the process of solving problems following taking knowledge and computational practices such as, systematization, representation, analysis, abstraction, pattern recognition, solving and interpreting problems.

On the other hand, and since its inception Augmented Reality(AR) showed promising in its use, but has not seen much popularity to its existence to the every day person. According to even by the very early uses back in [1], over the years AR has seen mildor small use but steady increase in its popularity and uses. Azuma defined AR by three characteristics: **Combines real and virtual**, **Interacts in real time** and **is supported in 3-D**. AR [3, 1], is a variation of Virtual Reality in which it allows the user to see the real world but with virtual objects imposed onto the real world as to integrate the digital into the real.

So, the objectives of the project here reported are study AR and the impact of building games to train Computational Thinking (CT); Develop a game based in AR and conduct tests to study the benefits of CT. The project outcome is expected to be a Learning Activity that can where there is a game that will help to develop the four characteristics of the CT described above. To guide the research, DSR (Design Science Research)[13] methodology was used.

The phases of the work are based on the DSR methodology and guidelines of the artefact design, understanding of the problem, evaluation of the product and the contribution. The project is split into a study of the technologies and topics of CT and AR, followed by the conception of the product to solve the question of the possibility of training CT via a video game and the analysis and testing of the product with subjects.

The paper is organized as follows: in Section 2 the importance of Computational Thinking to improve the humans' ability to solve problems using the computer is discussed; in Section 3 we describe the research work already done combining Augmented Reality and CT; in Sections 4 and 5 we introduce and describe the proposed game, Shrews, explaining how does it work, as well as the concepts of CT that it addresses; and in Section 6, some sketches illustrating how the game can be played are shown.

2 The importance of Training Computational Thinking with the appropriate resource

Pragmatics shows that a person only acquires a new way of thinking or behaving if he is trained with the appropriate devices, for that, we will use the concepts of Computational Thinking to build a game appropriate for training CT skills; The concepts are: *Pattern Recognition* is the procedure of recognizing common characteristics or traits in problems and solutions. This leads to finding possible and efficient solutions to problems. *Decomposition* is the process of splitting a bigger problem into smaller ones, which can then be solved individually and possibly solve the bigger problem together. *Algorithms* are sets of instructions for a determined solution of a problem. Lastly *Abstraction* is the ability of separating elements in a problem as a way of organizing the data structures to better understand the complexity and model of the problem.

CT has found its way into a lot of research agenda of all science and engineering disciplines. The author also say that CT as found it is way into a lot of other important professions and areas such as medicine, economics, finance, law, arts and even digital humanities and digital journalism. Data mining techniques are also heavily based on the CT process and its four principles. For that reason and the growing abundance of data to be processed in current time [7], due to the accessibility of computers and internet connections, developing these skills is important for future graduates and students alike to tackle these activities in their future jobs and professions. After showing the concepts about CT, in the next section, we present which characteristics of these related concepts can be explored using AR in Shrews.

3 Augmented Reality and Computational Thinking

Virtual Reality and Augmented Reality make up the Computerized Hybrid Worlds, these technologies fascinate and are absorbed naturally by society in the most varied ways and integrate into our everyday life, taking over new technologies to perform human tasks.AR is defined by Azuma [1] as the overlapping of virtual information in the real world through technology; and [4] shows the directions of future works and areas that are currently being researched. This information can be simple textual images or 3-D objects.

The author had seen numerous potential in it's uses in technology be it medical, manufacturing, repairs, entertainment, planning and military, which today, years later, does see much more use in our society [2, 10] such as in DIY car repairs, cooking aids, GPS navigation, video games, medical training, car mechanics, customer service, military airplanes, television broadcasts and even house interior modeling.

Augmented Reality has the characteristic of creating attractive interactive interfaces that we can interact without using conventional peripherals and thus providing greater interaction between users and impacting their motivation. AR supports pedagogical approaches through Constructivist learning by enabling educational experiments that complement the activities of the real classroom. Thus it is possible to explore AR as a technology that provides a wide range of skills such as problem-solving, abstraction, creative manipulation of the computer as a user, not only as a mere technology operator but as a computationally literate individual. In Figure 1, we see the main concepts of CT.

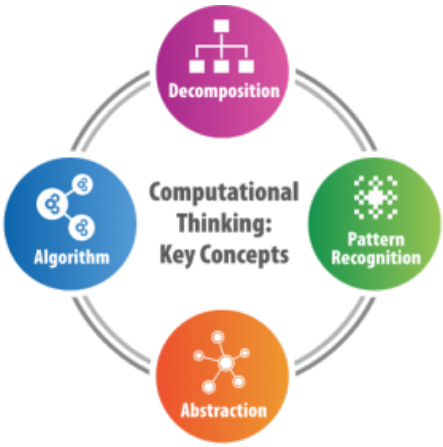

Figure 1 The four concepts of Computational Thinking.

In the research of results by using Video Games as tools, the study by [12] on the hypothesis if playing puzzle Video Games could improve executive functions, results showed that playing a complex puzzle game that demands strategy, problem interpretation and analysis improved several aspects of executive function. It is assumed that due to the variations of difficulty, strategies and problem solving methods may have led to a greater learning and generalization of the tasks used to test changes in the cognitive and control networks in the brain, responsible for high problem solving and executive functioning. Another study, this time more directed at fostering CT skills in middle school students by [16], it was discovered that by playing Penguin Go for less than two hours a day, improved students CT skills significantly, yet results on the impact of learning were inconclusive, but it might support the study on academic success and CT by [8] as being a factor of culture and the differences in the grading system on how we measure student success.

As AR has a steady increase in popularity and the use of this technology becomes more prominent in our lives, the question of its use in helping with education also comes into play. We know of its use in training and educating medical professionals but other areas or varying degrees and levels of education can see the potential and use of the technology. On work of [5] it's discussed how AR is used in learning and pedagogical approaches and exercises with lower thinking order as for example remembering, understanding and applying while high thinking orders of analysis, evaluating and creating have not been so thoroughly explored. Such activities include constructive learning, situated learning, games based learning and inquiry-based learning.

Games like CodeCubes [6] and HyperCubes [9] are both two game based solutions that employ AR to effectively train and teach programming and computational concepts respectively. CodeCubes is a game with an interface to stimulate CT in its users utilizing AR markers to program three different levels. HyperCubes is also an AR centered game that focuses on helping children understand computational concepts by interacting with their physical surroundings by utilizing the various commands in game and real cubes with AR markers. It plays more akin to a sand box like game to experiment. Both are game that utilize AR to teach and train these concepts and have had some success proving the use of these technologies in a learning environment.

A research on the use of AR in more commercial Video Games was done to better understand what constitutes a good use of AR and its interaction. A number of popular AR Video Games on the market were picked and studied in their uses of this technology in their game play. Some Video Games were found to use AR in a "good" and "bad" way, with good being the use of AR according to its definition of integrating the virtual with the real and the augmentation of the interaction in the Video Game such as using perspective of the camera to analyze the virtual object to solve a problem, while bad being a minimal use of the the technology as simple as super imposing the 3-D but not offering any other interaction other than viewing pleasure. Based on the research and our analysis of what constitutes good use of AR in a Video Game, the genre decided upon was to be a 3-D puzzle, that will use perspective and AR markers in its core game play to keep the engagement and interaction with the technology, which will be further explored in the following section.

4 Shrews: Game with AR for Training CT

After researching Video Games centered around AR, this section will propose the artifact intended to be developed based on the gathered information, data and research to develop a Video Game that will aim to train and focus on the four principles of and AR centered functionalities and engagement.

To develop a proposal of a Video Game to train CT, we have to look at the four main characteristics that compose Computational Thinking: **decomposition, abstraction, algorithms and pattern recognition**. In Video Games that tackle these four characteristics there is a genre that stands out among them and it is puzzle games, which make the player think and understand various concepts in the game to solve problems with the tools available. A puzzle Video Game that tackles these concepts is Lemmings, a 2-D puzzle-platform Video Game developed by DMA Design in 1991, in which the objective is to guide a group of characters through various obstacles in a 2-D view from a point A to a point B.

In a research on Scalable Game Design (SGD) used to give young students CT acquisitions by [11], Lemmings was used as a tool to train problem solving skills on some success for young students for their better understanding of computational skills and decision making.

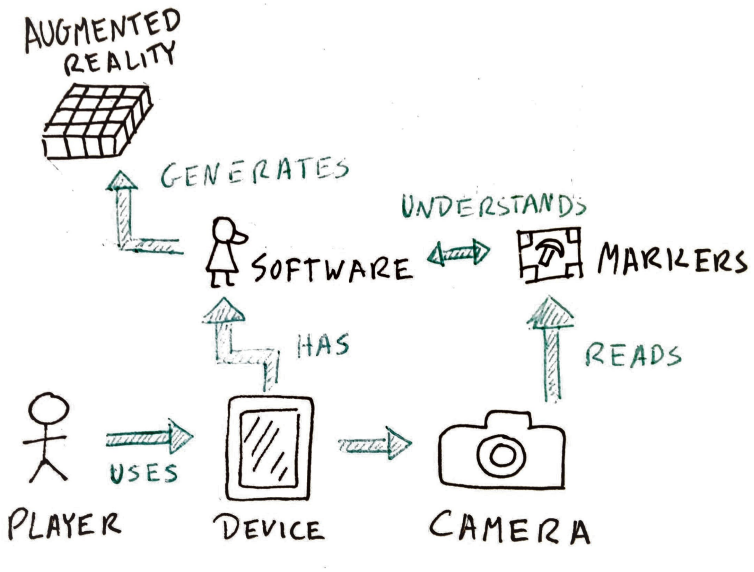

Figure 2 The Scheme of Shrews and the various components that make up it.

The Figure 2 represents the schema of the game, by components and interaction. The components that make up this system are the **device**, such as a smartphone or tablet, in which the player will use with the **software** that will be developed. This software will be tasked with the execution of the Video Game and creation of the AR environment that the player will use as a lens to see it. The game will use a camera to track a surface to project the AR environment and identify the various AR markers to execute the Shrew's tasks.

5 Game - How will the game work?

The Shrews are three types of characters: **Builder**, **Adult**, and **Elder** with different skills see in Figure 3.

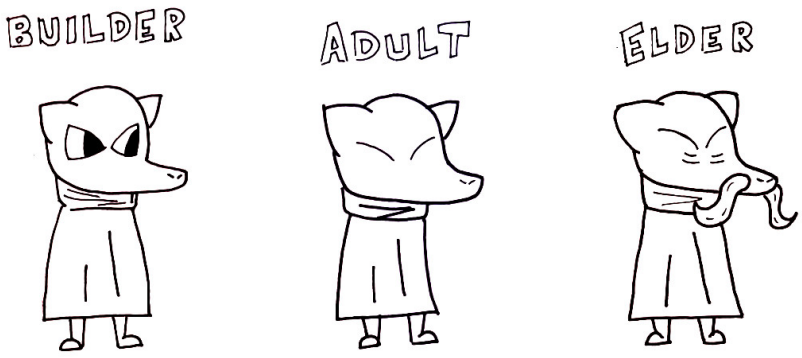

Figure 3 Three types of characters of SHREWS Game.

The objective of the game is to transverse a group of Shrews over the map, from the start to the exit. For this the player will use AR cards to instruct the **Builder** where to build such pathways for the Shrews. The **Adult** and **Elder** Shrews are moved by how the **Builder**

guides them safely across the map, as they cannot see in front of them. The player will find a flat surface preferably, to generate a map and will use perspective to analyze the map and terrain and figure out the best paths around the map to guide the Shrews. The player will focus on the Builder or the blocks and use cards to instruct which action the Builder will do. For example tapping on a block and choosing a card will make the builder move to that spot to build the path forward. The remaining Shrews will walk back and forth nonstop on the pathway the Builder shrew has moved in. The game will have a scoring system based on various statistics throughout the session like time it took to solve the puzzle, how many tasks were used and how many Shrews made it safely to the end.

The Figure 4 shows how the player will use a device to see the AR. The player will use a smartphone device or tablet as a scope into the game and see the AR map and game play happening. Moving with the device around the map the player will be able to see the whole map from different perspectives. Using the AR cards to read from the application will cause the various tasks of the builder shrew to be executed.

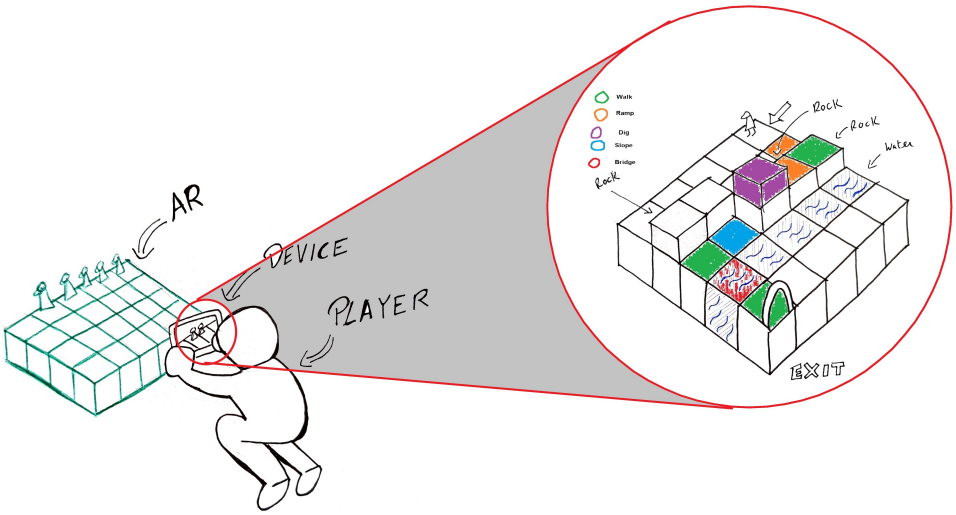

Figure 4 Example of user interaction with the game.

The game will be built with more than one way to solve the same problem. The map holds various normal dirt blocks, rock blocks and rivers or ponds composed of water blocks. We will go over many scenarios to solve this puzzle, but there can be more than one solution to a puzzle, it is up to the player to find them to promote each interpretation of the problem.

The skills the Builder can perform, illustrated in figure 5 are as follows:

- **Move**: Instructs which blocks the shrews can navigate, the player will tap the blocks and use the AR card to signal these blocks are for the builder to instruct the shrews to walk on.
- **Ramp**: Creates next to the selected, or more, dirt blocks a ramp allowing the shrews to go up or down in height to another block, depending on the direction they are walking from they will climb, or slide down the ramp. It is to note that the builder shrew does not slide down the ramps, only the adults and elders, depending on how many ramps elders slide down the more hurt they get on landing. These are the only buildings the builder Shrew can construct without needing to shape a block.
- **Bridge**: Constructs a bridge over blocks of water or more connecting blocks over a space, allowing the shrews to walk over the water blocks.

- **Tunnel**: Builds a tunnel through a block to move to the other side, this is only possible on dirt blocks and not rock blocks.
- **Dig**: Destroys a selected block near the builder shrew to open up space on the map for construction.

As the objective is to train CT skills in the players, the game play will focus on the four thought processes, this way the players will experience the problem solving methods used in CT and train them in game to solve puzzles.

- **Pattern Recognition**: By utilizing skills and how they interact with the blocks to give pathways, players will start recognizing patterns. Observing the behavior of the shrews as they are patterned will help to guide them better.
- **Decomposition**: The puzzle is a large problem with smaller problems in it via obstacles such as blocks in higher heights need to be climbed or other obstacles that require solving.
- **Algorithm**: The objective of the game is to trace an algorithm that will lead the Shrews from point A to point B.
- **Abstraction**: The difficulty of the puzzles are measured by the number of existing blocks and overall dimension of the map. It's important to abstract how flat surfaces of blocks can be paths as opposed to groups of blocks in different heights, as well as the different types of terrain. Also the perspective view of AR to visualize the map in all angles gives the player the sense of analysis and strategic planning.

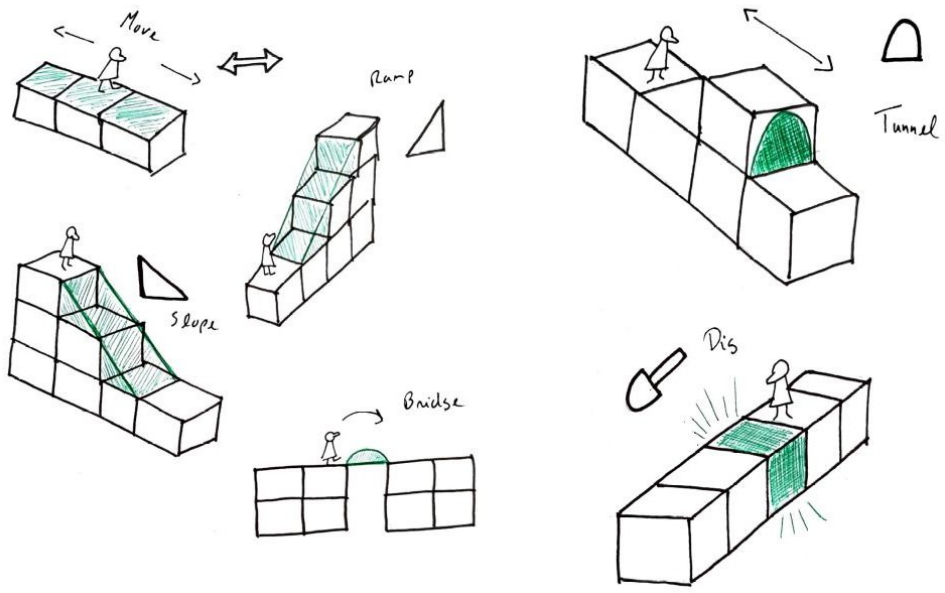

Figure 5 The first and second set of skills the Builder can perform.

In this example, Figure 6, it has been illustrated in colors the blocks and the tasks associated that the builder shrew will perform. Illustrated in green are the blocks indicated to walk over, followed by a block in brown that the builder will construct a tunnel, followed by red, a bridge to cross the water and the remaining tiles in green is to walk over to the exit. This is a more simple approach to this puzzle as it is straight forward, without going up in height and down to cross the the higher blocks.

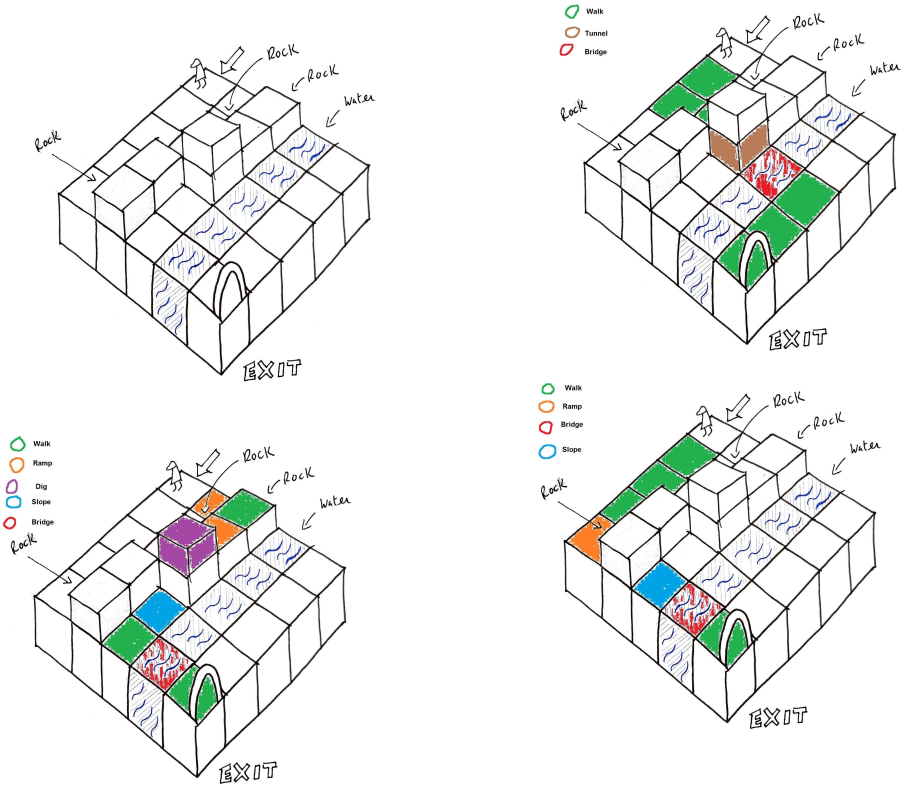

Figure 6 Example of a types of maps and solutions to the puzzle.

6 Prototype in Progress

As to better classify and organize the proposed game an ontology for game classification was used called **"Ontojogo"** by Teixeira [14], as a system to better classify the properties and attributes of games. Using the expertise already investigated by the authors, we can detail the characteristics of the game through this Ontology that classifies the games according to different perspectives or different categorization axes.

Listing 1 Classification of Shrews in **OntoJogo** by [14].

```
Shrews =iof => Game[name='Shrews', description='Shrews is a puzzle
solving game where the player helps guide creatures over a map.',
age_rating=7, storyline='fiction'];
Shrews =is_available => Digital Offline;
Shrews =has_mode => Casual;
Shrews =has_perspective => Third-Person;
Shrews =with_input => Movement-Based;
Shrews =with_input => Touch;
Shrews =has_player_number => Single Player;
Shrews =has_progression => Level-Based;
Shrews =belongs_to_platform => Mobile;
Shrews =belongs_to_genre => Puzzle;
Shrews =belongs_to_genre => Strategy;
```

We believe that the game, already classified within the ontology to guide the Computational Thinking approach, will be motivating and a tool with a positive impact. To implement the ideas presented here, we use Unity 3-D® v.2018.4, the tool builds Augmented Reality

systems supported by the Vuforia® version 9.8 library. We can see in Figure 7, the conceptual prototype of the game. In this scenario we have the shrews in a terrain with obstacles to be overcome and the options for the skills that the Builder Shrew can perform on the map.

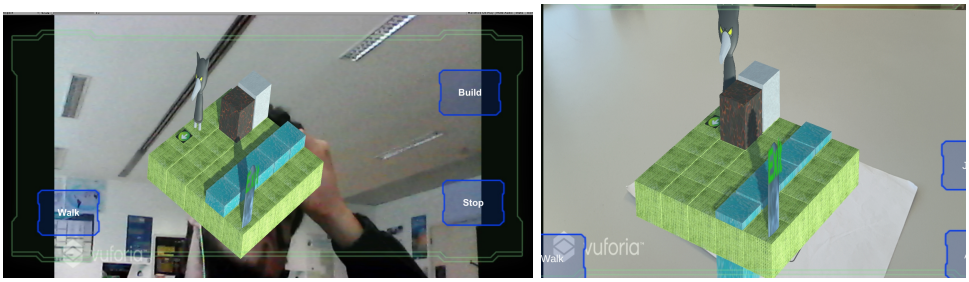

Figure 7 Prototype of the game currently in progress.

After the functional prototype is ready to be playable, it will be used to test on a demographic of young students to explore their interactions with the game and how they interpret the game and functionalities as to further improve the product to reach our results.

7 Conclusion

Over the course of this paper CT and related topics its definitions have been discussed emphasizing the four main concepts Algorithm, Decomposition, Pattern Recognition and Abstraction, its growing importance and interest of study in our modern society as well as the benefits to develop these skills. The it was discussed how Video Games help shape our way of thinking improving different and relevant strategies for with their intricate game play and thought process to solving problems. Previous games, like CodeCubes and HyperCubes, have proven to be successful in teaching CT due to the AR models they use; however that process was experimented with children working under specific technological environments like computer programming clubs. On the other hand, Shrews aims at making the difference with a real personality, able to captivate a wider range of people; to attain that purpose , Shrews has a proper design and style,as well as easy to use interface.

Along the paper it was also discussed AR, its variants and its uses. The growing popularity of the technology in our society was pointed out, as well as the Video Games that utilize it in their core and employ good uses of the technology in their interactions and practice. Combining the two subjects the our proposal, here presented, is to develop an AR 3-D game that will train its players to develop CT skills by adding the four main principles into the game. With a simple prototype being currently developed we hope for our next iteration to be a playable version of our vision for this Video Game to help train and develop the Computational Thinking skills of individuals with a immersive and interesting technological approach to hold and promote interest.

References

1 Ronald T Azuma. A survey of augmented reality. *Presence: Teleoperators & Virtual Environments*, 6(4):355–385, 1997.

2 Jacob Bell. 4 real world uses for augmented reality - primacy primacy | blog. https://www.theprimacy.com/blog/finally-4-real-world-uses-for-augmented-reality/. (Accessed on 04/06/2021).

3 Donna R Berryman. Augmented reality: a review. *Medical reference services quarterly*, 31(2):212–218, 2012.

4 Mark Billinghurst, Adrian Clark, and Gun Lee. A survey of augmented reality. *Foundations and Trends in Human-Computer Interaction*, 2015.

5 Matt Bower, Cathie Howe, Nerida McCredie, Austin Robinson, and David Grover. Augmented reality in education–cases, places and potentials. *Educational Media International*, 51(1):1–15, 2014.

6 Bárbara Cleto, Cristina Sylla, Luís Ferreira, and João Martinho Moura. CodeCubes: Coding with Augmented Reality. In Ricardo Queirós, Filipe Portela, Mário Pinto, and Alberto Simões, editors, *First International Computer Programming Education Conference (ICPEC 2020)*, volume 81 of *OpenAccess Series in Informatics (OASIcs)*, pages 7:1–7:9, Dagstuhl, Germany, 2020. Schloss Dagstuhl–Leibniz-Zentrum für Informatik. doi:10.4230/OASIcs.ICPEC.2020.7.

7 Debra J CPCM and Philip Noah. Big data in the information age: exploring the intellectual foundation of communication theory. *Information Systems Education Journal*, 12(1):15, 2014.

8 Hao Lei, Ming Ming Chiu, Feng Li, Xi Wang, and Ya-jing Geng. Computational thinking and academic achievement: A meta-analysis among students. *Children and Youth Services Review*, 118:105439, 2020.

9 Anna Fusté Lleixà. Project overview ' hypercubes: Learning computational concepts in augmented reality, 2018. URL: https://www.media.mit.edu/projects/hypercubes/overview/.

10 Christopher McFadden. 9 powerful real-world applications of augmented reality | ie. https://interestingengineering.com/9-powerful-real-world-applications-of-augmented-reality. (Accessed on 04/06/2021).

11 Hilarie Nickerson, Catharine Brand, and Alexander Repenning. Grounding computational thinking skill acquisition through contextualized instruction. In *Proceedings of the eleventh annual International Conference on International Computing Education Research*, pages 207–216, 2015.

12 Adam C Oei and Michael D Patterson. Playing a puzzle video game with changing requirements improves executive functions. *Computers in Human Behavior*, 37:216–228, 2014.

13 Rauno Pello. Design science research — a short summary | by rauno pello | medium. https://medium.com/@pello/design-science-research-a-summary-bb538a40f669. (Accessed on 04/07/2021).

14 Salete Teixeira, Raul V Boas, Francisco Oliveira, Cristiana Araújo, and Pedro R Henriques. Ontojogo: An ontology for game classification. In *2020 IEEE 8th International Conference on Serious Games and Applications for Health (SeGAH)*, pages 1–8. IEEE, 2020.

15 Jeannette M Wing. Computational thinking benefits society. *40th Anniversary Blog of Social Issues in Computing*, 2014:26, 2014.

16 Weinan Zhao and Valerie Shute. Can playing a video game foster computational thinking skills? *Computers & Education*, 141:103633, July 2019. doi:10.1016/j.compedu.2019.103633.