A discussion on the technology used in Recreation Room D

Abstract

The meeting was held remotely on 19 August 2022 5pm during the exhibition period of Recreation Room D, an exhibition under The Missing Link project. Recreation Room D is a technological recreation of a youth centre in the 1990s that explores the paradigm shift of interpersonal communication over the past three decades. It was exhibited at the Goethe-Institut Hong Kong, from 6 August to 3 September 2022. This paper documents the discussion of the technical aspects of the work.

Present

Kenny Wong	Artist and chief designer of Recreation Room D, director of Make Things Move.
Josh Tang	Hardware design and installation, Make Things Move.
Wesker Shek	Software design and installation, Make Things Move.
GayBird	Curator, the Missing Link.
Yan Lam	Project officer, the Missing Link.
Vanissa Law	Curator and project manager, the Missing Link.

Introduction

GayBird: The purpose of this meeting is to give our peers in the industry a brief introduction on the technology used behind the exhibits, e.g. what systems are used, and how different parts communicate.

Vanissa: When we are working on interactive exhibitions or performances, the major technical challenge is about how different parts communicate. It is very rare that we can use one single system or language to connect every part in the work. For instance, in this exhibition, the spectator playing the game provides the input. What will happen when a key on the computer keyboard is pressed? What journey does that piece of input data go until it gets to the robot arm? This is the information we want to record in this document.

GayBird: How many people are there in the team?

Kenny: I am the chief designer. Josh and Kelvin helped with hardware and kinetics design and installation, and the fabrication of the parts required. For game development we have Chai and Wesker, and 3 overseas freelancers that we hired online to help with the 3D modelling. Wesker and I were involved in the early development stage of the system design engineering, and responsible for the workflow of the whole project.

GayBird: Can you give us a brief introduction of the exhibits, Kenny?

About the work

Kenny: There were two exhibits that involved heavier mechanics: the Novuss, and the Table Football. The design process began by measuring and sketching the 3D models of the Table Football and the tabletop of Novuss. When the 3D models were ready, we constructed the mechanism of the automation of the gaming process. Simulations of the bigger movements such as movements of the motors, rocking of the Table Football, and the motions of the robot arm were done in the computer using the 3D models, while more concise and delicate actions were tested directly with the physical models. Josh was responsible for testing the smaller actions, making sure the football will keep running through the tubes every time when it falls from the opening of the goal.

Problem of limited space in Hong Kong

Kenny: Both the Novuss and the Table Football required a rather large aluminium frame to keep all the mechanical parts in place. Since both exhibits were built at Kenny's studio, at the beginning of the design stage we needed to take into consideration how to disassemble the exhibits for transportation and then reassemble them at the exhibition venue. As there were only 5 days for setup, the measurements needed to be precise and documented in detail. There was no room for mistakes.

Josh: Yes. It took about 4 people to transport the exhibits. To transport the Table Football machine we had to separate the machine into two halves in order to fit into the elevators and moving vans. Information about how the work was split, such as the exact positions of the motors, and how the cables, nuts and bolts were organised during dissembling, transportation, and assembling process had to be recorded in great detail to shorten the setup time.

Vanissa: And this will definitely increase the complexity.

Kenny: Yes. This is a puzzle we have to solve every time: how many pieces does the exhibit need to be broken into. It's not just the physical parts as well. The electronics would also have to be disconnected and reconnected. As such we had to build extra electronic connectors for this. This is a unique problem that Hong Kong artists need to face because of the limited space in this metropolitan city (figure 1).

Figure 1. The disassembling and reassembling of the exhibits due to limited space in elevators and transporting vans.

3D printing

Kenny: All of the customised parts were printed in-house. According to the need, four different types of materials of different toughness and impact resistance were used.

For example the connecting part between the head of the robot arm and the solenoid that propels the pucks took 12 hours to print (figure 2). We printed two just in case. The first one worked perfectly, and we kept the second one as a backup.

The other 3D-printed part is the distribution station of the pucks, which took 19 hours to print. There is another motor at the end of the distribution tubes, which pushed the pucks to the center of the table for the robot arm to pick up. This part had to be re-designed because in the original design the camera on the robot arm was blocked.

Figure 2. 3D-printed part attached around the head of the robot arm.

There were other minor but crucial parts that were printed as well. We printed 4 shields placed underneath the table to make sure the pucks follow the path and return to the reservoir. The lights around the Novuss table were also mounted by 3D-printed parts, for a cleaner and neater look.

In the Table Football, the motor that provides the torque of the control rods needs both strength and tenacity. We performed tests to find the maximum amount of torque that can be applied and not lacerating the 3D printed parts. Details such as how the parts are layered and the direction of the layering are needed to take into consideration.

GayBird: How does this compare to woodwork and metalwork? What is the advantage of 3D printing?

Kenny: 3D printing is essential in the prototyping process because of its precision.

GayBird: If most of the parts take more than 10 hours to print, is it actually more time consuming?

Kenny: 3D printing may seem very time consuming, but since the printer can work on its own, we usually finish the sketch at the end of the day and leave the printer to work overnight. The parts will be ready the next day when we arrive at the studio. It will take only another day if the parts need modifications.

GayBird: How many of the prints would turn out to be defective and need to be discarded?

Kenny: Since we have been using 3D printing regularly for the past few years we are getting better and better at it. Now we can usually get to a working design before the third modification.

GayBird: Is there a plan about what parts you need to fabricate? Do you sketch the parts based on the needs you encounter in the design process?

Kenny: We fabricate based on the needs that arise during the design process. That is exactly why 3D printing is handy.

Table Football

Vanissa: Josh, what was your involvement in this work?

Josh: I started with the installation of the motors on the Table Football. I sorted the parts that were ordered online. When they were sorted, I soldered wires onto them to make sure they are ready to be installed to the machines.

Vanissa: How many motors were there in the Table Football machine?

Kenny: There are eight sets of 18 motors that control the movements of the control rods, a motor that releases the ball at the start of the game. There are also two linear actuators that can rock the whole table when the player chooses; this is an “unofficial” move that players often do to the table and we wanted to include that in the virtual experience. There are also parts that are required to reset the game, such as the tubes that guide the balls back to the reservoir. A total of 18 motors and 1 solenoid are used.

We began by testing out the components needed to control one rod. The rod needs to move horizontally to adjust the positions of the “footballers,” and it also needs to rotate to perform the “shooting” or “kicking” gestures. Once the hardware and software to perform these gestures had been designed, we drafted a printed circuit board (PCB) for the final testing. There were 2 PCBs, one on each side of the table.

Josh: I was responsible for building the parts for all 4 control rods after the design for the first rod was finalised. That involved soldering of all the parts and PCBs, designing how the cables were wired and laid out.

GayBird: Is the Table Football we see now close to the original design? Did you make any major changes?

Kenny: Not really. It did not deviate a lot from the original design. Most of the effort was spent on testing and calibrating the parts, such as dropping the ball onto the 'pitch’ repeatedly to observe any errors that might happen, and recalibrate it again to ensure the ball drops onto the ‘pitch’ every single time.

Vanissa: What was the most challenging part in the fabrication process?

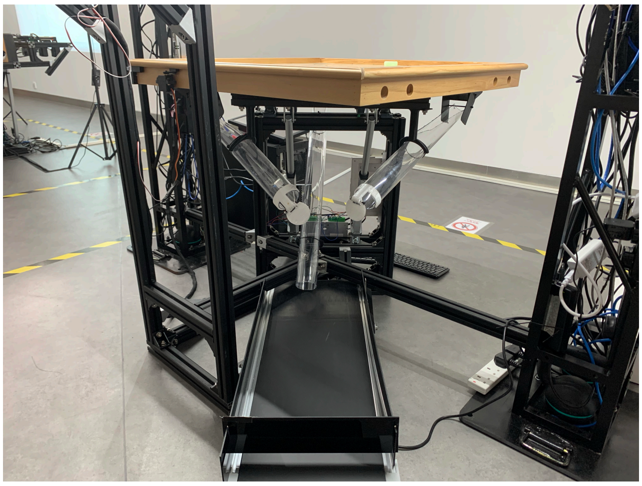

Figure 3. Tubes underneath the Novuss table to guide pucks to fall onto the conveyor belt.

Josh: One problem that took us a while to solve was how to collect the pucks underneath the Novuss table. Each corner of the table has a pocket, and we need to think of ways to collect the pucks from these four pockets. We put three collection tubes below 3 for each pocket to guide the pucks to a conveyor belt, which leads to a box where the pucks are stored (figure 3). The orientation of the tubes also need a lot of calibrations. At the end of

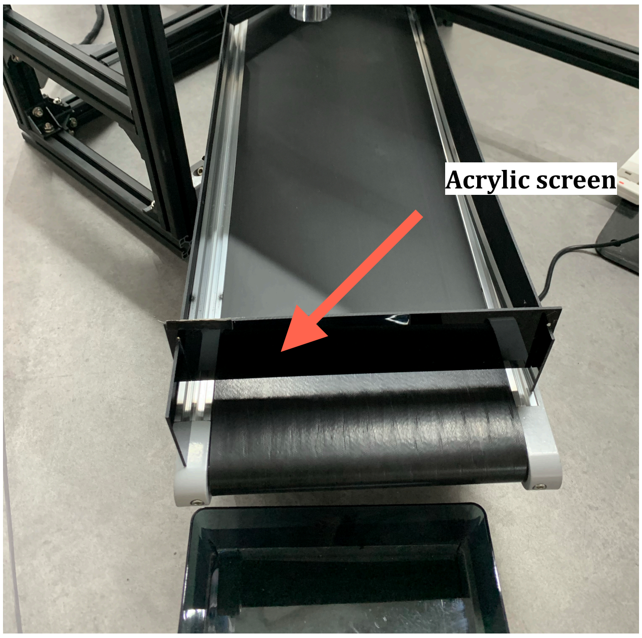

Figure 4. An acrylic screen was added to the end of the conveyor belt to make sure the pucks are falling into the box face down.

each game, the tabletop will be tilted so that the remaining pucks on the board will slide towards the bottom right pocket. This tilting limits the orientation of the collection tubes, which took awhile to adjust. Valves were also added to the end of the tubes to slow down the pucks; without them the pucks could bounce off the conveyor belt and drop on the floor. An acrylic screen was also added to the end of the conveyor belt to make sure the pucks would fall into the box face down (figure 4).

I think, in general, the tricky part is that it is very difficult to predict what problem will occur until we are actually testing things out. For example, during testing of the Table Football, the ball got stuck in the corner several times. The rods cannot reach the corners, so once the ball was stuck, there was no way to get it out even by rocking the table. In the end we solved the problem by adding a 3D-printed part to round out the corners, so that the ball would never get to the corners and get stuck in this location (figure 5).

Another 3D-printed part connects the exit of the ball and the tube that guides the ball back to the reservoir (figure 6). When the ball re-enters the vertical reservoir tube from the top, the momentum of the ball might push the balls at the bottom out of the tube. To solve this, the tube is inclined slightly towards the table, so that more force is needed to push a ball out of the tube. You could never anticipate small problems like these until the prototyping stage, and these need time, effort, and creativity to solve.


Figure 5. 3D-printed parts are added to round out the corners of the Table Football, to prevent the ball to get stuck.


Figure 6. 3D-printed part for the exit at the side of Table Football.

Vanissa: Any adjustments needed to be made for the 3D printed parts?

Kenny: 3D printed parts need adjustments and calibrations on-site. The testing done by computer simulation does not reflect all the possibilities that may happen in real life situations, especially situations that involve gravity, something that we rely on a lot in this project. For example, we spent a few hours adjusting the shape of the 3D printed part that connects the pocket and the tube for the Novuss. During testing, we realised that the puck would be stuck at the 3D printed part if it dropped into the pocket at a certain angle. Using metalwork tools we adjusted the size and shape of the parts. This is another benefit of using 3D printing because, compared to other materials, plastic, such as PETG and polycarbonate, is soft, and modifications can be done relatively easily on-site.

Novuss

Vanissa: Are you also involved in the making of Novuss, Josh?

Josh: Yes, but I only worked on the aluminium structure that holds the robot arm and lights.

Kenny: Novuss took more than a month to prototype. We started with the design of the pucks. Based on the weight and density of the traditional wooden pucks, we printed several pieces each day to see if the suction head of the robot arm could pick up the pucks every single time. We started with Fused deposition modelling (FDM), and with 0.3 microns layers, but the surface of the puck was not smooth enough for the suction head to work consistently. This could have been improved by post-processing methods such as sanding and polishing, priming and painting, or coating. However, considering the amount of pucks we have to produce, we thought it would be more efficient to increase the suction power of the robot arm head instead. In the end we used electromagnet, instead of suction, to pick up the pucks. To make the pucks magnetic, we inserted pieces of metals in the pucks midway through in the 3D printing process.

It took another four weeks to finish other more refined tasks such as calibration of colour recognition systems in different lighting settings, optimising the weight of the pucks, and determining the ideal distance between the pucks and the electromagnet.

Colour tracking

Kenny: Apart from deciding on the puck's shape, size, and texture, the colours also needed some prototyping to facilitate accurate and efficient colour tracking. The tracking was done by the RGB camera attached to the head of the robot arm. One thing we did not anticipate was the effect of ambience lighting at the exhibition space. There are a lot of windows in the rooms at Goethe Gallery. The amount of sunlight reaching the RGB camera affects the duration and result of the colour tracking process significantly. The problem was only discovered while we were setting up on-site, and left us little time to solve this. We eventually had to change the colours of the pucks. We sacrificed the aesthetics to facilitate the efficiency of the tracking process. Given enough time, the best way to solve this would have been to set up a library through machine learning. Building a data set that is large enough to perform machine learning, though, can take months however. So instead we changed the colours of the pucks.

Robot Arm & ROS

Vanissa: Is the robotic arm the biggest challenge of this project?

Kenny: Using a robotic arm in a real-time setup is the ambitious thing in this project. Since the arm was not designed to be controlled real time, the user manual did not give us a lot of information we need. Yes the exact measurements of the arm were provided, which are helpful for the computer simulation process, but a considerable amount of limitations of the arm that we learned about during the prototyping process, were not documented in the manual.

The movements of the robot arm are controlled through the Robot Operating System (ROS). It took a long time for the robot arm to 'think' about how to perform the task after receiving a command. The firmware of the robot arm is not open source, so we have no way to find out why it took so long for the robot arm to process the command. After we studied the error messages from the robot arm we believed this is due to the repeated safety checks being carried out to prevent itself from hitting other objects. Another possible reason is that the arm wrongly assumes it has hit something and refuses to perform the rest of the actions on the list. However, these are only guesses. The error messages are very primitive and do not give us a lot of information about what is going on inside the 'brain' of that arm.

These are problems that we face every day when using technology in art. These technologies are, most of the time, not built for the purpose of making art work. Including a piece of technology means endlessly testing the limits of the piece, and embracing its limitations as part of the work.

Vanissa: Wesker, were you responsible for dealing with the arm?

Wesker: Yes, I programmed the arm in ROS. ROS is a language that is used only by engineers. The syntax is not user friendly so the learning curve is quite steep. I spent a long time learning this prior to the project.

Telling the arm to perform one single gesture involves a lot of calculations.

ROS provides more than 20 types of algorithms to calculate the movement of the arm. So there are numerous possible movements, but they are not documented in a systematic way. Therefore it took us a lot of time to decide which algorithm works best with the movements that we need the arm to do. After reading some research articles, we picked 5 and tested them out.

The robot arm first one came out in 2017. That means the version we used has already gone through 5 years of revision. The manufacturer updates the software every time a new version is released, but the updates and performances are not documented in the manuals in detail. My experience is that the calculation speed varies a lot between different versions. New versions are not necessarily faster than the older ones.

The Game and Unreal engine

Vanissa: What environment was the game developed in?

Wesker: We wanted to develop the game in Unity, because that is the most commonly used game engine in Hong Kong, and it would be easier to find help if we use this environment. Since this game requires broadcasting and streaming, which are areas that Unity is weak in, There is no usable components such as WebRTC protocol in Unity to mimic real-time video streaming.

After some research we realised another game engine, Unreal, has more developed streaming functions. I built the 3D world using Unreal, and the streaming part was added to the game later by freelance engineers from Netherlands and Italy. Kenny then connected to the server through the internet from different locations. The latency was much more acceptable and so we decided to stick with Unreal. Another strength of Unreal is the level of detail (LOD) that it can achieve. It is also equipped with a lot of lighting pre-sets, which saved us a lot of time in building the scenes.

Vanissa: Yes, the graphic quality of the game world is amazing. I am sure the lighting plays an important part.

The ecology of the game design industry in Hong Kong

Kenny: Wesker was mainly in charge of ROS development and communication through OSC. After we were settled with Unreal, I hired freelancers online to do the game world modelling and to develop the multiplayer system. However, it was very difficult to find freelancers that are fluent in Unreal. Unreal is usually used by developers only, for the development of bigger game projects, film production, or architectural projects, whereas Unity has been accessible long before Unreal, and so has a larger community base which means it is easier to find engineers to work in Unity.

Vanissa: That means a lot of Unreal engineers are most likely hired by big firms; while freelancers more experienced with mobile games or smaller game projects use Unity instead of Unreal.

Kenny: Yes. We got in touch with a few programmers who are fluent in Unreal, but their experiences are limited to 3D modelling, instead of building multiplayer platforms.

Vanissa: I was quite shocked by this. I taught some courses in a game design programme at the Polytechnic University previously, and I thought we had put quite a lot of resources in nourishing talents in this field. Yes, almost all of my students use Unity, probably because this is the only game engine that is covered in the curriculum, but I had no idea we have such a shortage in this semi-professional or professional cross section.

Kenny: Yes. This is related to the ecology of the field. The time span of the projects in Hong Kong is usually very short, which does not allow enough time for research and development (R&D). For example, a seasonal project at a shopping mall usually takes less than 1 month to finish. If efficiency is always at the top of the priority list, studios like us will never be able to invest time to learn a comparatively complex environment such as Unreal. People who use Unreal are more interested in quality, not efficiency and cost.

Vanissa: Games that are developed in Hong Kong are usually of very small scale. The lack of opportunity for game designers to flex limits their imaginations. Graduation projects, both undergraduate and postgraduate, are usually of a similar size, with a small team of two to five people only.

Kenny: Leading game development companies such as EA and Ubisoft spend years, sometimes decades, to develop a game. It is impossible to find similar experiences in large-scale game development in Hong Kong.

Vanissa: A recently released game, Stray, uses scenes that look very much like Hong Kong.

Kenny: As far as I know, the 3D modelling of Stray was done by a team in Hong Kong.

Communication between the Game and the machines through OSC

Vanissa: What actually happens between the moment a player presses a button on the computer keyboard, and the moment the robot arm or the control rods start to perform the action?

Kenny: The Game and ROS (robot arm) communicate with each other through a software called Touch Designer which uses the Open Sound Control (OSC) protocol. The Game and ROS do not understand each other because they do not speak the same language. Touch Designer was therefore required as an intermediary to do the translation.

When a key is pressed, the game will send a message to the Touch Designer, which then translates the message to the ROS of the robot arm. The arm (or the ROS?) then does its own calculation to decide whether the action is safe and achievable before performing the action. After that action is complete, and before any other button is pressed, the arm will collect information about the current board layout (e.g. the locations and colour of the pucks, the XYZ position of the robot arm and head), and send this information back to the server through Touch Designer before the next action.

Wesker: When the game is running, the most time-consuming part is for the robot arm to determine the distance between the head of the arm and the tabletop. There are also a lot of obstacles in the surroundings, from the robot arm's perspective, such as the aluminium structure on the outside, and the pucks other than the target one on the table. For us human beings, our brains filter this information automatically, but for a robot arm everything looks the same and, due to safety, they are all treated as obstacles. During testing, the arm could perform tasks within 2 seconds in a much cleaner surrounding. When the setup is complicated up around the arm it definitely slows down the 'thinking' of the robot arm a lot.

Kenny: Table Football is relatively straightforward, because it does not involve ROS. When the game is initiated, all the control rods on the Table Football machine are restored to the default positions, and wait for the command from the players.

Limitations

GayBird: How do you deal with the limitations you encountered? There are limitations such as the amount of funding we can get, short project time span, or hardware limitations that can never be fixed. What is your approach on tackling these issues?

Kenny: In terms of hardware, Table Football is more straightforward. Novuss is where we had to deal with a lot of limitations. It is problematic, but at the same time I see that as a chance of pushing our limits. The robot arm brought most of the problems, mainly due to the incomplete and disorganised user manual. We had to learn about the mechanism and limitations of the arm on our own.

There is always a plan, but the plan is fluid. We have to evaluate the current situation and revise the plan constantly. When dealing with other art forms it is easier to plan and anticipate the results, but for ArtsTech there are too many variants that need to be taken into account. The changes in paint and brushes over time is negligible compared to the changes in technology.

The meeting concluded at 6:16pm.

Gallery

Figure 7. Pucks dispatch station on Novuss.

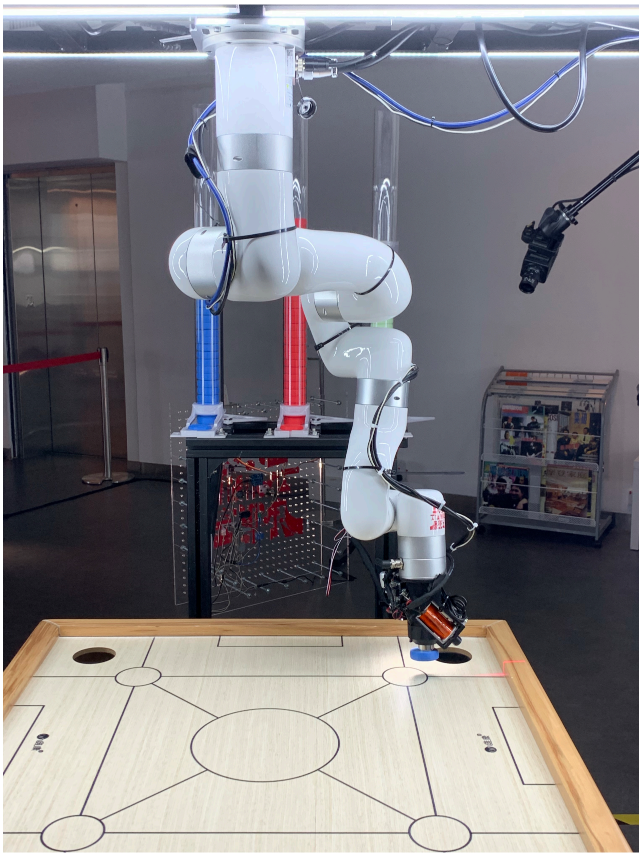

Figure 8. Robot arm and the Novuss table.

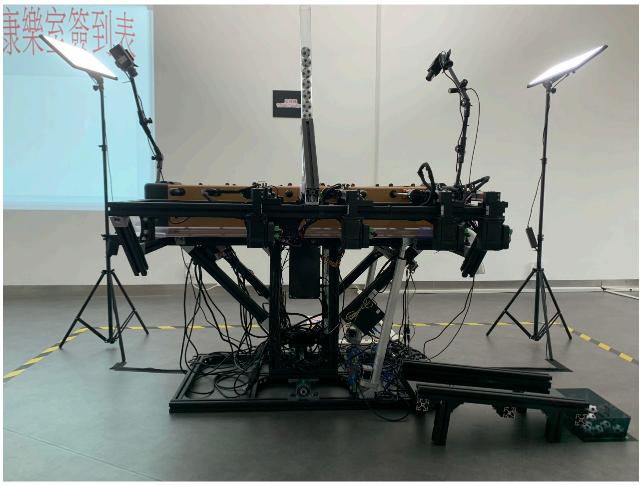

Figure 9. Side view of Table Football.

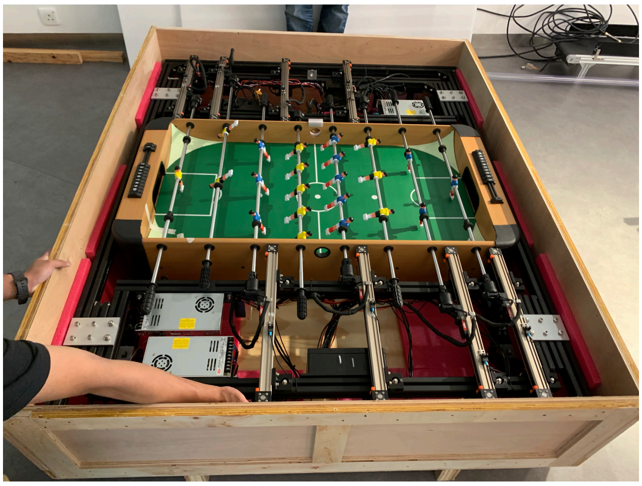

Figure 10. Table Football in wooden crate box ready for shipping.

Appendix

About The Missing Link

Curated by composers Gaybird Leung and Vanissa Law, The Missing Link consists of three Arts Tech exhibitions, an immersive performance, and a series of open lectures on the current issues in the use of technology in arts. By adding two essential elements —*timeliness* and *performance*— into art forms that do not originally exist in time, the two composers wish to inspire new creations and to give more perspective to existing art forms. Through the creation of multimedia artworks the artists explore ways to use technology to connect different types of media to facilitate storytelling.

The Missing Link is a two-year project funded by the Arts Capacity Development Funding Scheme (ACDFS) from 2021-2023. On top of commissioning new art works, the technical goal of this project is to develop a media synchronisation system, which will then become open source to benefit the future development of the Arts Tech industry.

About Recreation Room D

Recreation Room D was held at the Goethe-Institut Hong Kong, from 6 August to 3 September 2022. It is a technological recreation of a youth centre in the 1990s that explores the paradigm shift of interpersonal communication over the past three decades.

Filled with recreational activities and new faces, youth centres were once a place to hang out, make friends and shape one's social life. Two classic tabletop games, Novuss and Table Football, were re-created in such a way that can only be controlled through a computer interface.