Automata

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Abstract

An automata is a simple machine operated by a single source of energy, usually from a crank, which is turned by a person, transferring kinetic energy to the rest of its components which are designed to help create a specific movement to bring entertainment by telling a story. Besides entertainment, the same concepts and designs are also used in machines. However, many people do not know what an automata is, the basic parts of an automata and the mechanisms involved. Thus, we have decided to solve this by constructing an automata that allows people to see the mechanisms below working with the crank turning, and to observe how each part or mechanism works. The automata will also be made to tell a story, enabling people to see how different parts of an automata work together to help the system function and also be engaging and interesting, while exhibiting one of the purposes of automata which is entertainment. Throughout our process to construct the automata, we had thought of many designs, and due to the Covid-19 situation, spent more time testing out individual components and using 3D design software to get the dimensions and ensure that the automata would fit together, before finally booking the labs to construct our final product together when restrictions had eased.

Introduction

Automata

Automata has many components which help transfer kinetic energy to create many different types of movement.

Gears are the most basic and most commonly used parts of an automata. They can be found in different mechanisms, from old clocks to modern machinery. Gears help to increase speed or force, as well as transfer kinetic energy to other gears. Gears are mechanisms that have teeth that intersect the teeth of another gear to transmit energy.

Pictures of different types of gears

Pulleys are mechanisms that help to transfer force in a circular/round manner. They work similar to gears but are not directly joined but linked by either elastic bands, tubular springs or other flexible but strong materials which is referred to as a belt. To stop the belt from slipping they often have grooves in them, keeping the belt running in a straight line. These mechanisms can be found in some conveyor belts. They are useful for getting drive into awkward places.

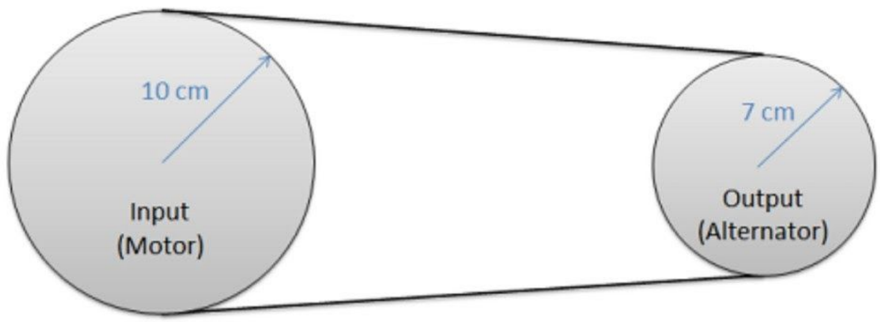


Diagram of pulley

Ratchets are devices that help to prevent parts such as gears from turning in the opposite direction or stop the movement of a gear immediately and abruptly, by producing a jerky movement which pushes a gear in the opposite direction that it is rotating, therefore stopping the movement of the gear. It is useful if you want to make a mechanism stop suddenly.

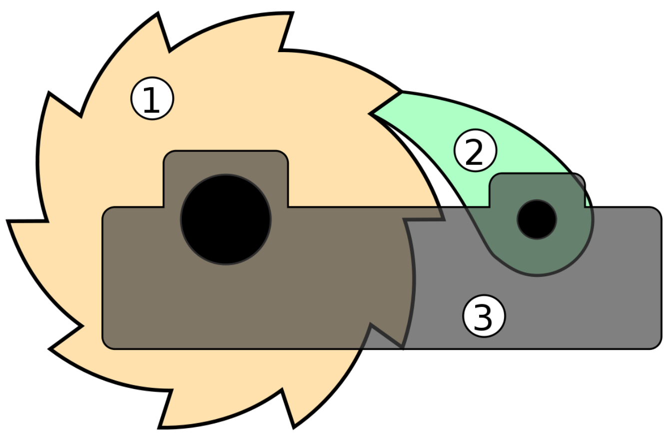


Diagram of ratchet

Cams are like small computers which store information that can be turned into movement. They can be very simple or complex and the only limitation is their size. Cams normally work in conjunction with a "Cam Follower". As the name implies this follows the movement of the cam and transfers the movement to the working area (object on top). The cam follower is normally a rod made of wood or metal which is supported by a shaft that limits the movement and direction.

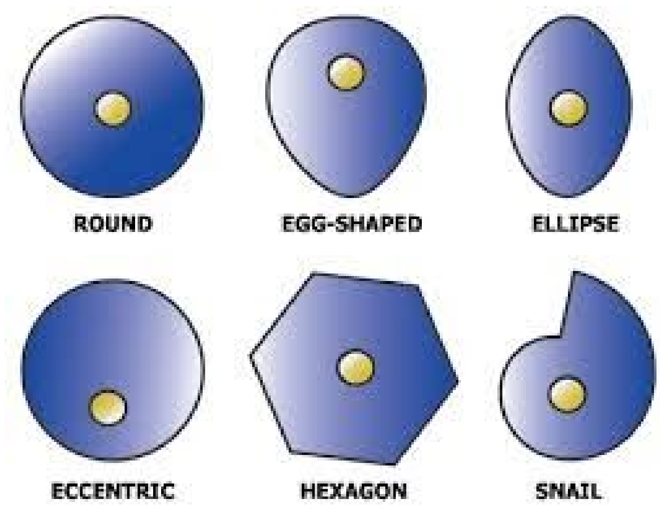


Diagram of types of cams

A crank is a useful part of an automata, as it is the part of the automata which people turn to make the automata start moving. It is turned manually, thus transferring kinetic energy to the crankshaft, which transfers it to the different parts and mechanisms attached to the automata.

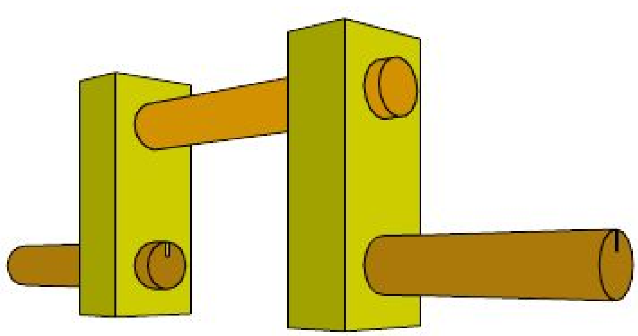
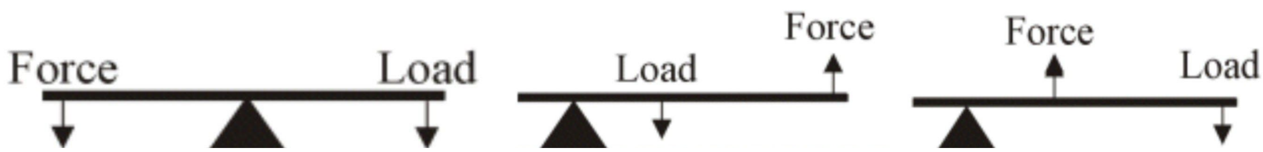


Diagram of a crank

Levers are mechanisms that apply force or transfer it. Normal levers consist of a stiff length of wood/metal pivoting around a fixed point called a fulcrum (similar to a see-saw).



Different types of levers. First order lever, second order lever and third order lever respectively

Problem Background

The problem is mostly in teenagers as most of them are not familiar with the basic parts and mechanics involved in an automata which makes it function, nor do they know exactly what an automata is and how it is beneficial and useful in our lives today. This can be seen from our survey results below, from a Google Form that was conducted early in the year.

Evidence of problem

Through the conducted survey of 10 people aged 13-14, we found out that: All did not know what an automata was and were unable to name parts. 30% felt that it was important for them to understand automata. 50% were unsure if it was important to understand how an automata works. 20% did not feel that it was important to understand about automatas. 80% felt that playing with toys which used the mechanisms of automatas would allow them to have a better understanding of automata.

Implications

Although the sample size of our survey was very small, it was definitely clear enough to show that people do not know much about automatas, and that our project will be beneficial towards them since about 80% of them felt that our solution, an automata toy, would be effective in giving them a better understanding of how mechanisms like these work. The aim of our project is to educate them about automatas. Knowing how an automata works is important as it allows them to have a better understanding of how to use machinery and objects with automata parts efficiently, which mostly include automata-like mechanisms as an integral part, allowing them to use it efficiently and be able to do repair work properly, such as repairing cams and cranks properly, or not replacing a gear with a gear that has a different number of teeth. It also allows people to know how to repair or build automatas in the process of assembling, disassembling and repairing. Learning how an automata works also allows people to learn how to innovate and create solutions to problems using automata in machines, especially when jobs in the future will likely be replaced by machinery which mostly involve the use of automata. Learning how an automata works will also promote logical thinking, as creating an automata will require the person to think about how it can be designed to operate smoothly within its capabilities.

Our Solution

We think that the lack of this knowledge is due to the fact that they do not have sufficient opportunities to interact and play with automatas, or that most basic automata comes from geared watches, toys and clocks etc. that are becoming increasingly uncommon and their components are hidden. Thus, our project will help to create an automata which will provide an opportunity for others to learn more about automata through first hand experience which is fun and engaging and our product also allows people to view the components within the automata as they are playing with it to see how every part works.

Solution Design

Ideas

We first formed a few ideas of a suitable storyline, which we then thought and discussed about how we would use automata to accurately present the storyline, taking into account the physical limitations and whether the ideas would be too complex to construct, while aiming to represent the most number of different components. After meeting up several times and having many discussions, we decided that our solution would use the theme of artificial intelligence (AI) as its storyline in order for it to be engaging and relatable. On the above section of the automata, it shows a camera using AI to detect the patterns and features on the face of the 2 characters in order to recognise which is the wanted criminal, causing the sign to indicate a cross and the barrier to be let down to stop the wanted person, whereas the policeman is unable to identify and distinguish the bad person from the good person and allows both characters to pass. This further emphasises the role of AI in our story, and the storyline will show that AI can do things that humans cannot. This is done through the use of gears, which help to move the characters in a circular motion, and cams, which help to move the policeman's arm to indicate he allows both characters to pass, open and close the barrier and push the sign. People will be able to see the mechanisms from the front of the automata, which is open, helping to teach people how the different mechanisms move and can be used to create a storyline.

Processes

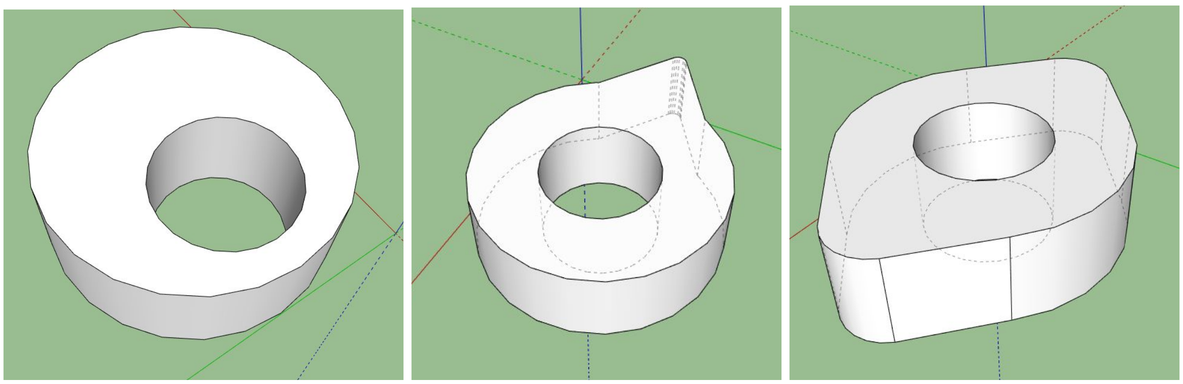
Planning

With the storyline, we decided to start creating the 3D designs on a design software, SketchUp, to get an idea of how the design would look like and whether there were any parts or dimensions and mechanisms that we had not previously considered, which would act as a replacement for meeting up physically due to restrictions. At the same time, we also constructed the components we would be using out of cardboard to learn more about and test the components themselves, such as by constructing the cams using cardboard, we had learned that the cam followers would easily slip past the cams if not placed properly or if the cams were too thin. We also learnt that if the cam was too big, it would cause the cam follower to get stuck. At the same time, we learnt that the crank could break very easily due to the shape. This process allowed us to familiarise with the parts of the automata that we would integrate into our project and final product. Through the use of the 3D design and this process, we had discovered that we had to use different types of cams and that we had to use a specific type of gear.

Cam model made with cardboard *Gears made with cardboard*

Parts: Cams

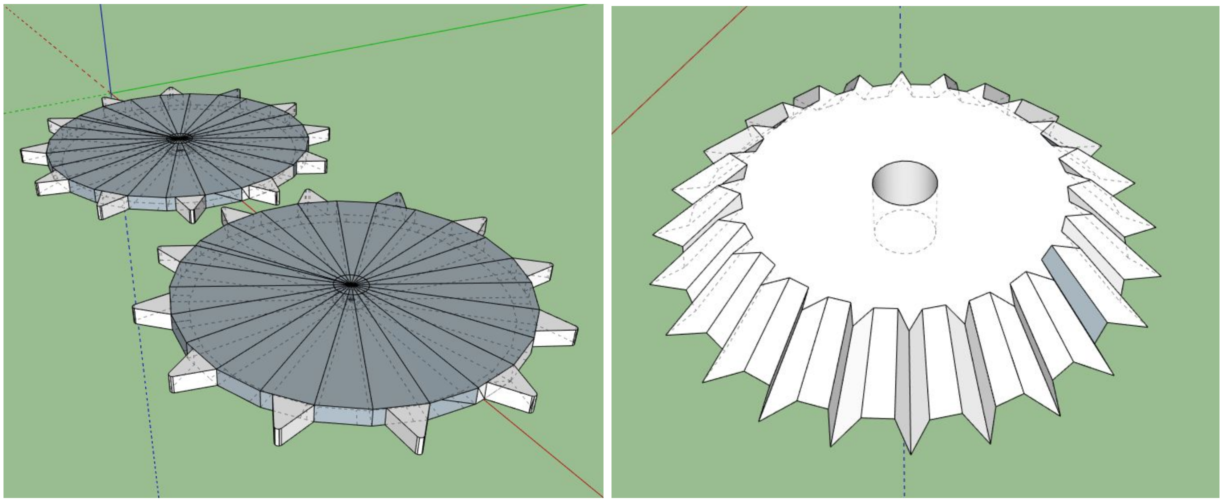
Due to the 3D designing process, we had found out that the cams needed to be of different types. The first type would be the eccentric cam, which is a circular cam where the crankshaft would be off centre, creating a rise and fall in the upwards and downward movement of the cam follower. This would be used for the tick and cross sign, as it would move the sign up and down once per revolution which would correspond to the 2 characters. The next cam would be the egg-shaped cam, which would be a circular cam with a crankshaft through its centre point and an edge elongated to help push the cam follower up and down for a short time. This would be used in the barrier, as the barrier needed to close for a short amount of time or it would hit the characters. The last cam would be the circular ellipse cam, which would be a cam with a crankshaft through its centre point and with 2 opposite sides having protrusions to push the cam follower up and down twice in one full rotation. This would be used to move the policeman’s arm, showing how he allowed the two characters to pass through. The dimensions of each cam was chosen such that they would move the cam followers the correct height.



Picture of 3D designed eccentric cam, egg-shaped cam and ellipse cam respectively

<u>Parts: Gears</u>

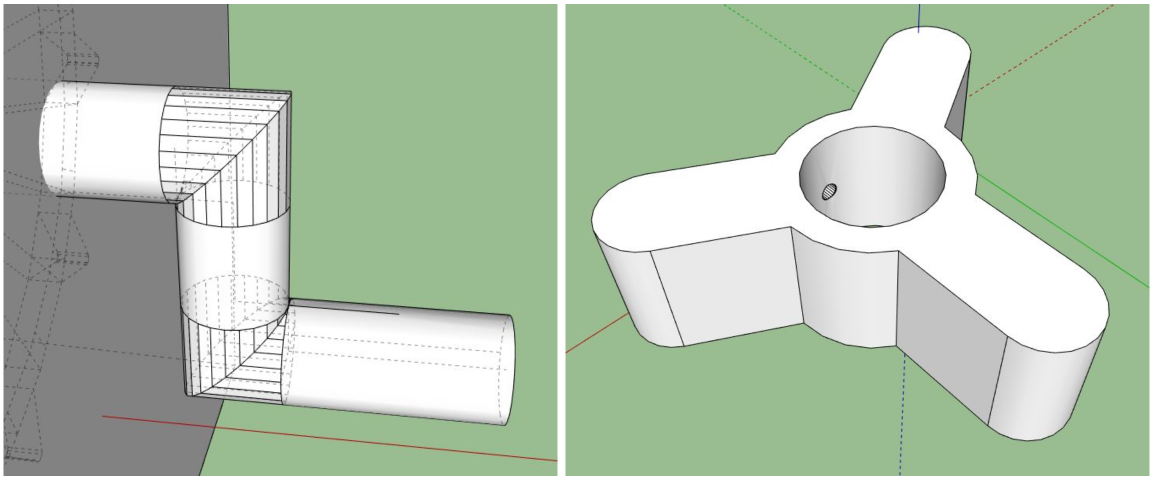
In the beginning, we had decided to use spur gears, the simplest type of gears, to be used to transfer movement from the gear placed vertically attached to the crankshaft to the gear placed horizontally above. However, upon further research, we decided to use the bevel gears, which would be able to transfer horizontal and vertical motion between the two gears much better. The dimensions of the gears were chosen such that they would be able to intersect one another to transfer the kinetic energy efficiently.



The picture on the left shows the previous gear design while the picture on the right shows the final gear design

Parts: Crank

At first, we decided to use a normal crank (shown in the picture on the left) as it seemed easier to turn, and that most basic automatas used that kind of crank. However, we saw another automata that was made by our seniors with a crank that looked like the one in our 3D design on the right. After careful consideration and planning, we decided to use a crank inspired by the model that we saw, which we 3D printed using the 3D design on the right, as the previous design broke easily when we were testing it, and at the same time, the shape was difficult to create. The small hole in the side of the crank was originally for a screw/nail to be drilled/hammered in in case the crank handle slipped off the wooden crankshaft, but in the end we did not need it.



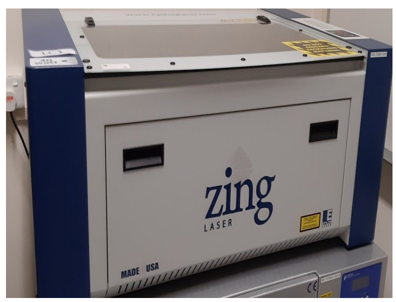
The design on the left was the previous crank handle design, while the design on the right is the current one

Parts: Others

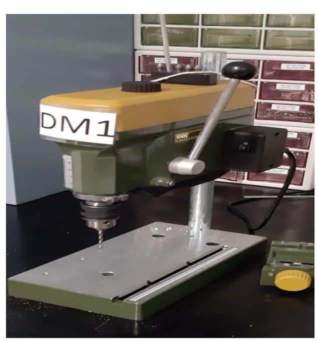
These parts are not automata components. However, they were used to help with the storyline and ensure that the automata functions properly. For the crankshaft, wood was used as it would be strong enough to hold the objects while it could be easily cut to fit the dimensions. We would use pieces of wood to help hold up the gear and one cam, as the gear had to be placed horizontally and had to be held up, while the cam follower was not directly above the cam and had to be pushed by the wood piece, which acted similarly to a lever. The characters, barrier, signboard and various other parts used for aesthetics and storyline were cut out of wood that was available too. The box was also cut out of blocks of wood which would help to hold the entire automata together, and the dimensions were all carefully calculated to ensure the dimensions would be correct, while at the same time being tested on the 3D design software.

Creating, trimming and drilling the parts for the automata

We used several different machines in the Physics lab In the Science Research Centre, such as the 3D printer, the scroll saw, the drills and the laser cutter. The 3D printer was used to design the cams and cranks using hardened plastic as the material. We used the 3D printer for these parts as the dimensions would be the most accurate and precise compared to other methods of making them, such as cutting and sawing. The scroll saw was used to cut blocks of wood in for the parts and figures in the automata, such as the box, the shaft, the good and bad figures and the policeman. This saw was automatic and made sawing very easy and effortless compared to the other methods of sawing and cutting. We do not have the strength and accuracy to use manual saws to cut the blocks of wood to our dimensions accurately. The big and small drills were used to drill holes in the wood for parts such as the crankshaft and the barrier. The bigger drill was for thicker pieces and wood and bigger holes, while the smaller drill is for thinner wood and smaller holes. Lastly, the laser cutter was used to cut the circle for the figures to move and rotate. The laser cutter was able to cut a hole in the middle of the wood and the dimensions are also accurate, so the figures will not get stuck or fall over due to the hole being too large or too small, and at the same time cutting a circle accurately using any other means would be too difficult.

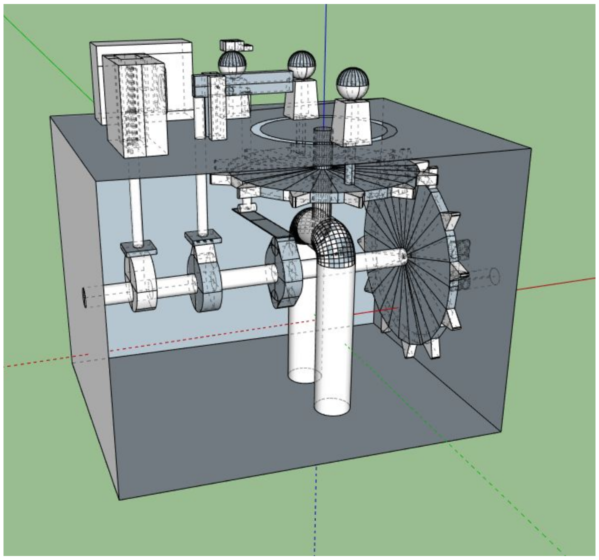
The pictures show the scroll saw, laser cutter, 3D printer machine found in the SRC physics lab

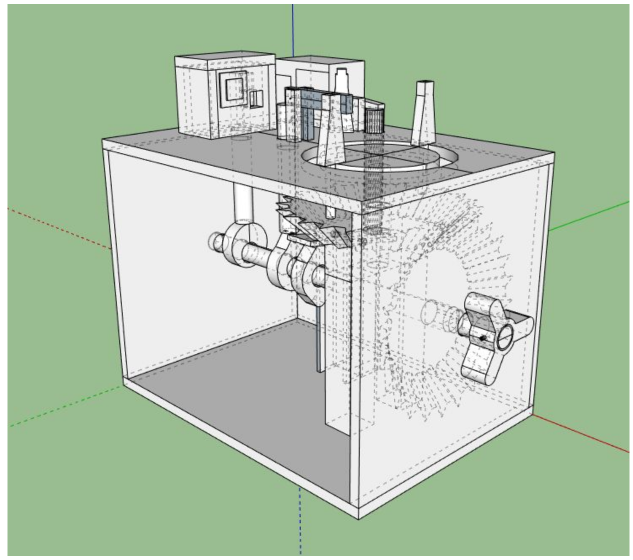


The pictures show the 2 drills for different ranges of drill bit sizes found in the SRC physics lab

Summary

In summary of our solution design, these are the different designs, from the previous to the final one, including the final product and the different parts.





This picture on the left shows the initial design, while the one on the right shows the final design

The picture on the left shows the gears and cams that we 3D printed, while the picture on the right shows the pieces of wood we used, along with the crankshaft.

Results & Discussion

Our Findings

By creating a Google Form, we had sent out a video of our automata in movement, asking for feedback from others. In the form, open-ended questions were used for our group to receive clearer feedback on whether the respondent was able to learn more and whether there were any problems with our product. Out of the 21 respondents, all of which aged 13-14, none had a clear understanding of what an automata was before watching the video. However, after watching the video, 17 agreed they had learnt more, which was a big majority, as the automata allowed them to see how the parts functioned and interacted with one another, while those that did not agree felt that they were unable to see certain parts of the automata, and thus did not understand. Others felt that the model looked flimsy.

Response

Regarding the responses that the automata had hidden components, this was due to the angle of the camera and the lighting at the time of the recording. At the same time, this toy would be meant for them to play with in person, which would mean they would be able to spend more time to get a closer look at it, as some components are not very obviously shown due to the storyline affecting the layout of the pieces, and that some of the mechanisms may be blocked by the others. Regarding the concerns that the model was flimsy, the box and most parts of the model was made out of wood, while others were made of durable 3D printed plastic, and was glued together with hot glue. The design was also made to ensure the model would not have any mistakes through using calculations and 3D modelling and also using “sleeves” stuck to the box to hold the cam followers and ensure they would not slip and cause problems. Thus, the model will not break or fall apart easily.

Conclusion

Significance and possible application of findings

We learnt that a good storyline which captivates the people who play with them will make an automata more effective in its purpose of teaching users the functions of the different parts in them. We now know that being able to interact and physically play with our product will help users to learn more instead of reading information and looking at images as the fun and real life experience is not therapeutic.This automata can be used in both primary and secondary schools for students to play with and for them to learn how the various parts and mechanisms work in automatas. Various different automatas with different parts and storylines can be displayed in science exhibitions in places like the Singapore Science Centre and the Art and Science Museum. These automatas will attract people's attention as they can be decorated to make them look attractive, or can have detailed and complex mechanisms to give the characters and props above multiple movements which can impress the viewers.

Limitations and recommendations to solution design

Firstly, the automata we created may fall apart if it is not used with care and also due to wear and tear. This is because the glue which is used to join the different parts together may break off or become loose over time due to excessive use. Secondly, the automata did not come out perfectly the first time it was made and had some issues in its functionality, so many checks and corrections had to be made to ensure that it would be in perfect working order, for example the orientation of the cranks, the height of the gear supports, cams and more. The process of brainstorming for ideas also took time as some of the storylines were not feasible due to the lack of access to the required materials, limitations in capabilities of automata components or due to its size. Therefore the process of making an automata was extremely time-consuming and laborious. Instead, the automata could have been made using stronger materials, but at the same time this would have added greater difficulty to our assembly process due to limited materials and time.

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