Task 1: Chording Keyboard++

A high-level description of a new chording keyboard design

The initial prototype consists of a flat foundation as a base and five flexible sticks as shown in Figure 1. These five flexible sticks are used as controllers and are attached to the base, they differ in different lengths. When a stick is sensed as being vibrated, it sends the signal to the microcontroller, and the microcontroller runs the code to find the corresponding alphabet to the stick vibrates.

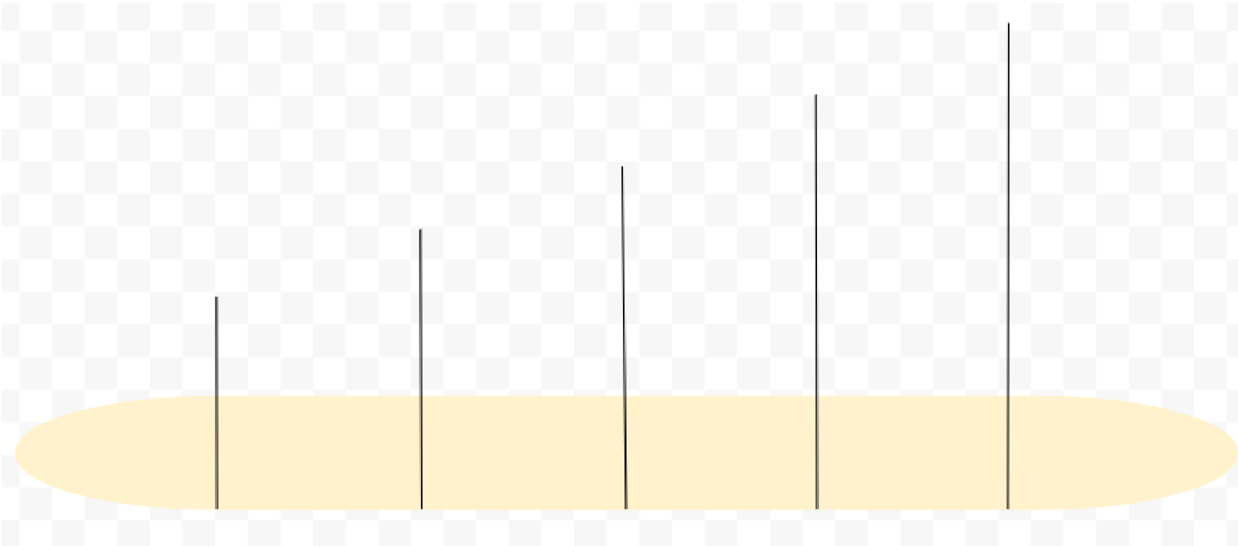

Figure 1: The design of initial prototype

The high-level prototype consists of a flat foundation as a base and five rockers as shown in Figure 2 in the later part. These five rockers are used as controllers and are attached to the base with springs, they differ in different colors. When a rocker is sensed as being touched and vibrated, it sends the signal to the microcontroller, and the microcontroller runs the code to find the corresponding alphabet to the rocked rocker. Each rocker represents a alphabet on its own, but to represents 26 alphabets, I add a function to each rocker that the rocker can be tuned by itself and change the corresponding alphabet. So, there is tuning indicator on the base to show which alphabet the rocker is turning to.

A list of sensors required

For the rocker being sensed, using force-sensing resistors and resonant sensors.

A description of the fabricated parts necessary for your design and how you would make them.

I use piece of wood as base, and 3D printing for the springs with non-flexible material, so they are stable but bouncy due to the structure. Then connect them to resonant sensors, and on top of the spring, the gap between the spring and rocker, there are gears to indicate the rocker tuning function. The rockers are connected to the force-sensing resistors.

A diagram of your diagram.

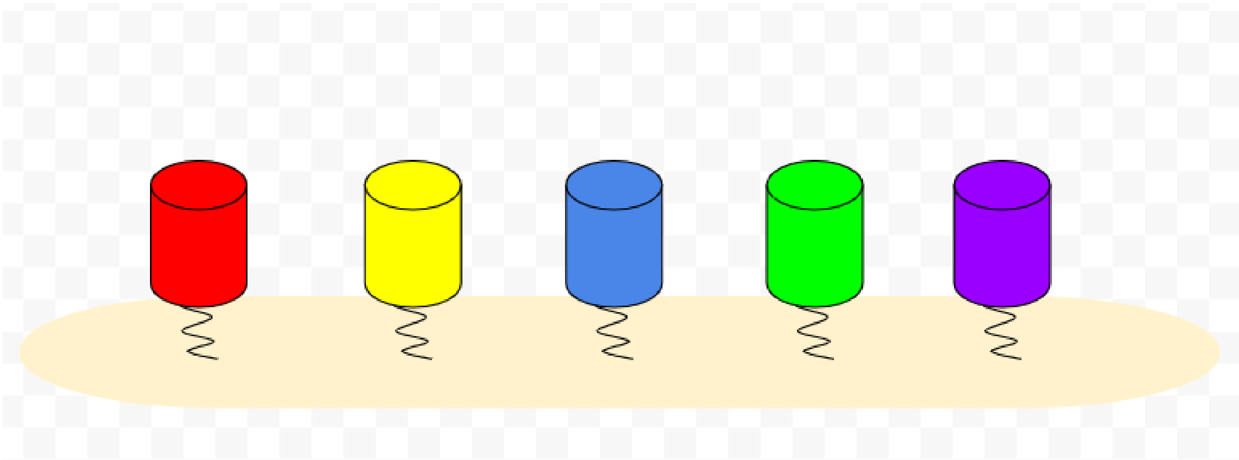

Figure 2: The design of high-level prototype

A high-level description of the software or firmware necessary.

For the tuning part, connect each rocker to the force-sensing resistor and resonant sensor. Because of the structured gear, when the rocker is tuned, it first sensed force, then the gear provides sound which gives sound frequency to the resonance sensor.

Task 2: Theory & Evaluation

The published paper I select is "Ion A, Frohnhofen J, Wall L, Kovacs R et al. 2016. Metamaterial Mechanisms: Proceedings of the 29th Annual Symposium on user interface software and technology. In: ACM Conferences. https://dl.acm.org/doi/10.1145/2984511.2984540. Accessed 15 May 2022".

Metamaterials are objects created by artificial structures with repetitive patterns usually based on 3D cell grids. The essential concept of the paper is to think of metamaterials as machines that perform mechanical functions instead of physical materials. The key element of their research on metamaterials is to transform mechanical input forces and movement into mechanical output forces and movement. Furthermore, they implemented a specialized 3D editor to design metamaterial mechanisms efficiently with different structured cells. It can also simulate how the designed structured object performs under mechanical input forces and movement.

Theory

The UI theories authors have used are Direct Manipulation, Post-WIMP UIs, Reality-Based Interaction, and Instrument Interaction. The theory I think they used on this research the most is Direct Manipulation, so I will discuss the paper based on this theory.

In this paper, the authors achieved metamaterial mechanisms by designing objects that support controlled directional movement, which means the objects need mechanical forces to activate the controlled directional movement to transform mechanical input forces and movement into mechanical output forces and movement.

This transformation indicates there is an immediate effect on objects from mechanical forces. For example, the metamaterial door latch transforms the traditional rotary movement into linear movement by the special designed cell grids, so once the mechanical input force and movement are applied, the central hinge of the cell grids can deform, and lead the whole structure to move and pull the latch inwards, so it gives the same output as the traditional door latch. The output movement is performed by deformation with no physical friction, which reduces wastage and maintenance.

Also, there is execution and evaluation gulf between the design and the final product. The 3D editor is an easy toolkit to learn to design and modify metamaterial mechanisms. The 3D editor simulation shows how the designed object performs under a simulated mechanical input force and movement which gives direct feedback on whether the designed metamaterial gives the expected mechanical function, which also is a continuous representation of objects of interest.

The 3D editor’s simulation tries to span the gulf of execution, in this case, the object of interest is the simulated designed object. Under the simulation, users can play around with using different materials, and different force directions and so on, to see more about the usability of metamaterial mechanisms. The 3D editor's simulation also tries to span the gulf of evaluation, in this case, the object of interest is still the simulated designed object. As under the simulation, if the simulation fails, users can check whether the error occurs because of material, force, force direction, etc. Then the users can do modifications immediately and test again. If without the help of 3D editor's simulation, users must try to 3D print the designed product and wait for it to be successfully printed first before testing the actual application. Many users may fail plenty of trials during printing because of the uncertainty of the 3D printers' quality, and the success rate of 3D printers affect by various factors, such as the material types, the printing temperature, whether the designed structure fits to the printing method and so on. It takes a lot of time before the application test. Therefore, the 3D editor simulation method helps the evaluation in the design stage, gives fast, incremental and reversible operations with immediate effect on the product's simulation, but not in the production stage due to the same issue of 3D printer uncertainty. These limitations are the reasons for execution and evaluation gulf.

Here are some of my suggestions, since the metamaterial mechanisms object are designed in the 3D editor to fabricate using 3D printers. However, there are some researches about metamaterial mechanisms are focus on fabricating with other methods, which not use 3D printers' materials. The 3D editor could add more material choices, or design a material toolkit, that the users can manually add the features of variety of materials to test more on the simulation.

Evaluation

The UI theories authors have used are Past, Present, and Future of User Interface Software Tools (PPF), Evaluating User Interface Systems Research (Sys), and Evaluation Strategies for HCI Toolkit Research (Tool). I will discuss the paper with all these evaluation methods, and then mostly focus on Tool.

The main UI problem is creating mechanisms with metamaterials. The authors notice that in the past the users traditionally used CAD software to design. To improve this user interface, they created a tool - a custom 3D editor including different types of cells and a range of functions and can simulate the object movement under input forces. This tool has a low threshold and high ceiling. It contains different types of cells which is the foundation of metamaterial and a range of functions which is the foundation of basic mechanisms. The simulation functionality increases the path of least resistance, as it gives feedback simultaneously during the modification.

The unsolved problems of metamaterial mechanisms are not adjustable, adding more cells increases stiffness, and unable to perform continuous rotation because the movement is performed by deformation and cells are connected, which affect the usability range of metamaterial mechanisms. They also have low usability, although there are traditional mechanisms to learn from and compare, metamaterial mechanisms still require lots of experience in 3D design, 3D editor and simulation, and printing success rate from 3D printers, which takes a long timescale for testing. Also, metamaterial mechanisms already have low viscosity according to their feature. They can not scale up too much because of the limitation of scale and quality of 3D printers.

One solution is to use multi-material 3D printers to print different regions in order to achieve different mechanical properties due to various stiffness. For example, the new research of a printer that prints hydraulics (MacCurdy, R., Katzschmann, R., Kim, Y. and Rus, D. 2016. Printable hydraulics: a method for fabricating robots by 3D co-printing solids and liquids. In Proceedings of ICRA'16 (2016)) give the 3D printed objects new features. However, multi-material 3D printers are limited to the omnidirectional mechanical behavior of traditional materials. This requires researchers into exploring another solution based on only using single material to achieve mechanical behavior.

Another solution is designing more types of cell grids and their combinations. It is driven by recent research in high-resolution 3D printing with structured pores (Bickel, B., Bächer, M., Otaduy, M., Lee, H.R., Pfister, H., Gross, M. and Matusik, W. 2010. Design and fabrication of materials with desired deformation behavior. ACM Transactions on Graphics. 29, 4 (2010)), that lower the material's resistance to uniform compression, so the overall stiffness reduces.

As I discussed earlier, the specialized 3D editor actually is a toolkit that helps users create and modify metamaterial mechanisms efficiently with combinable and different types of cells using a range of functions. The simulation function also gives simultaneous feedback to the designed domain objects. However, it does not simulate how metamaterial mechanisms perform if printed with different materials. Since the toolkit contains a range of functions to have basic mechanisms, I suggest it adds functionality to compute material stiffness and performance after printing, to simulate the metamaterial mechanisms not only with force and movement but more precisely with the products' physical features, such as flexibility, elasticity, stiffness. Another evaluation strategy is to explore more possibilities of new materials.