The Pinocchioverse
- a fictional universe for computer science education

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ABSTRACT

The Pinocchioverse analogises concepts of computer science through marble tracks, which can be used to trigger actions of mechanical devices. In combination with special track pieces like branches and loops, control sequences can be constructed to solve complex problems. In the course of learning about marble tracks and their behavior, one will be able to construct their own mechanical devices and control them through marble tracks.

In consequence of the approach of basically declaring computer science natural law, the concepts become directly experienceable and enable new ways of teaching them. Furthermore, the Pinocchioverse can be easily integrated in the classroom through means of storytelling, exercises, video games and virtual environments and could by that also enable a more seamless integration of immersive technologies in the classroom.

1 INTRODUCTION

The idea behind the Pinocchioverse is that every technical device runs on marbles. For example in Figure 1 you can see an easy puzzle, in which we see Pinocchio and the marble track that runs inside him to help him get through the labyrinth. This works because of the actions that are both in the marble tracks as sticking seals pasted on the running tracks and inside Pinocchio to trigger the displayed mechanical actions. When the marble then roles over these seals, the action is triggered and Pinocchio moves. Because of the way the marble track is constructed, it would help Pinocchio get through the labyrinth by guiding him step by step to the exit.

The Pinocchioverse basically combines the world of Pinocchio with a different understanding of computer science that is based on the idea that technical devices run on marble tracks. This understanding of computer science is in this paper called marble steampunk, derived from the term "steampunk", which describes a genre-mix of fantasy and science fiction, in which key innovations of humanity are achieved earlier than in actual history. Because this leads to modern technical devices being described with the simplified technical means of earlier times, their functioning often becomes easier to understand and therefore, could be suited for teaching concepts of computer science. In most fictional works of the genre, this innovation is steam (hence the name), often accompanied by the achievement of building computers through mechanical means as done in theory by Charles Babbage. But now, instead of steam, in our case, magic marbles are discovered and enable basic digital innovation right away. That means, in the Pinocchioverse, the development of complex digital devices becomes possible earlier than in actual history and, from the point of view of a visitor, the digital revolution can be experienced from the beginning and through more simplified means.

The special properties of the marbles, their inner functioning and the construction of marble tracks based on them to power machines, were developed in the form of three sequential modules, through which they can be understood step by step. These modules, together with the world of Pinocchio, make up the entire world description of the Pinocchioverse and can be seen in Figure 2.

In the following paper, first, the world of Pinocchio will be described shortly. After that, the three modules of marble steampunk are introduced, each of which describes marbles and the devices that can be build with them on different layers of abstractions; namely the application layer, the medial layer and the cosmic layer.

The first layer is the one with the highest degree of practical application. It describes all the components to build marble tracks and the devices, which run on them. However, it is not explained, how they work exactly.

The next layer, called the medial layer, is kind of an intermediate layer between the application layer and the cosmic layer. It describes how to make use of the cosmic laws through writing symbols on the marbles and by that, also enables to understand how the marble tracks introduced in the application work in detail. However, the potentials of this are only scratched here, because the complex creation of marble tracks is already explored in the application layer. The medial layer merely enables a deeper insight.

The cosmic layer then describes the natural laws that come with marble steampunk. It describes which laws need to apply for a world in which devices run on marbles to be possible. This will be mainly done through an ore, out of which the marbles in the Pinocchioverse consist, called "the marble ore". Its properties and inner workings are described in this section. For example, it will show how the symbols that can be written on the marbles, are interpreted by the ore. Theoretically, all other layers build upon this layer and make practical use of its laws, however, because of its abstract nature, it is introduced last here.

And finally, a few thoughts will be given about how to apply all of this for class.

2 THE WORLD OF PINOCCHIO

The world is slightly different from that of the original Pinocchio tale, because it is not set in italy but in an entirely fictional high fantasy world with minor fantasy elements. Also, as described in the next sections, the magic from the original tale will be replaced with mechanics build on special kinds of marbles. However, the characters and settings of the world stay the same, meaning there is no industrialisation and there are one or the other eccentric character.
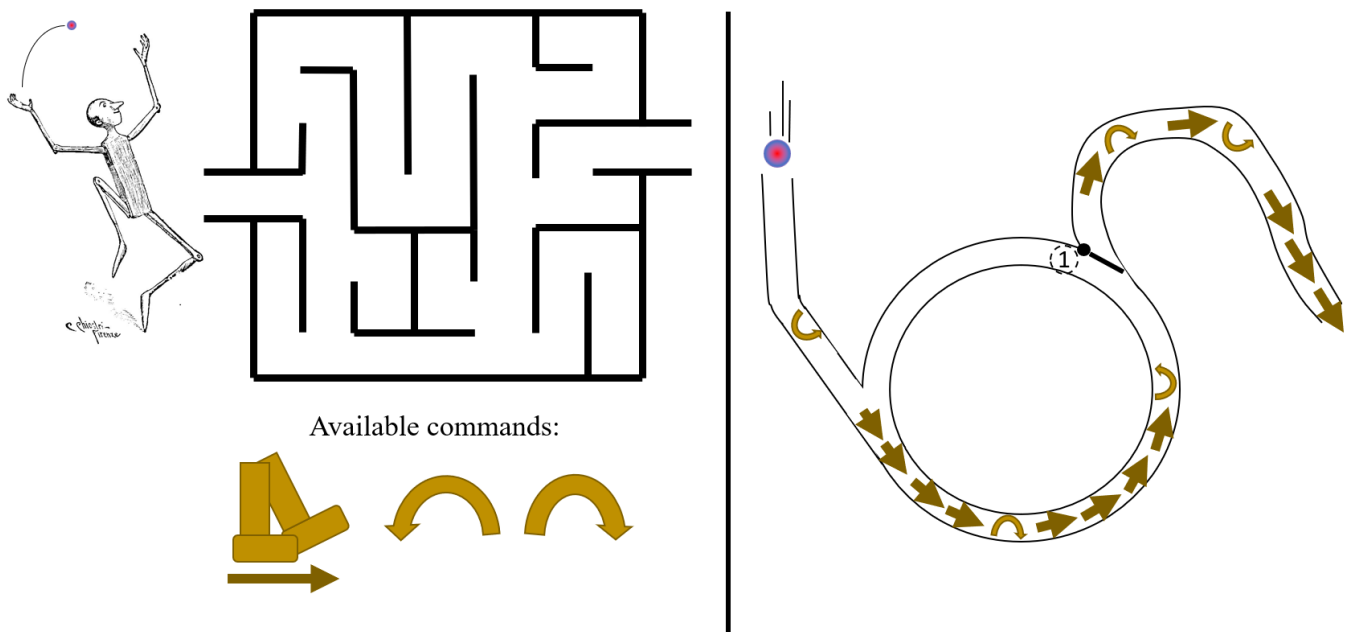
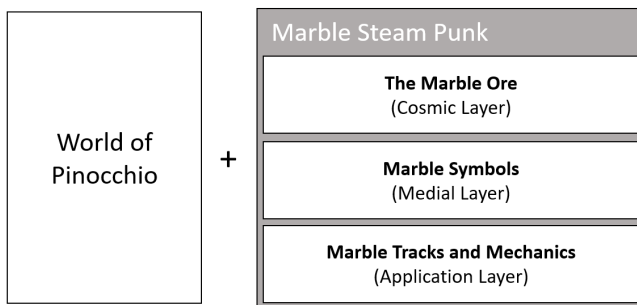**Figure 1: Help Pinocchio through the Labyrinth-puzzle**

Figure 2: Main modules of the Pinocchioverse

3 APPLICATION LAYER: MARBLE TRACKS AND MECHANICS

This section shows how marble tracks can be used in the Pinocchioverse to create complex mechanical apparatuses. The main components of marble tracks are the physical marble track pieces and the so-called symbol seals, which can be pasted on them to trigger certain actions. There are also mechanical components, which can be build in mechanical devices to control them with a marble track (in the general case the marble track is build inside the device). This could for example be the Pinocchio-puppet from last section. And finally, there are also complex marble track components, with which to store values inside of marbles to modify and access them throughout the marble track, and thereby influence the course of the marble track with them.

The different components will be explained in the following sections.

3.1 Basic marble track components

The basic marble track components can be seen in Figure 1. They consist of the track pieces itself and symbol seals, which can be pasted on them to trigger certain actions.

The example already includes the three main track pieces: the standard track, the branch and the loop. They can be build together to construct the physical track through which the marble will later run. Standard tracks can be used to make the marble move on a determined route. Branches can be used to determine the further course of a marble based on a condition. Loops can be used to repeat track sections multiple times, usually with a build-in branch to determine the end of the loop.

The example also has some symbol seals pasted on the track pieces. These are the second group of basic marble track components. They can be used to trigger certain actions when a marble roles over them, for example a function in a mechanical device, as the feet movement of Pinocchio in the example. There exist two variants of symbol seals: actions and sensors. Actions directly trigger an action, while sensors trigger an action depending on a certain condition, for example in Figure 1 there is a sensor that determines how many times it was rolled over by a marble.

An overview of all basic marble components can be seen in Figure 3.

Another example, which also makes use of sensor seals can be seen in Figure 4. It is a remote-controlled wooden car, which has been made working with the marble track on the right using action sensors to determine whether an action on the remote was pressed or not.
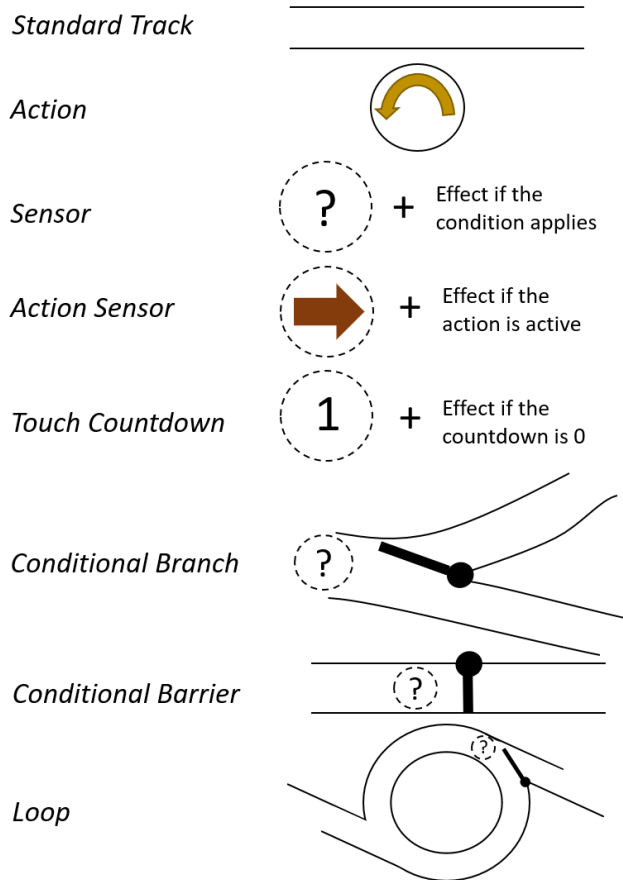
Standard Track

Action

Sensor   ? + Effect if the condition applies

Action Sensor + Effect if the action is active

Touch Countdown 1 + Effect if the countdown is 0

Conditional Branch ?

Conditional Barrier ?

Loop (?)

Figure 3: Basic marble track components

3.2 Basic Mechanical Marble Components

In Figure 5 we see different mechanical components that can be used when building devices that should later be controlled with marble tracks.

Based on this, we can now better imagine what the inner workings of the wooden car could look like. In Figure 6 we see a try to model it with mechanical components.

If one uses the car, to drive around with it, one would not need to know about its inner mechanical construction, one wouldn't even need to know about the marble tracks running inside of it. But if one would like to know how it works on a basic level, one could now understand it and even build ones own car with it.

3.3 Advanced marble track components: complex symbol seals

Additional to basic marble track components, there are advanced components, which are more complex but enable to build more powerful tracks. They consist mainly out of complex symbol seals, which work just like symbol seals but allow values to be stored inside marbles. These values can be given names, they can be modified and accessed throughout the marble track and by this influence the course of the marble. Because the values are stored inside the

marbles and can also be modified by manually writing symbols on them, this now also makes it possible to pass input data to a marble track by writing values on the marble before putting it on the marble track, which is then checked inside the marble track by specific marble track components. This can enable to solve new kinds of problems and make marble tracks more interactive. Values attached to names inside of marbles are in general also called "marble variables".

Complex symbol seals can either be complex action seals, which somehow change the state of the marble, which means change one or more of its variables, or a complex sensor seal, which condition somehow depends on the value of a variable. In the case of a complex action seal, the commands are executed one by one.

In general, the following variable operations are possible:

- **Creating a variable**: using alphabetical symbols to create a new variable
- **Assigning a value to a variable**: using a numerical value and the arrow-symbol to assign a value to a variable
- **Doing complex variable operations**: using arithmetic operators to access values of variables and do calculations with them; and assigning them afterwards with the arrow-symbol to a variable, for example $X \leftarrow Y + X * 5$

Operators can be any mathematical operator. An example for various action seals can be seen in Figure 7.

In the case of a complex sensor seal, the commands are executed and the seal is activated, if the condition is evaluated to true, and in the other case, not. In contrast to the actions seals, the symbol sequence ends with the "?"-symbol. An example for various conditional seals can be seen in Figure 8.

It is also possible to access variables that have been written on the marble before it was put on the marble track. As seen in Figure 9 this can be easily used to implement bubble sort as a marble track. To run it successfully, the positions of the foods need to be written on the marble beforehand and because of the way it was constructed, the marble then has to be put on the marble track at least four times in order to arrange all items of food correctly for every case.

4 MEDIAL LAYER: MARBLE SYMBOLS

The last section focused on the construction of marble tracks, however, the constructs with were used in the tracks as well as the devices, which they controlled (or were build into) were treated at some point as black boxes. One was for example not able to explain the inner workings of a sensor seal. With the knowledge about the behavior of marbles introduced in this section, a deeper insight in the construction of marble-run devices will be enabled and theoretically, one will be able to fully understand the functioning of any mechanical device that can be crafted in the Pinocchioverse. With this more complete understanding about marble tracks and the devices they power, one will be able to construct them completely on ones own and solve problems of arbitrary complexity with them.

To enable this deeper understanding, this layer further examines the powers of marbles and how they can be made use of to construct mechanical devices and marble track components. This happens mainly through their special properties of information processing, which allow their powers to be remotely activated through symbols.
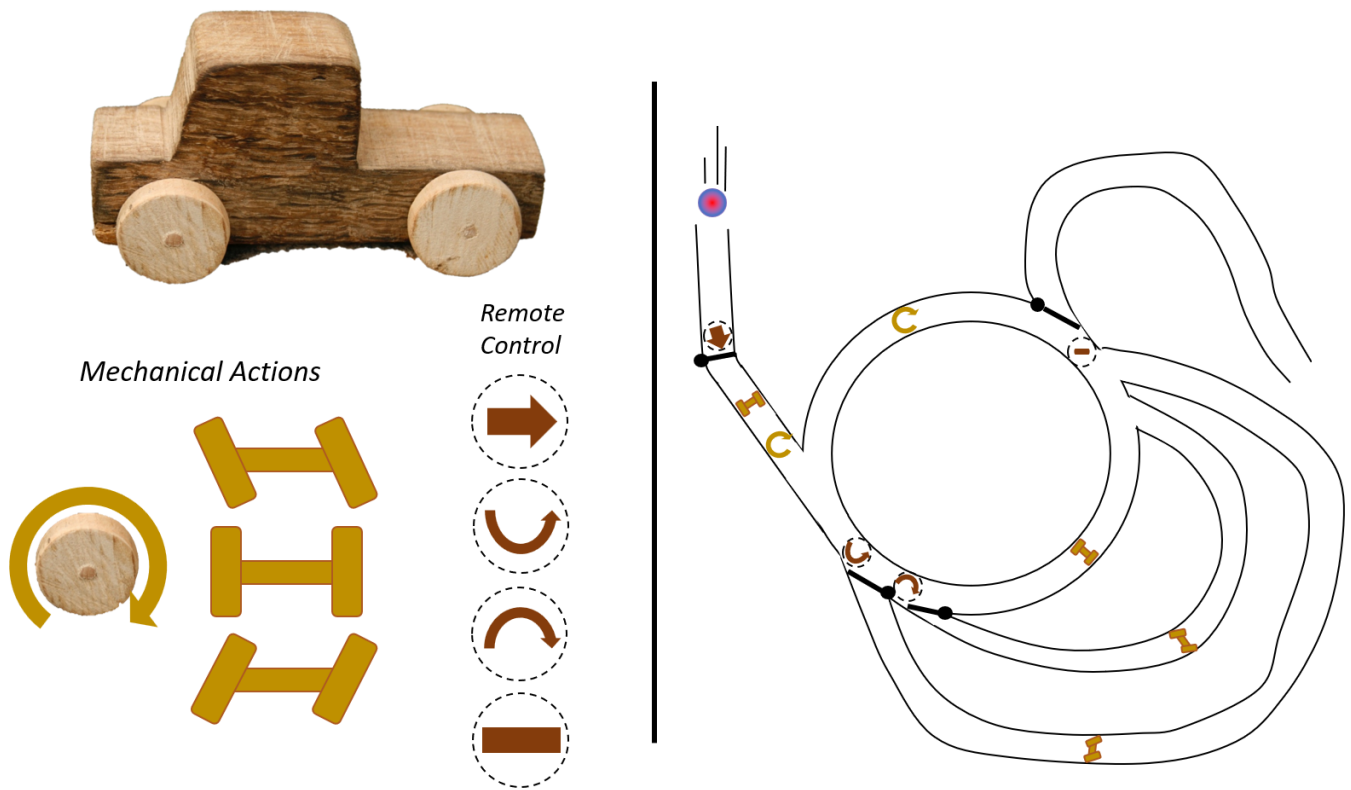
Mechanical Actions

Remote Control

Figure 4: A remote-controlled wooden car constructed with a marble track running inside of it

Gear wheel

Touch-Buttons

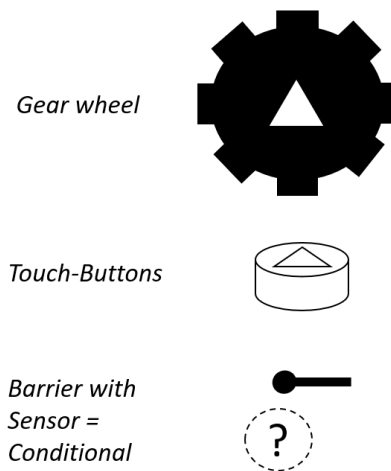*Barrier with Sensor = Conditional*

Figure 5: Basic mechanical marble components

After that, the workings of processing of symbol sequences is explained.

4.1 The rotation power of marbles and its activation through symbols

In Figure 10 all possible ways to activate the power of a marble can be seen. In the first one, the activation happens through direct touch, in the following ones, the activation happens remotely through symbols.
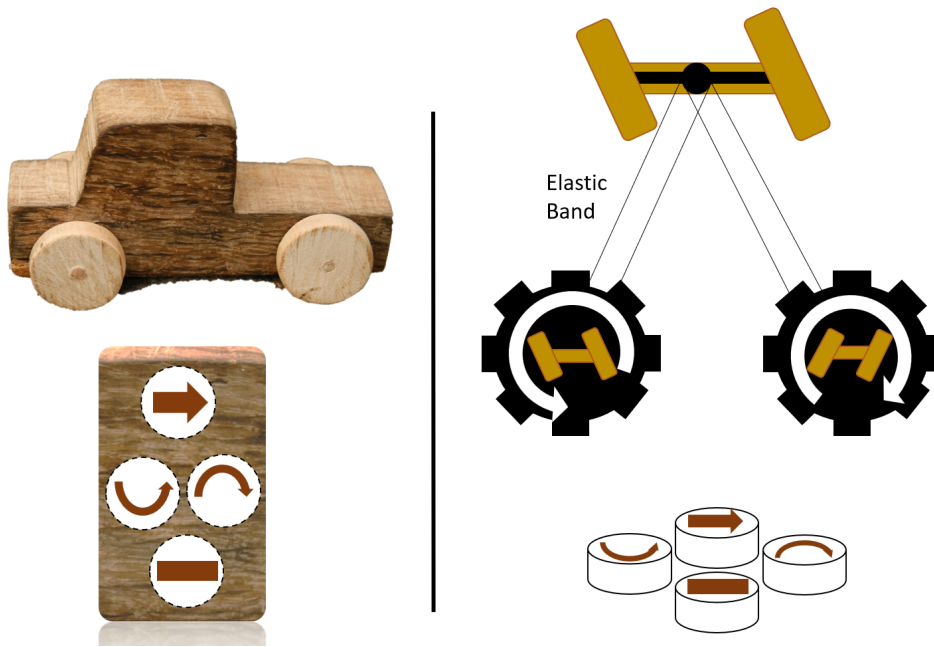
Figure 6: Mechanical construction of wooden car based on marble mechanics
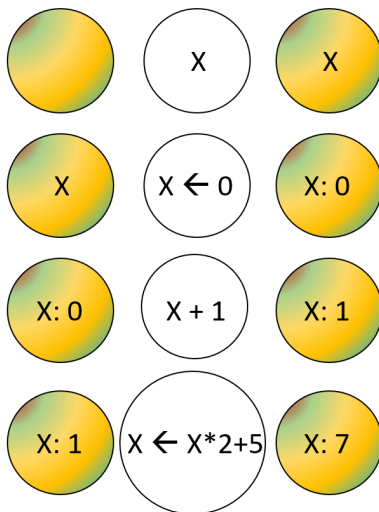
Figure 7: Complex action seals

Figure 8: Access/complex conditional seals

To activate the rotation power of a marble, one simply writes the rotation symbol on it making use of the marble's power to process symbols (which will be explained in the next section), and afterwards, touches the marble with another marble as seen in the first example of the figure. After this was done, the marble will start to rotate and because it is no longer connected to the other marble, eventually stop.

But there is another way of activating the rotation power of a marble: by connecting two or more marbles with symbols. This again makes use of the information-processing of marbles, but this time, the symbols have another function, because the symbol this time serves kind of as a global tag, for which matching marbles with the same tag are searched for. How this processing works will be explained in the cosmic layer; for now, it is just assumed that marbles are able to do that somehow. Now, if another marble has the same symbol written on it, the two marbles are connected as if they were touching and because of that, also their powers are activated (of course only for those marbles, which had the rotation symbol written on them). This time, the activated marbles will not stop rotating, until the rotation symbol is removed again.

That means, now there exist two types of symbols: the rotation symbol and connection symbols. While the rotation symbol is fixed, connections symbols may be any symbol imaginable except the rotation symbol.

It is important to note that as seen in the last two examples of Figure 10, symbols do not even need to be written on the marbles, it is enough if they touch them. That means that if a marble roles
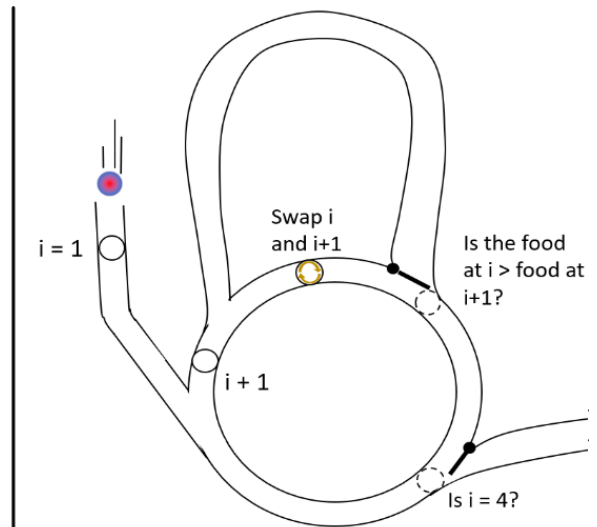
Figure 9: Help the farmer order his food-puzzle
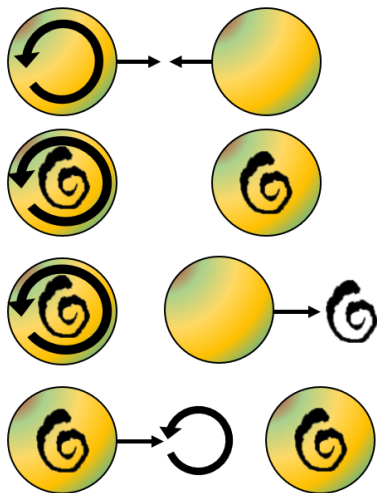
Figure 10: Different ways to activate marbles (in every example, the left marble would move)

components. While we already saw in the last section, how the wooden car could work internally, we could now also understand how the mechanical components we used worked and by that understanding it (in the Pinocchioverse) in its entirety. This does not mean that we necessarily need that knowledge to use or build the car. If the medial layer has not yet been covered or this degree of detail is not necessary, they can just be used as seen on the left side to build the car as described in the last section. Generally speaking, one does not necessarily need this to understand how the wooden car works in principle, how it drives around and can be remotely controlled, but if one wants to build ones own car in all its detail, one would. And if one would want that, one needs to know the workings of the medial layer.

With the medial layer, one truly understands, what a mechanical world, solely running on marbles means and how it works in the Pinocchioverse. It is maybe not essential for the programming-aspects of the world but if one wants to freely explore the world and be able to create every device possible, it is basically impossible to do without the knowledge of the medial layer.

over a symbol, this symbol is immediately processed and may, for a short amount of time, activate another marbles rotation power.

In the Figure 11 and Figure 12 we can see the different marble track components and their inner workings constructed based on the knowledge from this layer. Their inner functioning is explained with the knowledge of the medial layer on the right. It also shows that the sensor seals are in fact not seals that can be pasted on the tracks but are hard track pieces, which have to build into the marble track.

With this, one is now able to understand every component of a marble track and the mechanical devices it controls in its entirety. We can now easily imagine, how the wooden car from the last section was actually mechanically build inside down to its smallest

4.2 Conditional activation

The behavior of marbles can be modified by special symbols, which are the alphabetical symbols and their combination. If they end with a ?-sign, this is called a condition. If they are written on a marble, it can only be activated, if that condition is true, or if it is removed.

Actions to modify variables inside the marble can be written on the marble but have no direct effect on the activation.

That means, now there exists a third type of symbol, which consist of all symbols that can be used as variable names, numbers, as well as their operators. From now on, these cannot be used as connection symbols anymore.
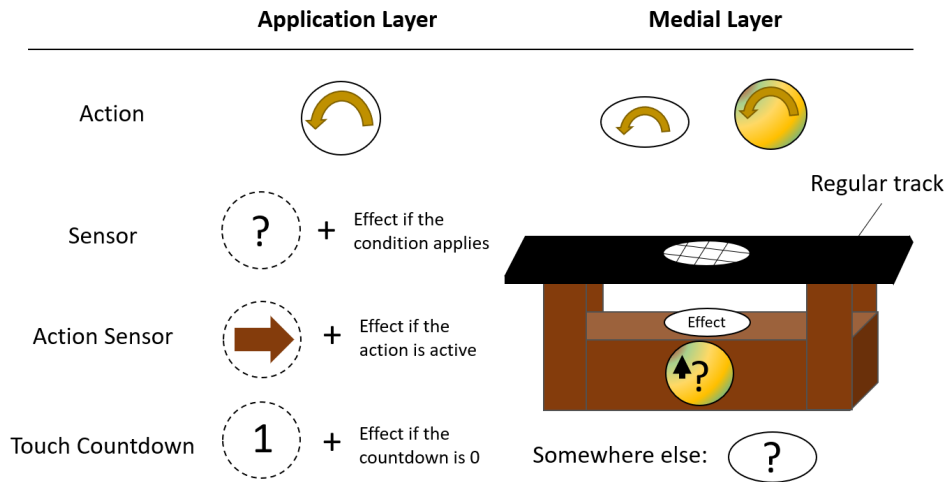
Application Layer   **Medial Layer**

Action

Sensor   ? + Effect if the condition applies

Regular track

Action Sensor   → + Effect if the action is active

Effect

Touch Countdown 1 + Effect if the countdown is 0

Somewhere else: ?

Figure 11: Symbol seals

Application Layer   **Medial Layer**

Gear wheel

Touch-Buttons

Barrier with Sensor = Conditional   ?
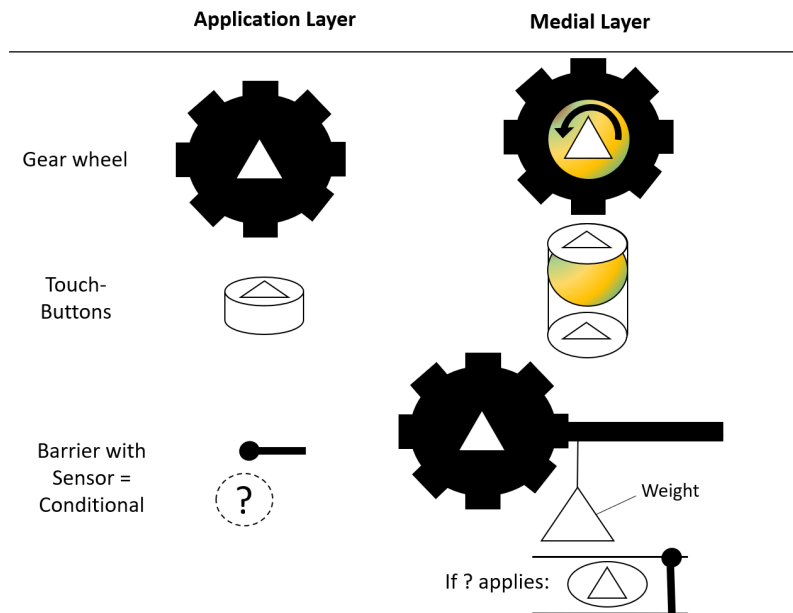
Weight

If ? applies:

Figure 12: Mechanical components to build marble-run apparatuses

5 COSMIC LAYER: THE MARBLE ORE

In this section will be explained, how the communication between different marbles and their interpretation of symbols works. It will also be further elaborated on, what marbles in the Pinocchioverse are (an ore) and one will get a better understanding of some of their special properties. In other words: in the last sections, the functions of the marbles were just taken for granted and not questioned. In the cosmic layer, the cosmic laws, which make them behave as they behave are described, making for a more round understanding of the world of the Pinocchioverse.

This will be further explained in the next section. Also, each marble has access to a basically infinite amount of energy inside them, which will become clear later.

5.1 The marble ore collective

First of all, the marble ore is an ore floating in space in the form of asteroids, occasionally hitting other planets.

The marble ore has many interesting properties. For once, instances of the marble ore are always perfect spheres, which may vary greatly in size. Furthermore, each marble has access to an infinite amount of energy saved inside it, which can be made use of for rotating the marble. Also, if different marbles touch, they

are activated and if configured correctly, they can transform said energy into physical energy, meaning rotation.

The other main property of the marble ore is that every instance of the ore in the whole universe is connected to each other instance of the marble ore. That means that all marbles are directly connected to one another. Through symbols, which were already introduced in the last section, marbles can be activated over these connections without them touching. That means through their cluster-form, they are able to process information, usually symbols, for example to form connections between instances and active each other's powers. This is done by sending a message with the written symbol to all other marbles, which they answer whether they have the same symbol written on them or not. If this is the case, they are activated and send a positive answer back. If not, they are not activated and send a negative answer back. Depending on the answers from all the other marbles, the initial marble is activated if there was at least one other marble with the same symbol, or not, if there was none. This was also already be made use of in the last sections to remotely activate a marbles power without needing to touch it with another marble and use it for technical innovation.

The collective union of all marbles in the universe is called the marble ore collective, the marble net, the marble cluster or the marble myzel. The marble ore is unbreakable, it cannot be melted and crafted together with other marble ore instances. That means that the marble ore collective will always stay fully intact.

A representation of parts of the marble ore collective can be seen in Figure 13.

One does not need the marble net to understand how any of the last examples work, neither does it give one any advantage in constructing marble-run devices; however, it does give one a better understanding of the marbles and the workings of the world of the Pinocchioverse in general and makes for an overall rounder world understanding, contributing to a more confident and possibly also more effective use of marbles, marble tracks and the devices they run.

5.2 Processing of symbols and symbol sequences inside of marbles

In the last layer, the processing of symbols and their sequence inside of marbles was just considered working. However, in this layer it is assured that inside a variable is endless energy and endless storage and processing power for any command sequence written on them.

6 USAGE IN CLASS

Because upper layers are more abstract and thus harder to understand, it should be started with the application layer, and slowly build up to the cosmic layer. Figure 14 shows a proposition for using the Pinocchioverse in class, ultimately, to enable an accessible entry to actual "hard" computer science knowledge. The question remains, whether the cosmic layer need to be taught at all or whether it should be assumed that the knowledge is automatically acquired by the interaction with the world and its stories. Probably, it does not need to be taught, because it does not give one any new possibilities that cannot be done without the knowledge of the cosmic layer. However, it is still necessary for it to be there, to have a consistent

world to build teaching material upon even if it is not explicitly mentioned in class.

After looking at every concept of marble steampunk, a more complete overview can be seen in Figure 15, and slightly modified suggestion how to teach them in Figure 16.

6.1 Adaption for the classroom

As the introduction, the modified version of Pinocchio is told, which introduces marbles as a way of constructing complex mechanical devices. Then the teacher could show the children real marble tracks and go on to show them how they could do actions with them in the Pinocchioverse. Then the teacher could start with existing exercises, video games or virtual environments based on the Pinocchioverse, or create ones themself.

6.2 Integration in original Pinocchio-Story

For that, the original tale of Pinocchio needs to be modified such that it serves as an introduction to the Pinocchioverse. This could for example look like the following: Geppetto does not bring Pinocchio to life with magic. Instead, one day he sees a star fall from the sky and hit behind his house in the nearby forest. He goes searching for it and finds a perfect sphere in the middle of a crater, but it is not hot at all. He carries it home and discovers that it consists out of a fascinating new ore, which he soon finds out that it has some remarkable properties. He then builds with the new ore Pinocchio and together they build new apparatuses. At some point of the tale, Pinocchio and Geppetto together share their knowledge of the new marble ore with the people of the local village and build apparatuses to make all their lives better.

6.3 Creating own teaching resources

Teacher, schools or researchers could also decide to create their own learning resources based on the Pinocchioverse. Because it is free and open-source, this would be possible without hurdles. The Pinocchioverse could be adapted for various media, including standard exercises, stories, video games and even virtual environments. Possibly, depending on the media, teachers/schools and researchers may need to cooperate with publishers to realize their ideas.

7 OUTLOOK

In the future it could be thought of to expand the cosmic layer of the Pinocchioverse and give the marble ore collective more powers to process information. This could enable to also teach basic concepts of networking through the Pinocchioverse and possible explore different aspects of programming through marble tracks as well and enable new devices to be constructed. Because it would have consequences for the other layers, the theory of the cosmic layer would have more relevance and therefore the motivation would be higher to acquire that information. However, it would need to be made sure, that the overall workings of the universe stay consistent and the new ideas do not feel as if they have been added as an afterthought.
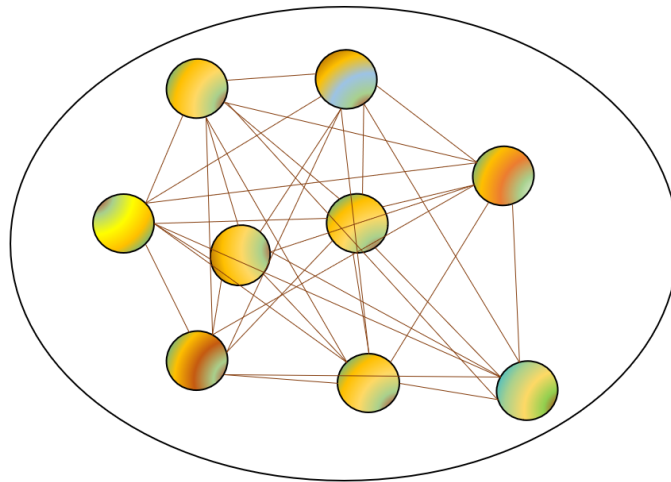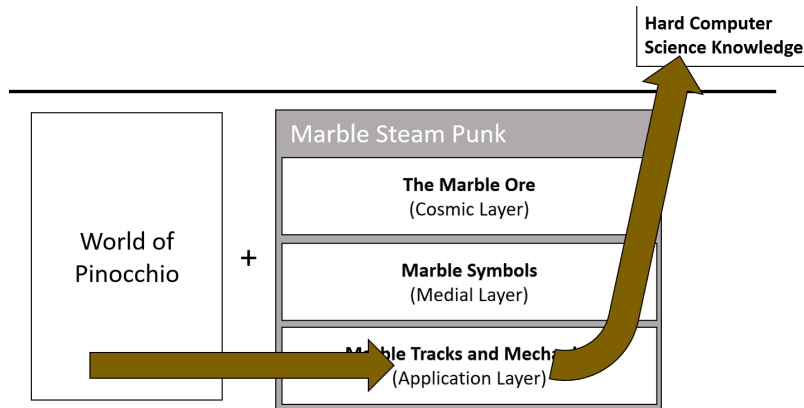
Figure 13: The marble ore collective

Figure 14: Pinocchioverse used in class to enable slower entry to hard computer science knowledge

Figure 15: Complete overview of the concepts of marble steampunk
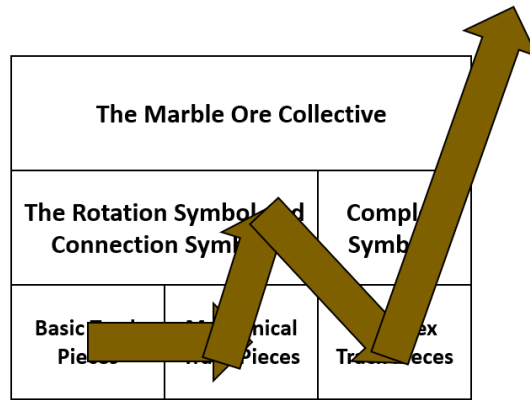
Figure 16: Suggestion for teaching the concepts of marble steampunk