Ji Zhao

PORTFOLIO

Selected Projects 2008-2023

Maker /Creative Engineer

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In my career, I have consistently demonstrated an **innovative fusion of technologies**, exemplifying my ability to push the boundaries of what's possible by merging disparate technological fields into integrated, cutting-edge solutions. This innovative approach is matched by my proven **leadership in interdisciplinary collaboration**, where I have successfully built and directed diverse teams, skillfully connecting dots across various technology areas to catalyze groundbreaking advancements. At the heart of my work lies an **embracing of a hacker's ingenuity**, a unique blend of creative problem-solving coupled with innovative thinking.

Mobile Surface (2009)

Project Type: Original Initiative Project

My Role: Algorithm / PC Software / Embedd Developer

Impact and Results: UIST 2010, A Microsoft TechFest 2010 Public Day Demo, U.S. Patents

Mobile Surface is a pioneering mobile device designed to transform any surface into an interactive workspace. It can project images on any free surfaces and enable interaction in the air within the projection area. The projector used in the system scans a laser beam very quickly across the projection area to produce a stable image at 60 fps. The camera-projector synchronization is applied to obtain the image of the appointed scanning line. So our system can project what is perceived as a stable image onto the display surface, while simultaneously working as a structured light 3D scanning system

Why Mobile Surface?

- Back in 2009, the screens of mobile devices were small, we wanted portable large screens.
- Pico laser projectors, enabled by MEMS technology, offered high contrast, brightness, and efficiency, all within a compact size. This emerging technology was ready for a thorough exploration.
- Microsoft Surface provided an excellent multi-channel interactive experience, but its large size restricted its everyday usability. We were also interested in exploring the potential of Surface's interactive methods within the context of mobile internet scenarios.

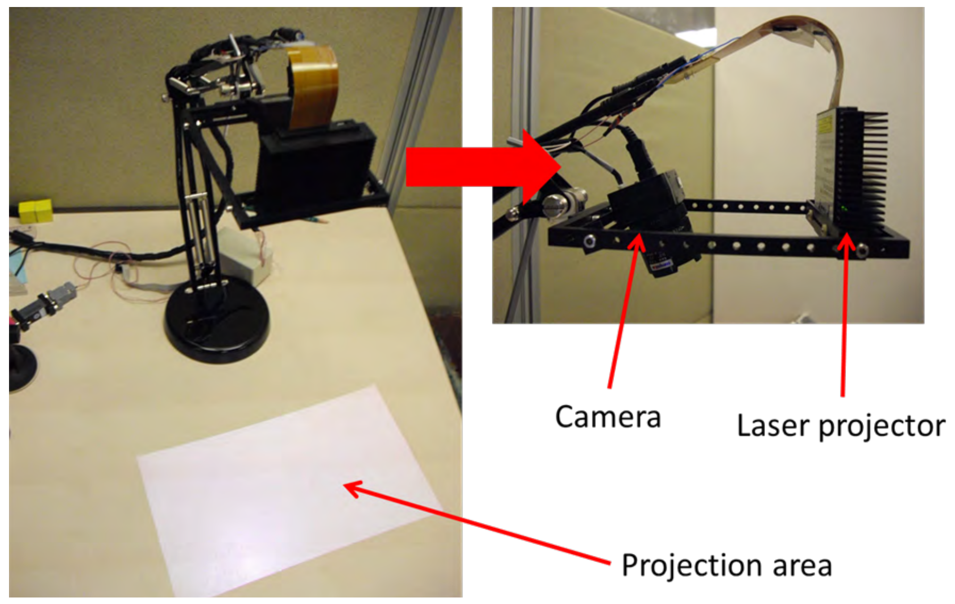
MobileSurface: Interaction In The Air For Mobile Computing

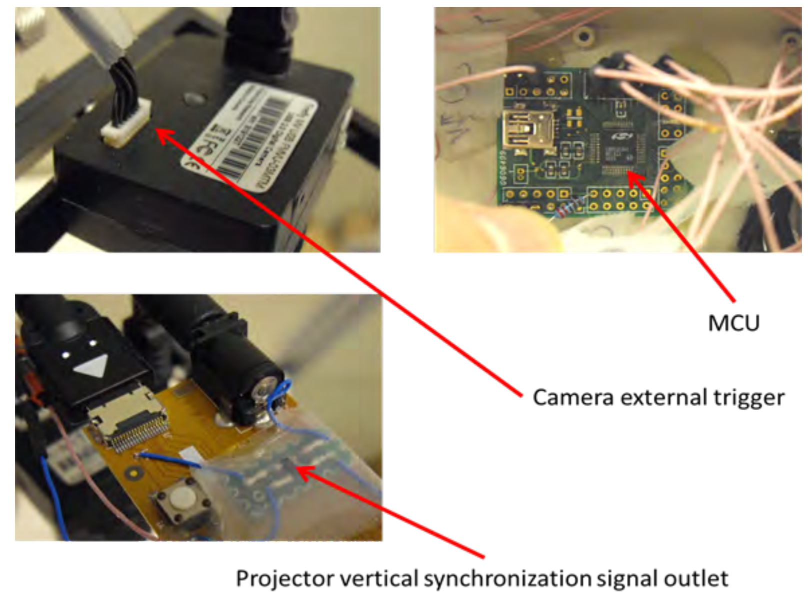
MobileSurface: Interaction In The Air For Mobile Computing

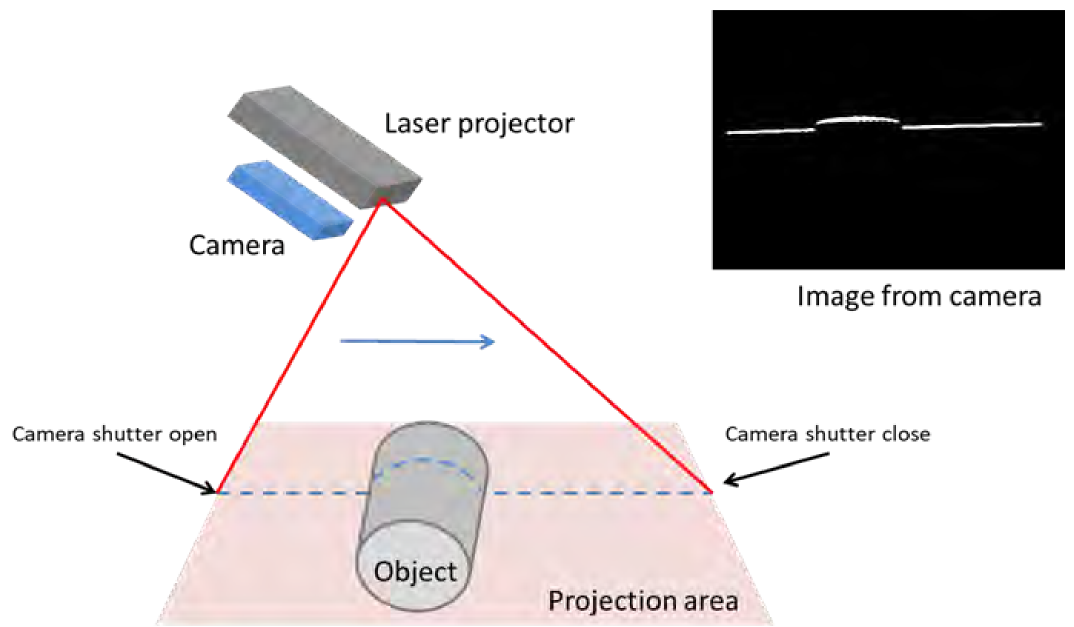
Mobile Surface (2009)

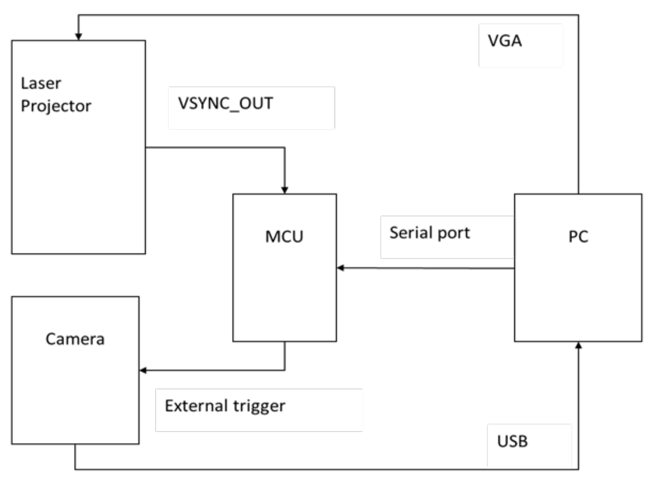
Generating a real-time depth map while displaying.

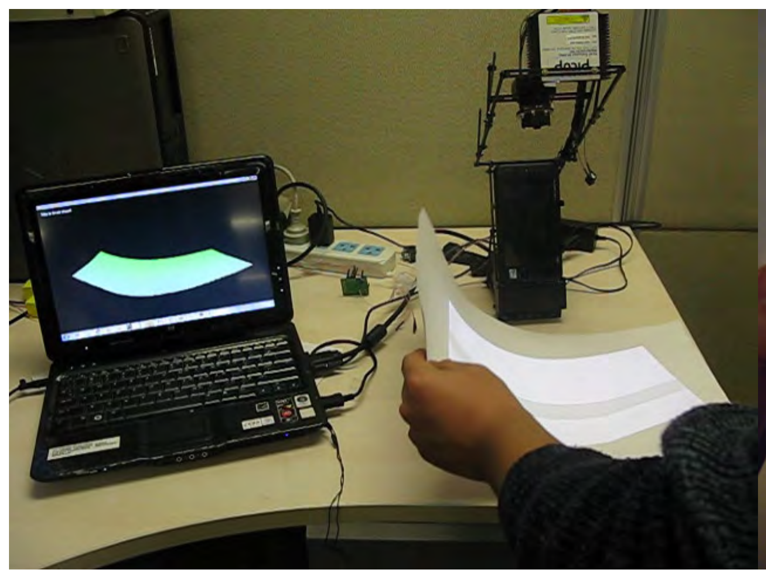
As the all-in-one developer, the biggest challenge I faced was the absence of a depth map acquisition solution designed for low-power mobile scenarios. After conducting an in-depth study of the working principles of the pico laser projector, I found that its operational process resembled that of a CRT monitor. By precisely synchronizing the camera's exposure time with the projector, it became possible to create virtual scanning lines at any position within the projection space. This approach allowed for the simultaneous creation of a structured light 3D scanning system within the projected image, thereby enabling the on-demand acquisition of useful depth information from the scene.



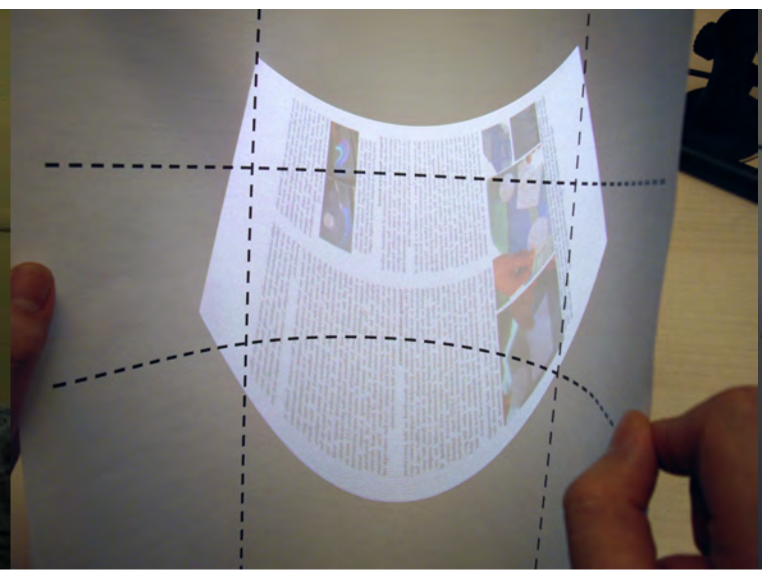




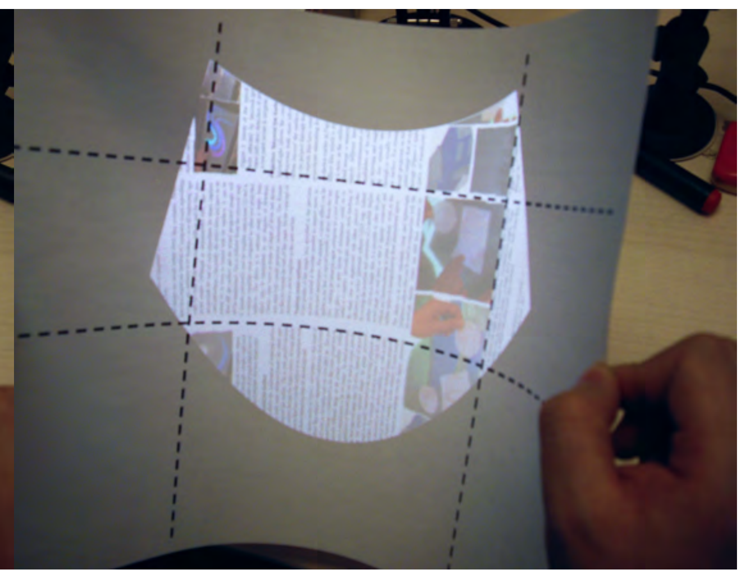




Surface modeling



Orignial projection



Corrected

"Adaptive distortion correction" textures physical objects.

I utilized a camera with a maximum frame rate of 60 fps, with proper triggering, to obtain 60 measurement results per second from the virtual scanning lines. Depending on the specific usage scenario, we dynamically adjusted both the position and the number of these virtual scanning lines to fulfill the varying measurement requirements. For simple surface modeling, we employed 6 scanning lines, thus creating a surface mesh model comprising nearly 400 triangles. This surface model can be updated at a rate of 8.6 times per second. After acquiring the surface mesh, we textured the mesh with the content intended for projection. By applying the corresponding rendering rules, we were able to create virtual textures on the physical surface, giving the impression that they were printed directly onto it.

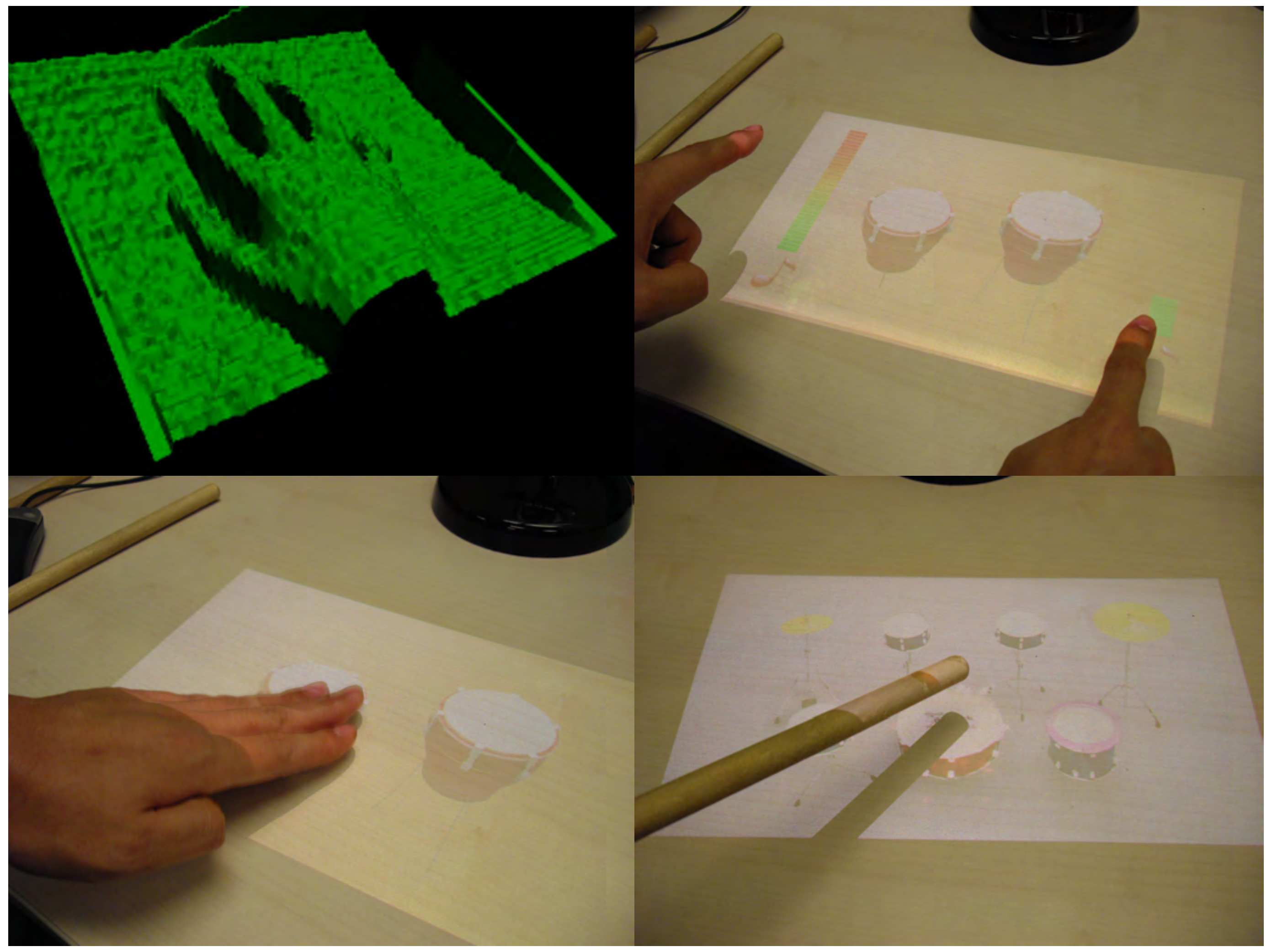
3D interaction from mobile device

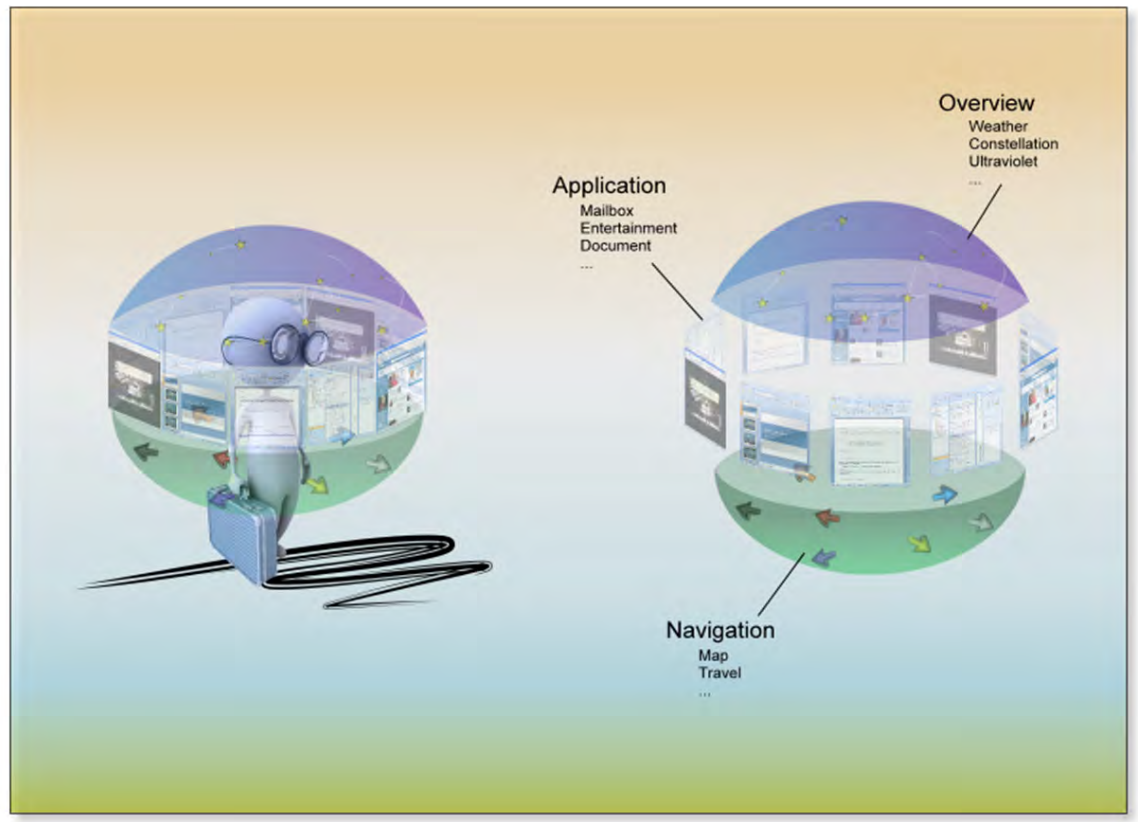
Original demo video

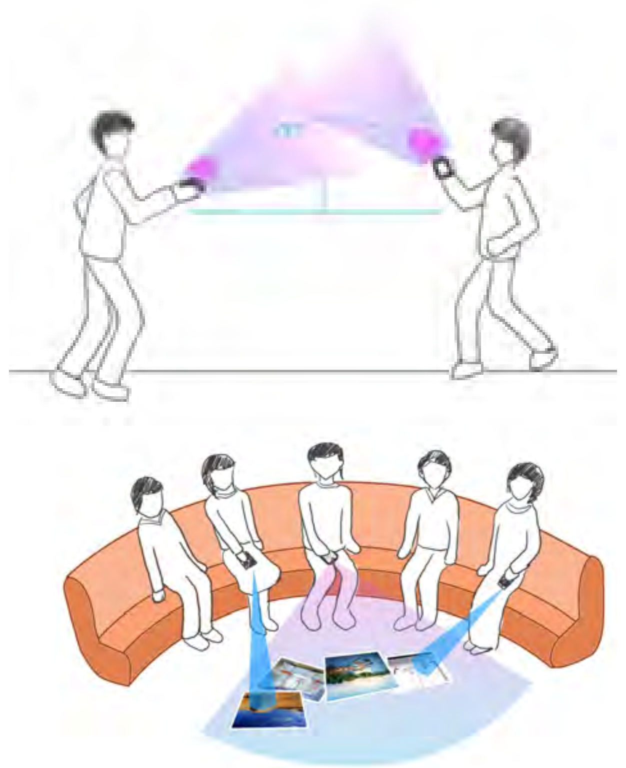
Mobile Surface (2009)

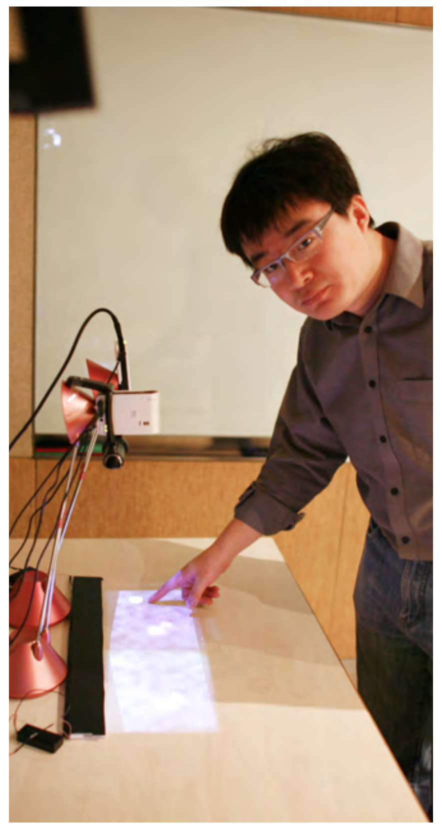
3D Interaction with fingers

In interactive scenarios, I maximize scanning frequency by focusing exclusively on hotspot areas. Through the careful design of user interfaces, our system's responsiveness can achieve up to 60 frames per second.
Additionally, our system is capable of providing precise depth information along the Z-axis. This feature not only adds a new dimension to interactions but also broadens the range of potential user interface designs. For example, in the virtual drum playing program I developed, users have the ability to modulate volume by moving their fingers along the Z-axis. This interactive capability allows for a more dynamic and intuitive drumming experience.
My system is equipped to handle more advanced scanning operations for complex interactions. I can even roughly model the hands in near-real-time..









Later, I collaborated closely with the design team, and based on the unique display and interaction capabilities of the Mobile Surface, we created usage scenarios such as **personal information sphere** and **multi-user interactions**, and completed the development of a multi-projector interactive demo.

Multi-layer display

Interaction with gestures

Multi-device colabration

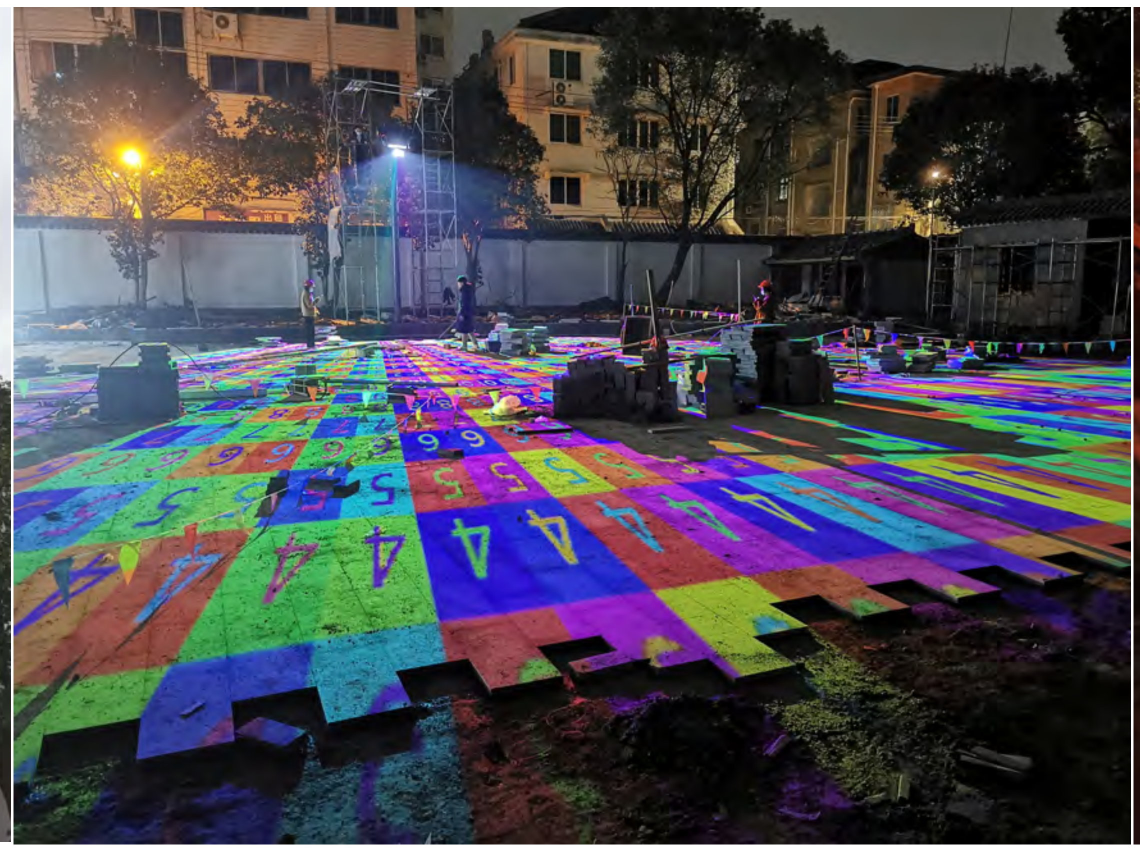
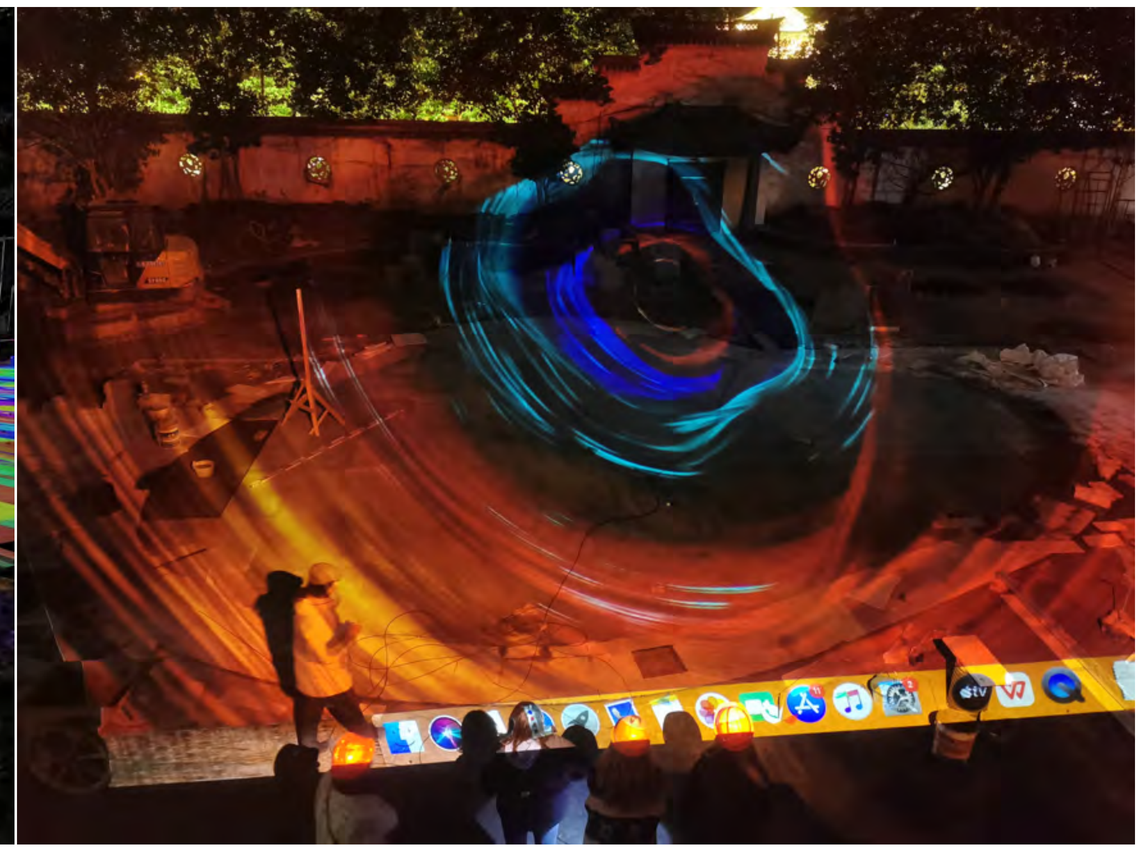
Combined surface user interface

Mobile Surface (2009 - 2021)

This was my last project at MSRA. In 2010, I left MSRA for Alibaba and did not continue to advance this project. It was an early attempt in my career to explore natural human-computer interaction and augmented reality. At the same time, it successfully pushed the boundaries of possibilities with a mixture of existing technologies.

Projection technology continues to evolve to this day, and so do I. **The story continued in the winter of 2021** when I led a team in the development and delivery of an outdoor interactive project. I had the opportunity to expand the creativity of 2009 into the size of a basketball court. Through a camera projection system, we created an interactive virtual fish pond.



Magic Cube (2022)

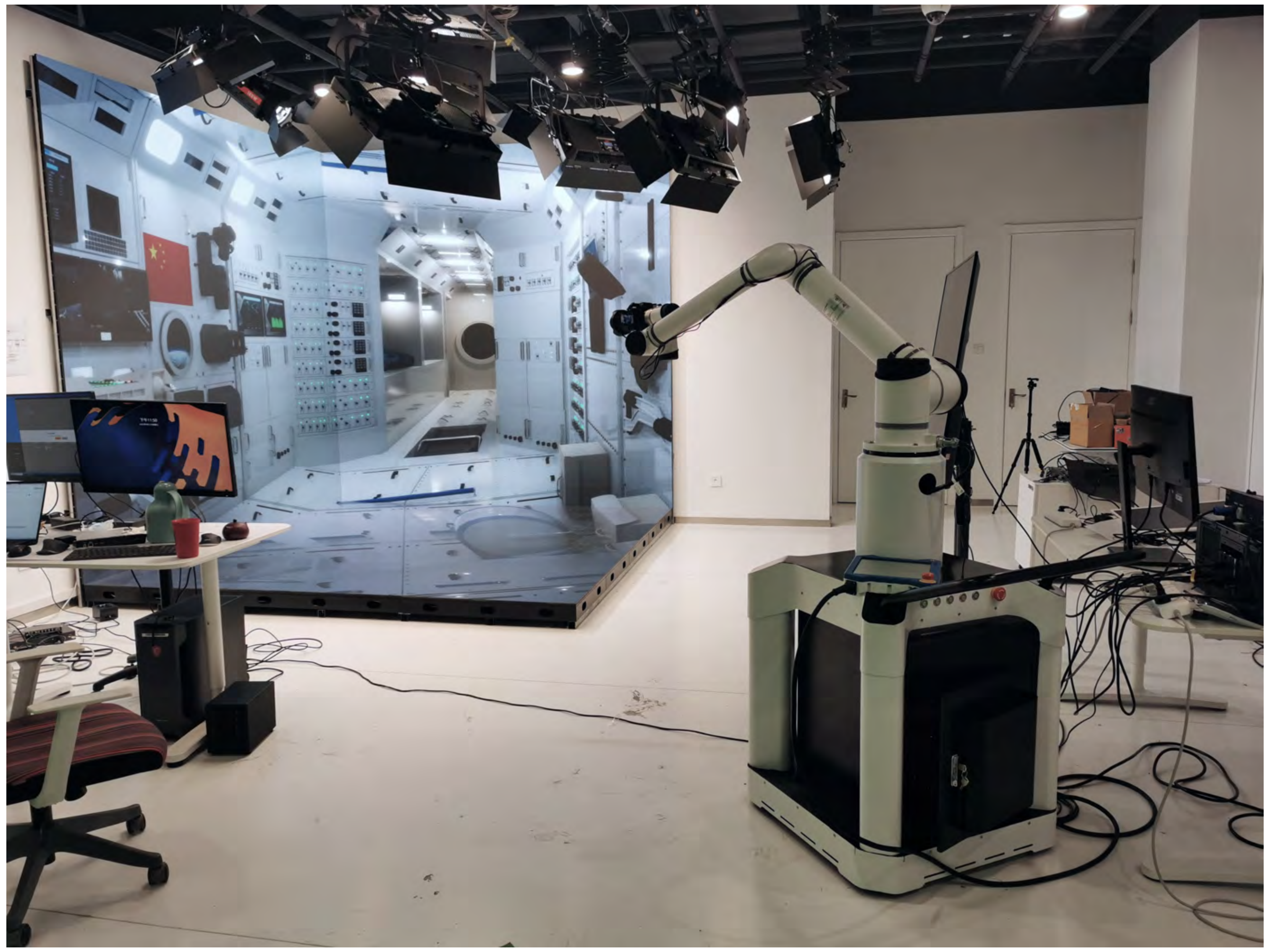
Project Type: Original Initiative Project

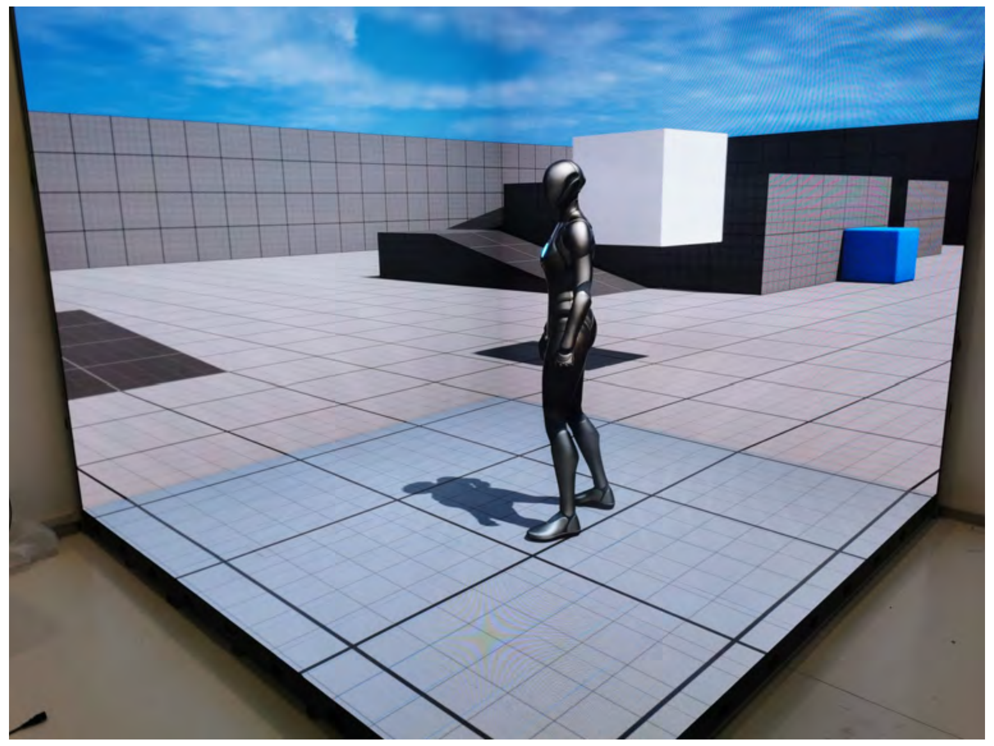
My Role: Team Leader; Architect; Unreal 5 / Algorithm Developer

Impact and Results: Pioneer Award at the Global Digital Trade Expo China 2022

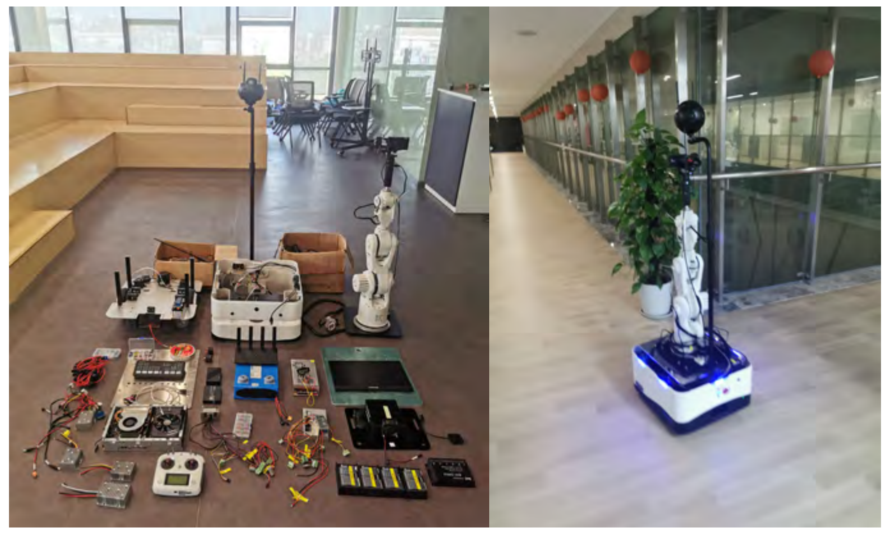
Magic Cube is a Smart Space facilitated by a robot, initially implemented for virtual production in the cultural and tourism industries. It is designed to transform any room into an immersive space, making it ideal for mixed reality vlogging and cultural experiences. Magic Cube is also an **unmanned virtual production stage** which automatically generating videos. By tracking the user's viewpoint, it offers an **immersive experience** tailored to the individual's perspective.

Magic Cube is also a significant component of the National Key Laboratory for Media Convergence Production Technology and Systems.



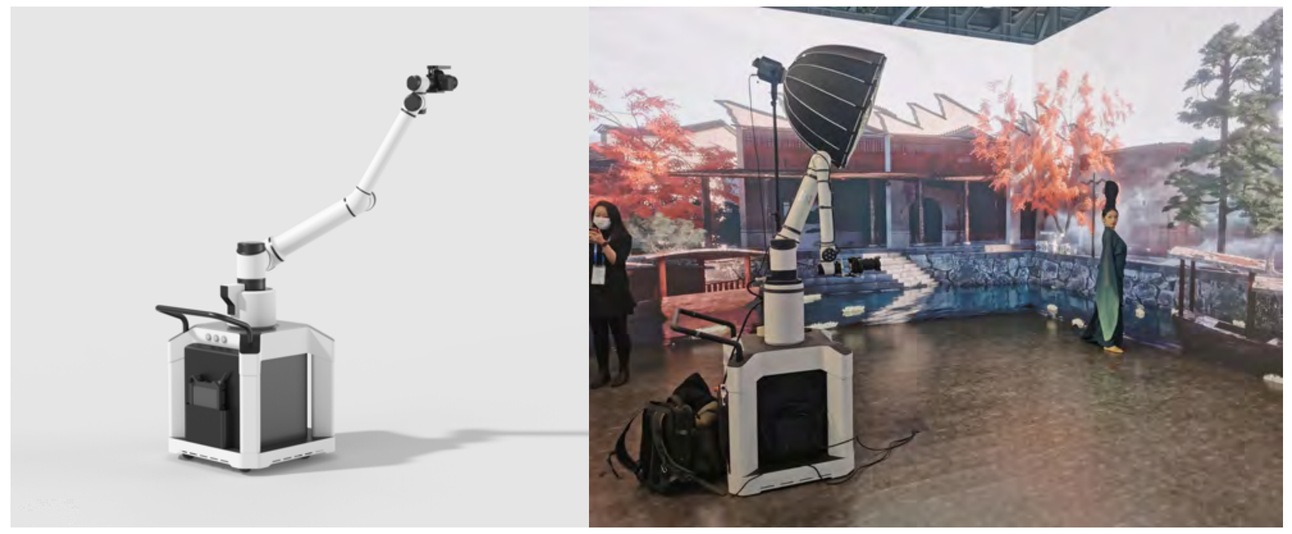


Magic Cube (2022)



2020

2021



2022

First Generation Camera Robot

Magic Cube Introduction Video

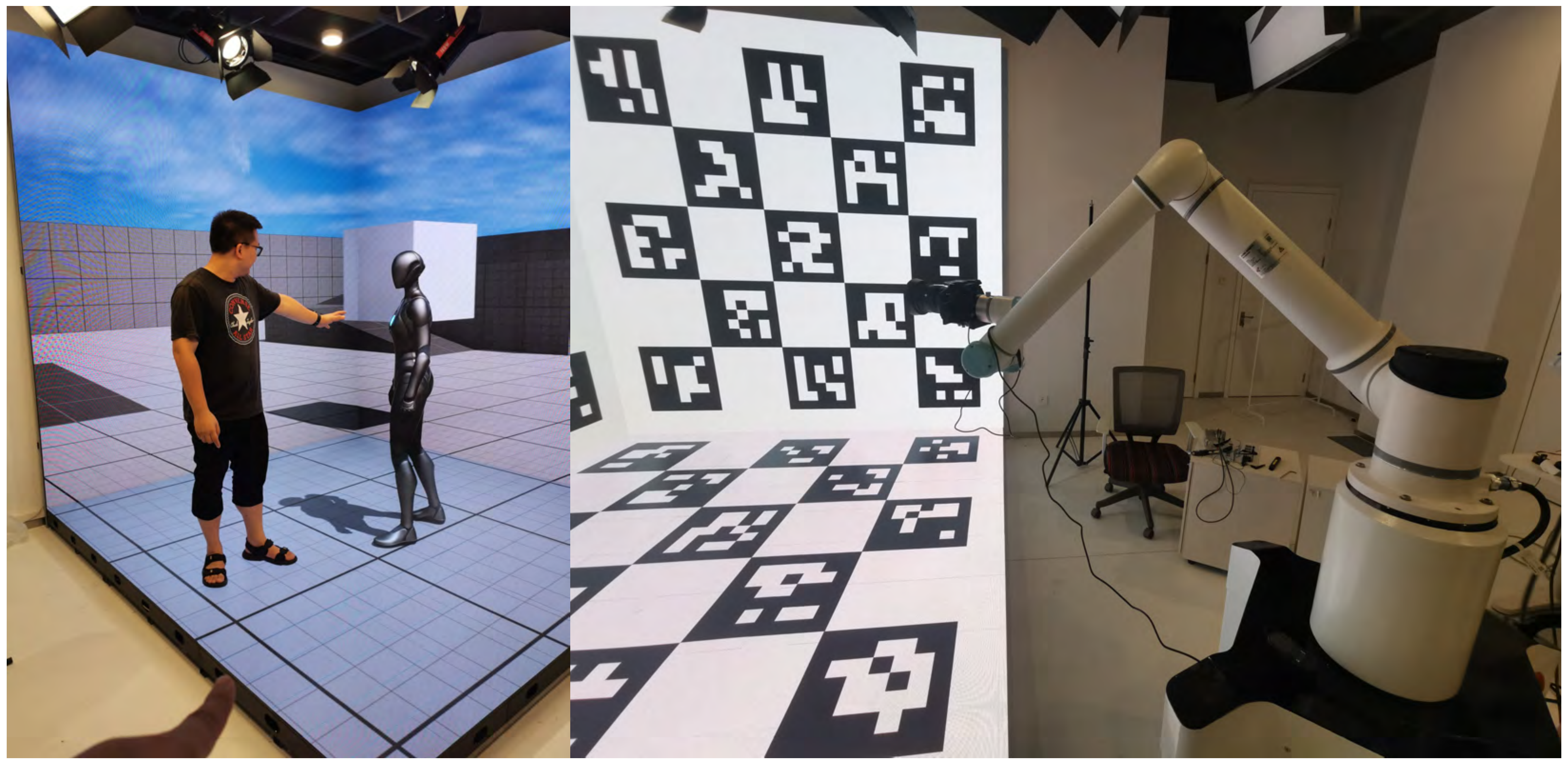
Since 2020, my team have been consistently creating various robots for video shooting. Combining a robot with virtual production has been the best approach we have found.

Single computer virtual production

As the Unreal Engine 5 developer for the project, I implemented a complete workflow of rendering, interaction, compositing, and compression on a single computer.

Calibration for geometry and color

In virtual production, the positions of the physical camera and the virtual camera need to be synchronized in real-time. I developed an automatic calibration program that can calibrate the relationships between the tool coordinate system, the base coordinate system, and the world coordinate system. Once the initial position is successfully calibrated, the robot arm can continuously update the precise camera position.

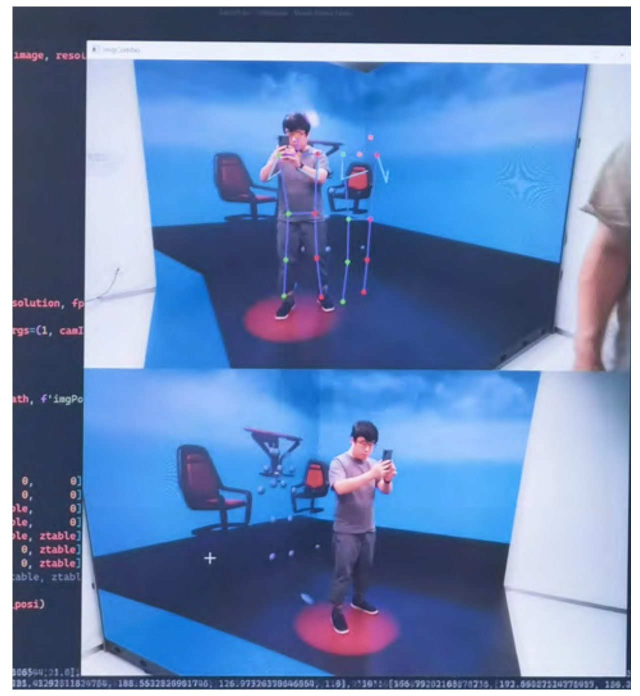


Since I used non-cinematic-grade LED screens, the issue of color discrepancies was more pronounced. For this, I also developed a color calibration tool to generate color profiles for unreal 5.

Magic Cube (2022)

Sensor enabled Smart Space

I use multi-angle perception cameras in Magic Cube for 3D detection and tracking of people. The robot can identify the number of people in the scene and their approximate locations to facilitate shooting.
Additionally, in immersive mode, the content in the LED space can also interact with users



Magic Cube provides unmanned virtual production services

Magic Cube made its appearance at the Global Digital Trade Expo

Delivery Robot (2019)

Project Type: Original Initiative Project

My Role: Architect; Product Manager; Hardware Engineer

Impact and Results: Served in multiple campuses

In 2018, I joined CaiNiao ET Lab, and my first task was to provide robot delivery service on Alibaba Campus. I collaborated with the R&D team and retail service providers to set up 4 fixed delivery docking points, as well as a mobile delivery robot. After accumulating operational data for a period, I realized that for an on-demand delivery robot, **size and cost matter**. Therefore, I decided to **redesign the robot**.

Order ID	Departure time	Arrived time	Duration	Date
114067034919011035	10:20	10:33	0:13	2019.1.10
113999146719011050	11:32	11:47	0:15	2019.1.10
114618487019011056	16:30	16:45	0:15	2019.1.10
114714777119011032	17:20	17:37	0:17	2019.1.10
113963691519011016	18:04	18:21	0:17	2019.1.10
114356466219011044	18:04	18:21	0:17	2019.1.10
114811176119011151	11:16	11:30	0:14	2019.1.11
115108220719011124	12:04	12:22	0:18	2019.1.11
114775239719011120				
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115076395619011132				
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114509537419011162				
114356466219011044	18:04	18:21	0:17	2019.1.11
114717229219011207	10:07	10:21	0:14	2019.1.12
115660065019011253	11:18	11:36	0:18	2019.1.12
115083771219011219	14:34	14:50	0:16	2019.1.12
114829880819011254	15:32	15:48	0:16	2019.1.12
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115888008419011213	16:19	16:37	0:18	2019.1.12
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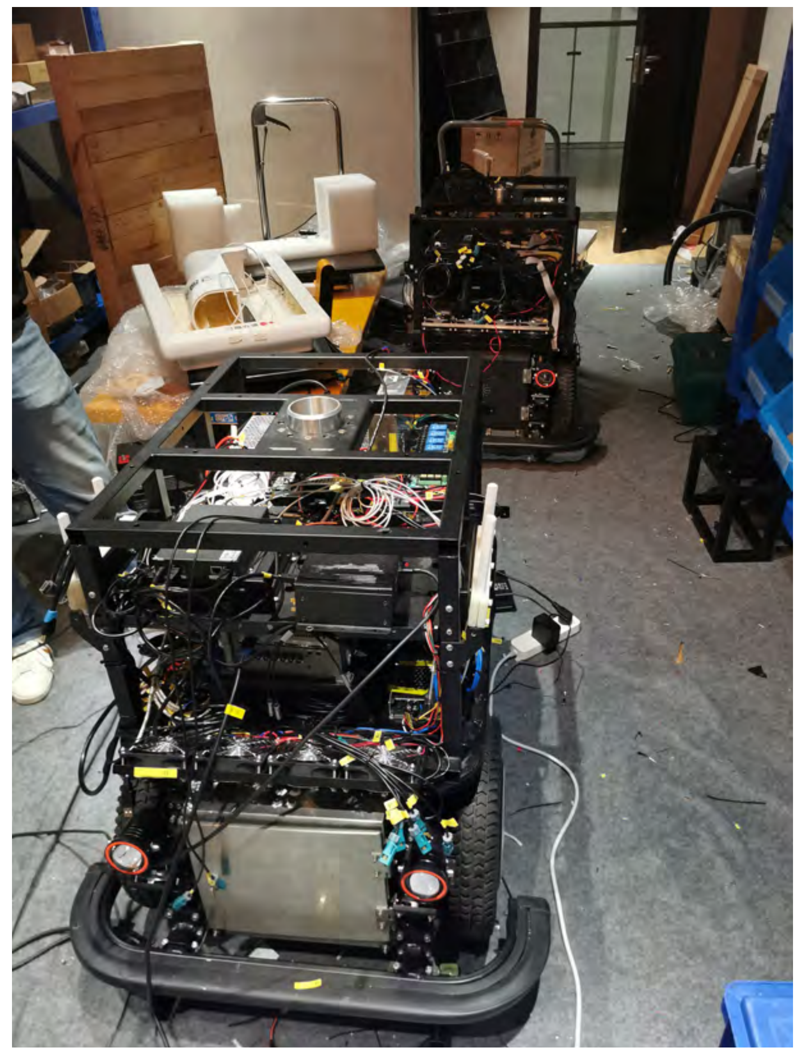
116566965419011436	16:33	16:48	0:15	2019.1.14
116183926319011406				
117050030719011443	17:48	18:03	0:15	2019.1.14

The delivery robot mentioned above cost over $40,000, with a curb weight close to 1 ton. Due to its oversized cargo box, it was rarely able to operate at full capacity. Our goal was to reduce the per-unit cost to $3,000. To achieve this, as an architect, I chose a solution based on a mature and reliable **electric wheelchair as the foundation**, using **two cameras and a low-power embedded computing unit**. This approach eliminated the need for expensive LiDAR and industrial PC computing units.

Delivery Robot (2019)

I designed an embedded computing unit with 4T computing power, connected to two wide-angle cameras, one in the front and one in the back, via GMSL. Instead of using high-precision radar maps commonly employed in traditional autonomous driving, I innovatively used **image segmentation algorithms to identify drivable areas** within the robot's field of view, **simulating human-like behavior**. With accurate segmentation of drivable areas, the robot can navigate routes under the guidance of GPS signals and also execute obstacle avoidance maneuvers. In locations without GPS signals, I use UWB base stations as a supplementary positioning method.



Based on our low-cost autonomous wheelchair chassis, I further envisioned a **community shared mobility solution** and had industrial designers complete the preliminary design work. However, due to COVID-19, the work was not continued. These efforts were later applied to the filming robot projects.

Wireless Power (2008)

Project Type: Cooperated Project

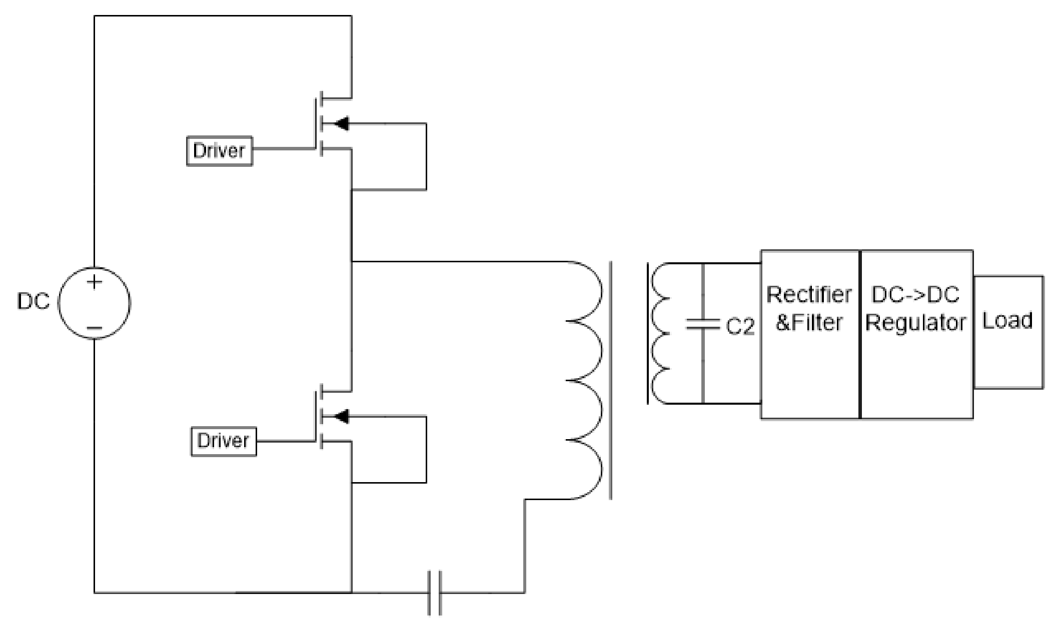
My Role: Embedded / PC Software Developer

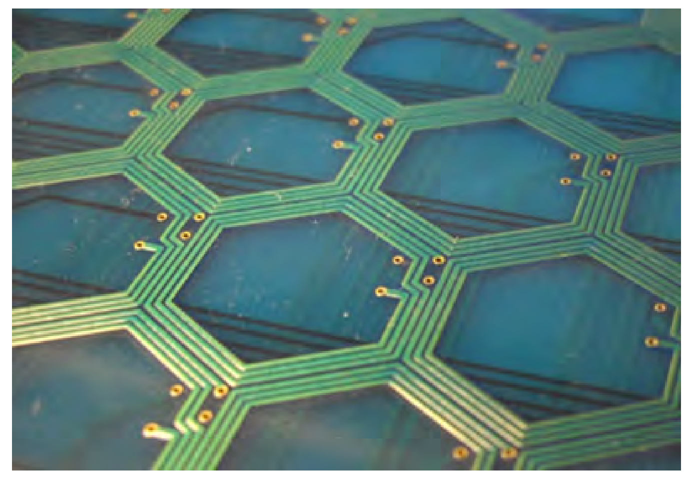
Impact and Results: A Microsoft TechFest 2008 Demo, First MSRA Project hits 1K+ production

Wireless Power was a groundbreaking project at MSRA, initiated well before wireless charging solutions became common to the public. It was my first project at the institute. By 2007, MSRA had developed a prototype of a wireless charging desk using a honeycomb-like PCB coil array, capable of powering a high-performance Windows tablet computer. My objective was to not only miniaturize the wireless charging solution but also reduce the BOM (Bill of Materials) cost, making it suitable for smaller mobile devices like mice and game controllers.

This project was a collaborative effort between MSRA and MACH (Microsoft Asia Center for Hardware). By 2008, we had successfully adapted the technology for smaller devices and subsequently manufactured and shipped over 1,000 units of wireless charging computer mice.

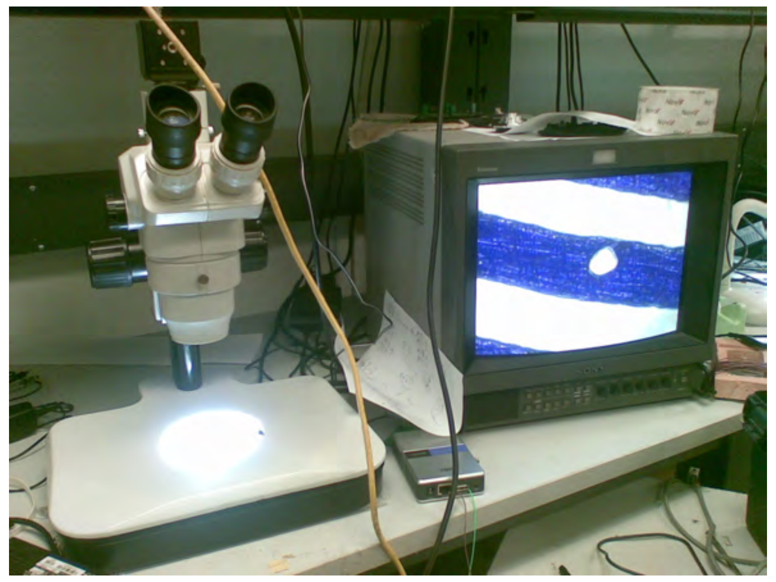
I simplified the previous Full-Bridge Oscillator circuit and switched to a Half-Bridge Oscillator circuit suitable for low-power scenarios. Additionally, I involved the receiving coil in the resonance as well, allowing us to confirm whether the charging device is in place through the initiation of resonance.

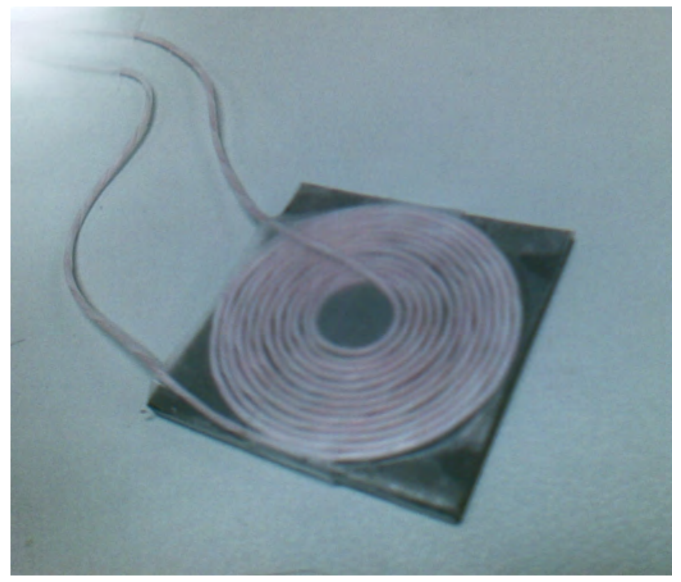




Searching for the best coil design

I created coils of various sizes and turns through PCB etching for testing purposes, in order to find the optimal shape. Then, I used insulated wire and anti-magnetic materials to make a high-power prototype.

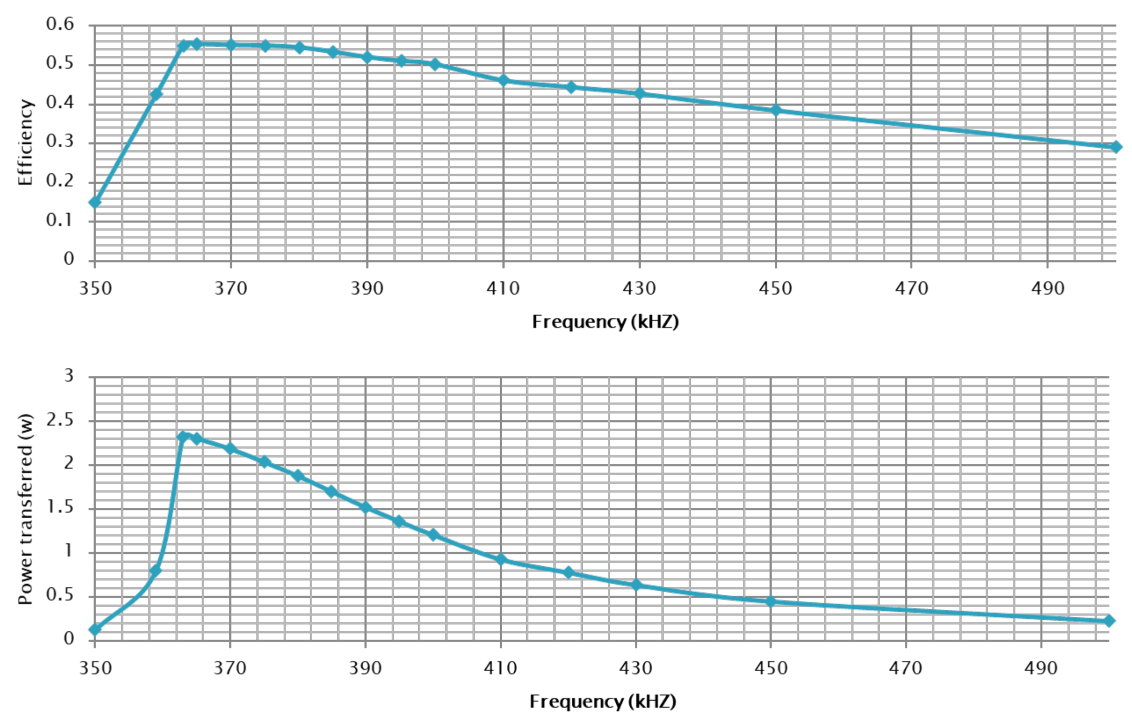




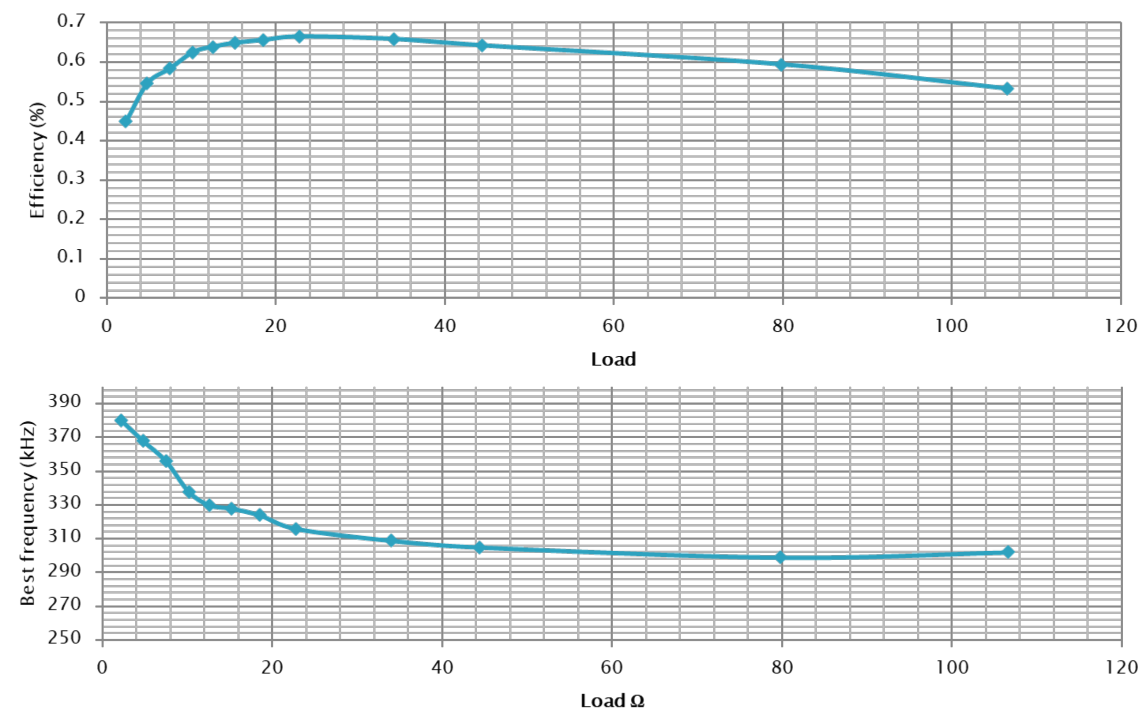
Searching for the best combinations

I identified four key factors affecting wireless power transmission: **pulse voltage, resonant frequency, load, and air gap**. I conducted systematic research on these factors and, with parameter optimization, we were able to increase the transmission efficiency to 60%-70%. This is consistent with the best commercialized solutions today .
Through systematic study of these four key factors in wireless power transmission, I can determine the optimal air gap, load, and pulse voltage in product design. The only uncertain factor is the resonant frequency, as the position of the device being charged cannot be fixed. I used the frequency synthesizer in an MCU to periodically scan and identify the optimal resonant frequency point.

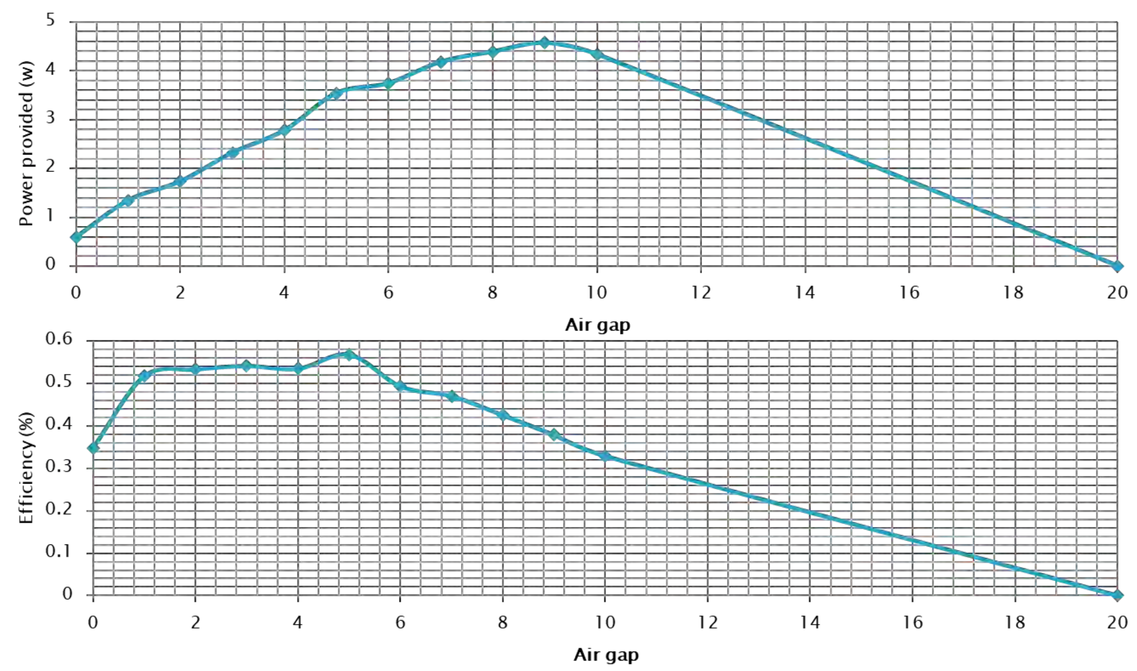
6.5V pulse voltage/ 4Ω load /3mm air gap



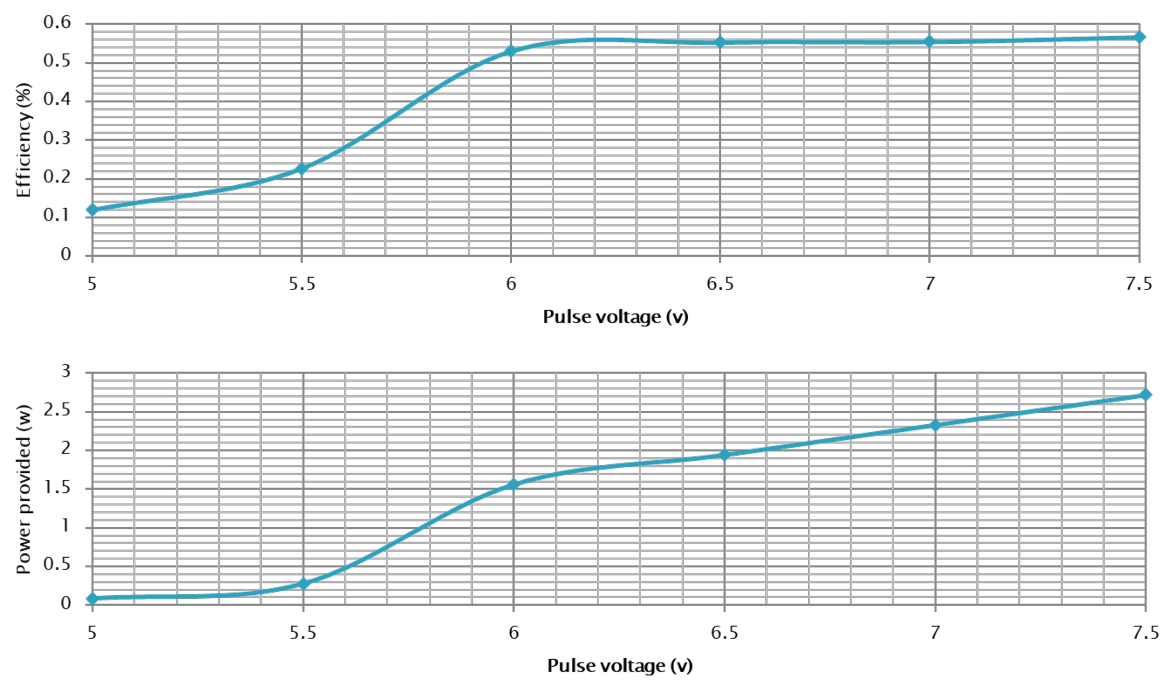
6.5V pulse voltage / Best frequency /3mm air gap



6.5V pulse voltage / Best frequency / 4 Ω load



3mm air gap / 4Ω load /Best frequency

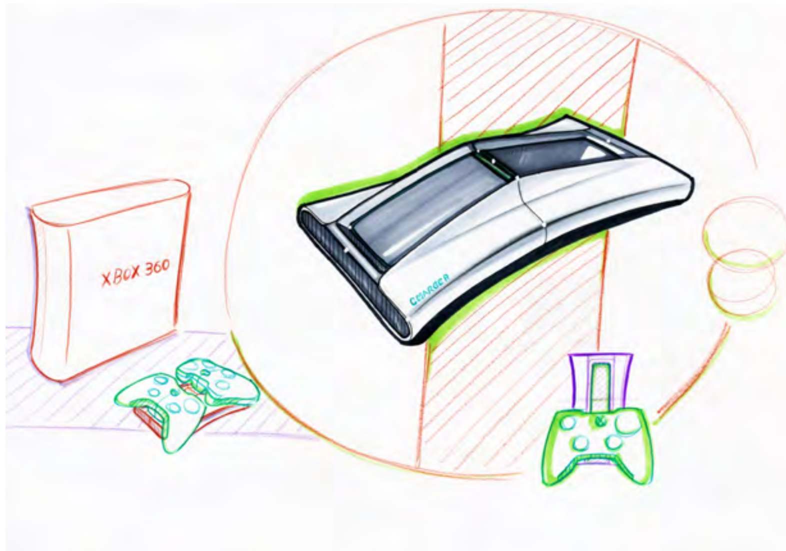


Wireless Power (2008)

Then, I began **collaborating with the design team to turn it into real products. uPad** was the code name we used.

uPad for XBox

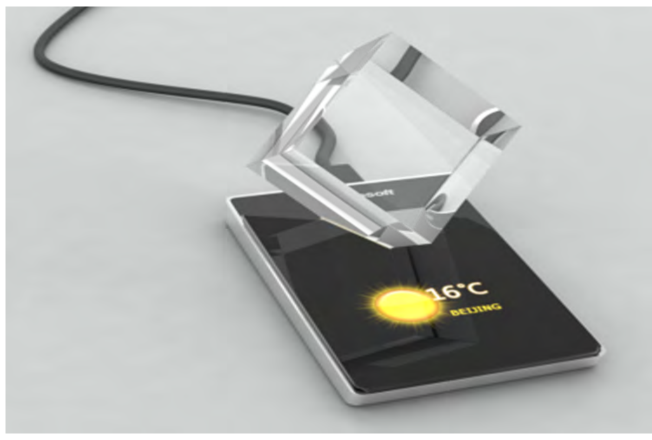
We first attempted to use wireless charging technology in **Xbox controllers**. As a gaming enthusiast, who wouldn't want to elegantly display their controllers, and of course, it would be great if they could be charged wirelessly at the same time. I collaborated with industrial designers to fit a complete set of wireless charging components inside the the Xbox battery pack, and we also created a dual-controller charging dock.



XBox Wireless Charger Demo

uPad for PC

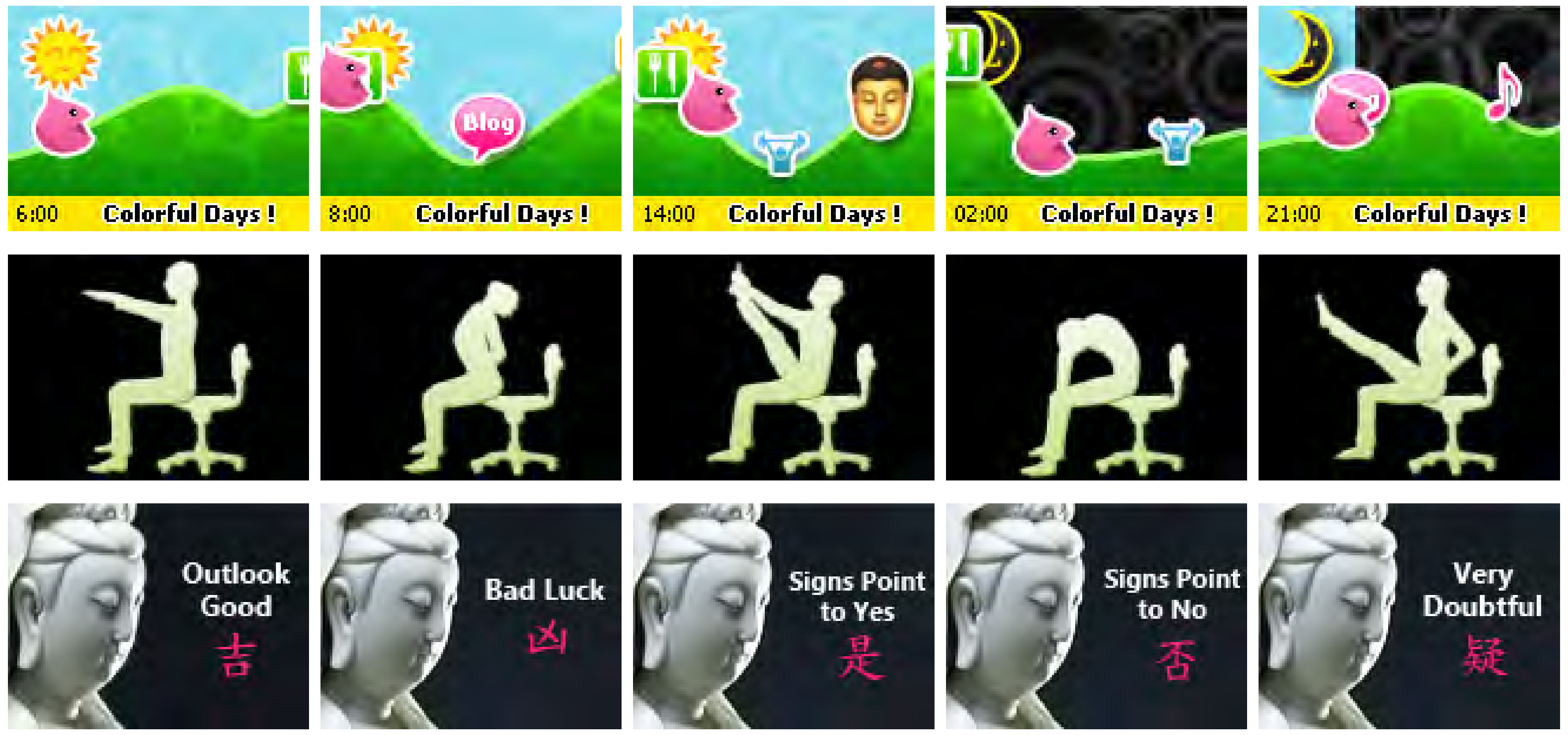
For MSRA's 10th anniversary celebration, we designed a **fashionable device**, uPad, that not only decorates a user's physical desktop and displays reminder information but also wirelessly charges a mouse.
In terms of design, our focus was to make uPad an accessory that enhances fun rather than solely productivity. Therefore, we integrated a variety of personalized content into uPad, adding to its appeal and uniqueness.

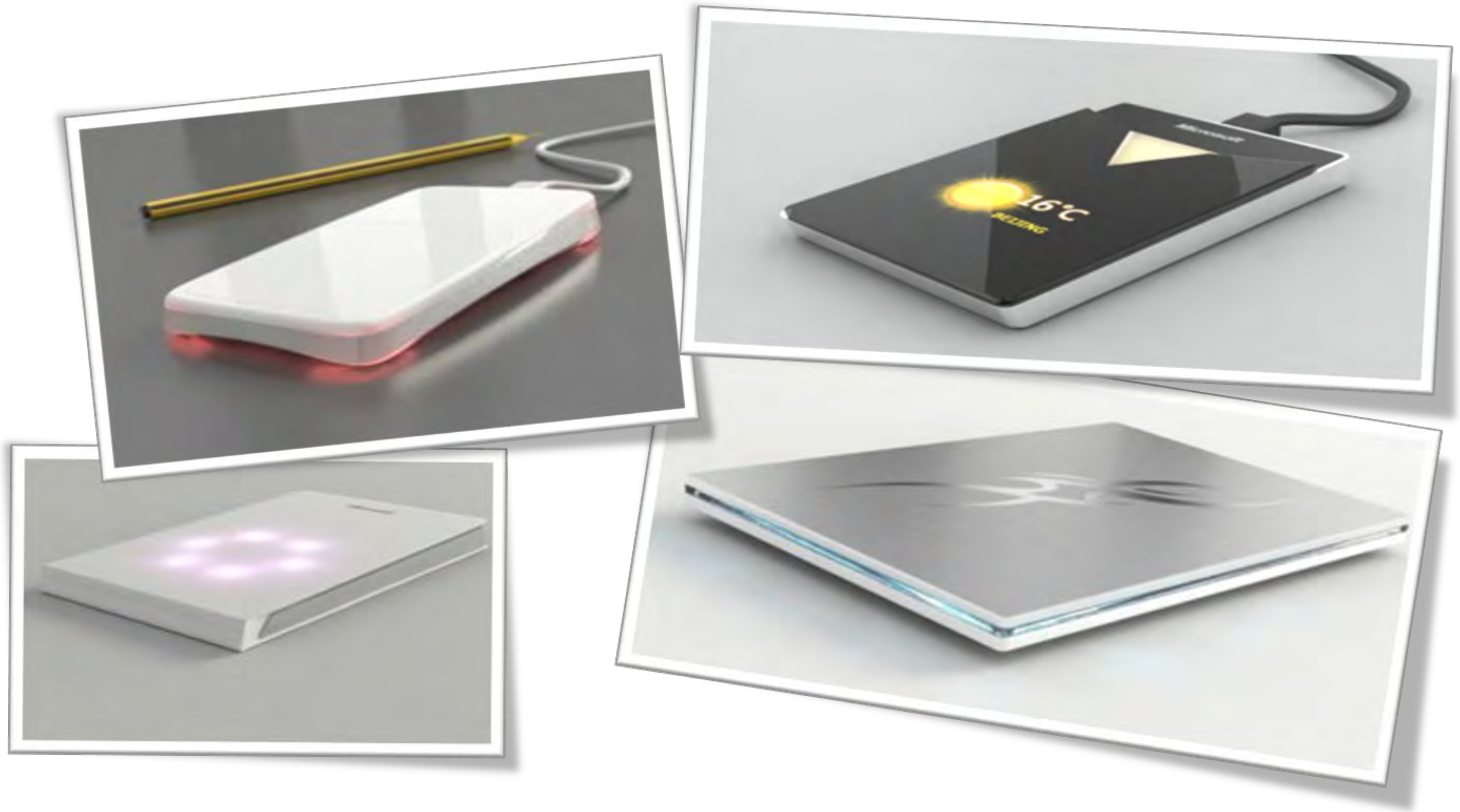


Wireless Power (2008)

As the **software development engineer for uPad**, I developed a full suite of software for uPad.

- Windows sidebar gadget program, which allows users to customize LED effects and download custom animations to uPad.
- uPad firmware for playing animations.
- uPad interaction program.
- Modified the firmware of the Microsoft Laser Mouse 7000 to adapt it for wireless charging.





Smart Holo-Conference (2020)

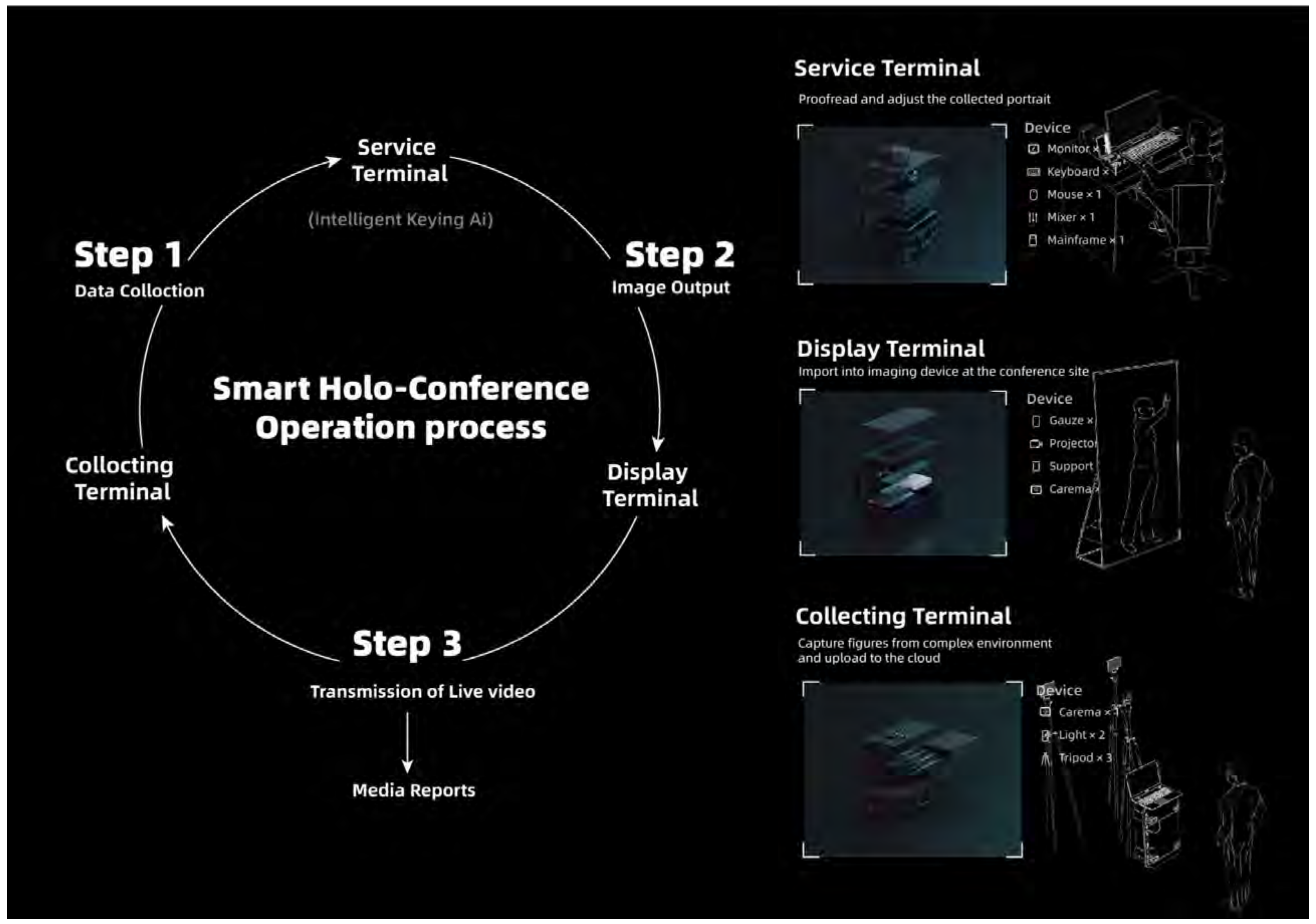
Project Type: Original Initiative Project

My Role: Architect; Software Developer

Impact and Results: 2022 iF Award; Used in 2020 / 2021 Design Intelligence Award (DIA)

DESIGN AWARD 2022

The Smart Holo-Conference System is a holographic conference system I designed during the pandemic to support the China Academy of Art's Design Intelligence Award (DIA) . Due to the pandemic, international review experts were unable to come to the evaluation site or even leave their homes. Therefore, we mailed a set of carefully designed, standardized collection equipment that could fit in a carry-on suitcase. Using a specially trained U-NET model, I completed full-body image extraction in complex environments. This allowed the review experts to join the meeting as holographic images from their homes without a green screen environment. At the site, I designed a projection system using a human-sized gauze screen and provided real-time feedback video with an equivalent viewpoint for the remote review experts. Through these methods, I constructed a real-time bidirectional holographic communication system.



Smart Holo-Conference iF Award Link

Smart Holo-Conference (2020)

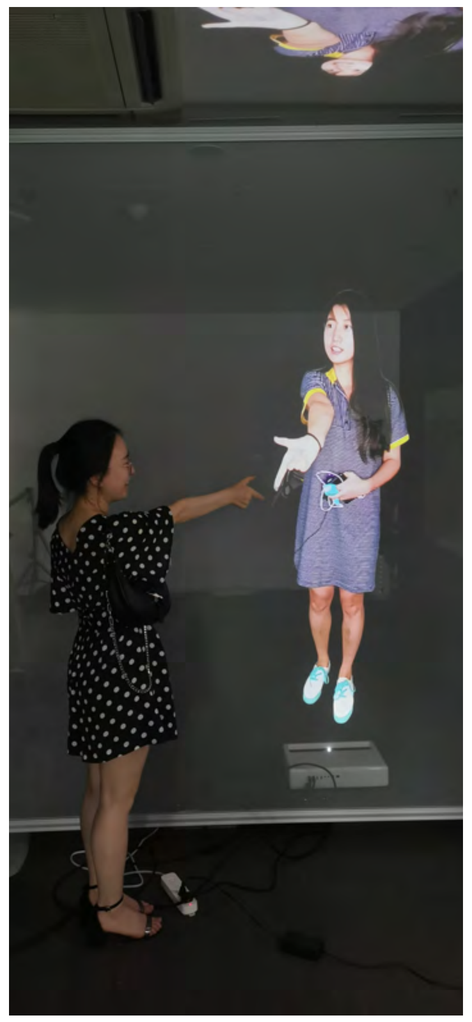
This system created a very good sense of presence, and there were several instances where the onsite review experts **mistook it for a real person.**

I observed them attempting to communicate with the holographic image through eye contact, but due to technical limitations, we were not able to achieve this yet, though certainly, it is something that could happen in the future.

In 2022, in collaboration with artists from the China Academy of Art, we were honored with the iF Award.

On-site setup

Remote setup



Dripo (2013)

Project Type: Personal Project

My Role: Sensor Inventor; PCBA / Embedded Software developer

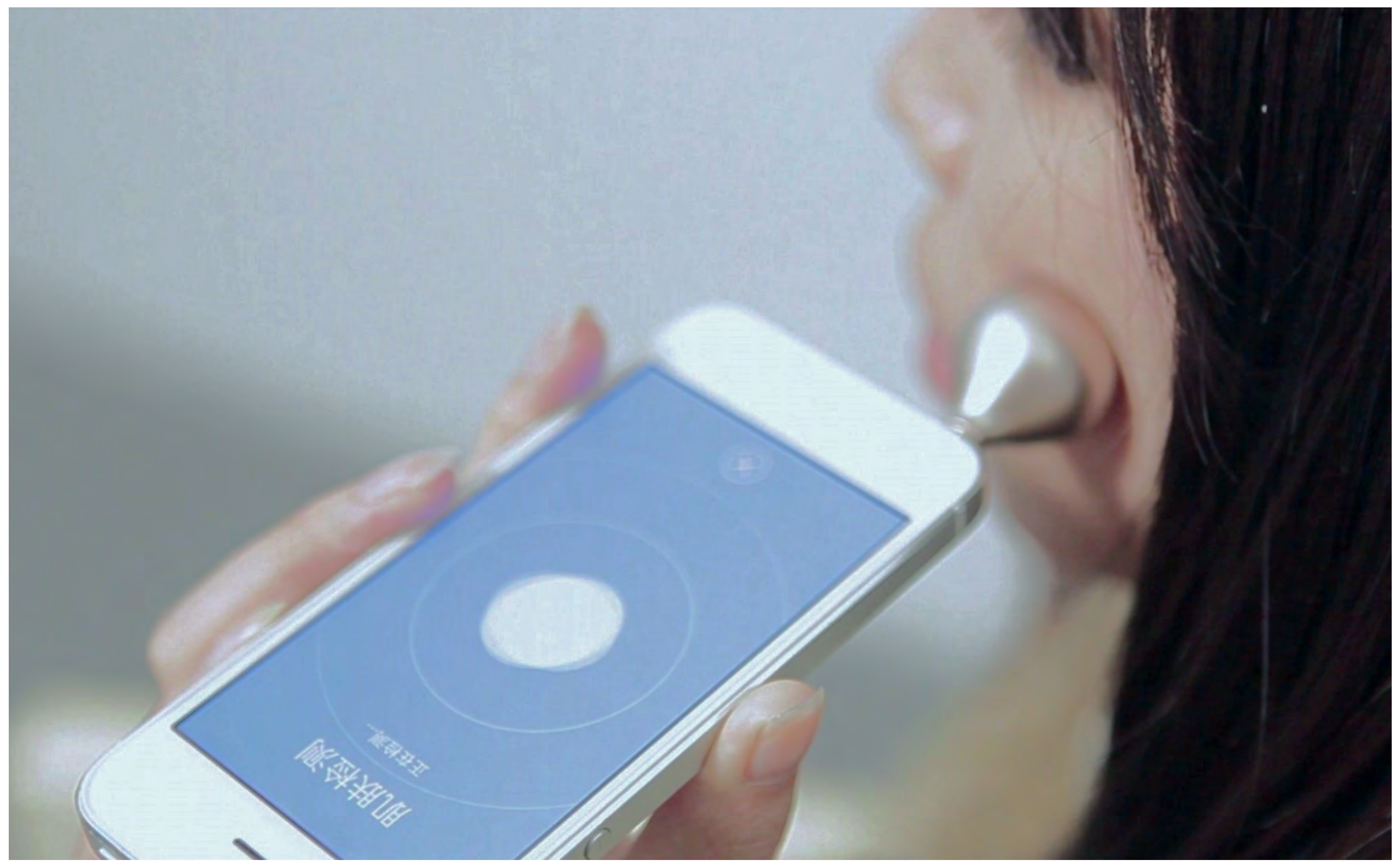
Impact and Results: Product launched to public

GitHub [osonic/Dripo (github.com)](https://github.com/osonic/Dripo)

Dripo is an ultra-portable cellphone add-on **skin decoder**, it is designed to obtain basic daily skin data, which was then used for skin modeling to personalize skincare formulas through AI.
Skin care can be troublesome, as most people don't truly understand their own skin characteristics and therefore choose skincare products that aren't suitable for them, leading to skin problems. My aim is to help people with different skin types to easily understand their skin condition anytime, anywhere using their mobile phones. Through continuous monitoring, they can gain insights into their skin.

Why Build It Like This ?

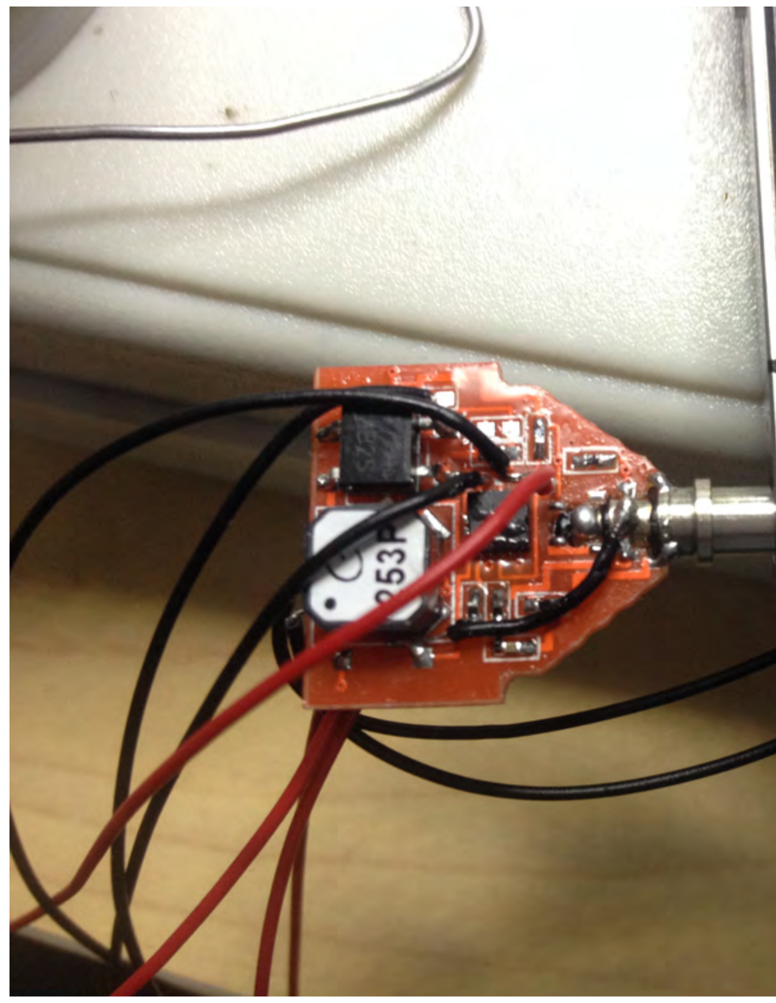
In 2013, every mobile phone was equipped with a 3.5mm audio jack, so I chose to use this port as the data communication interface. At the same time, my goal was to minimize sensor costs as much as possible, so I eliminated the battery and opted for energy harvesting directly from the audio interface.

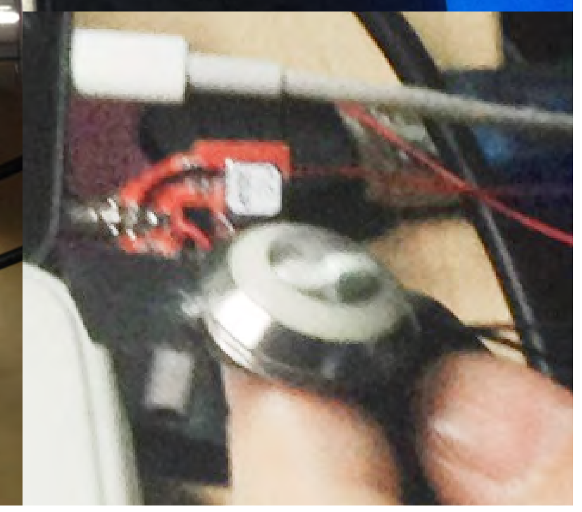


Dripo (2013)

Hacking the audio jack for energy and duplex communication

The idea of energy harvesting from the audio port is very straightforward. By providing a sine wave signal through the phone's audio output, and then rectifying and filtering it, a usable DC signal can be obtained. To achieve maximum energy efficiency, impedance matching and frequency matching are also necessary. My previous experience in wireless power greatly assisted me in this.
To realize bidirectional communication, I reserved one audio channel as the uplink communication channel, while the MIC channel being used for transfer downlink modulated data.

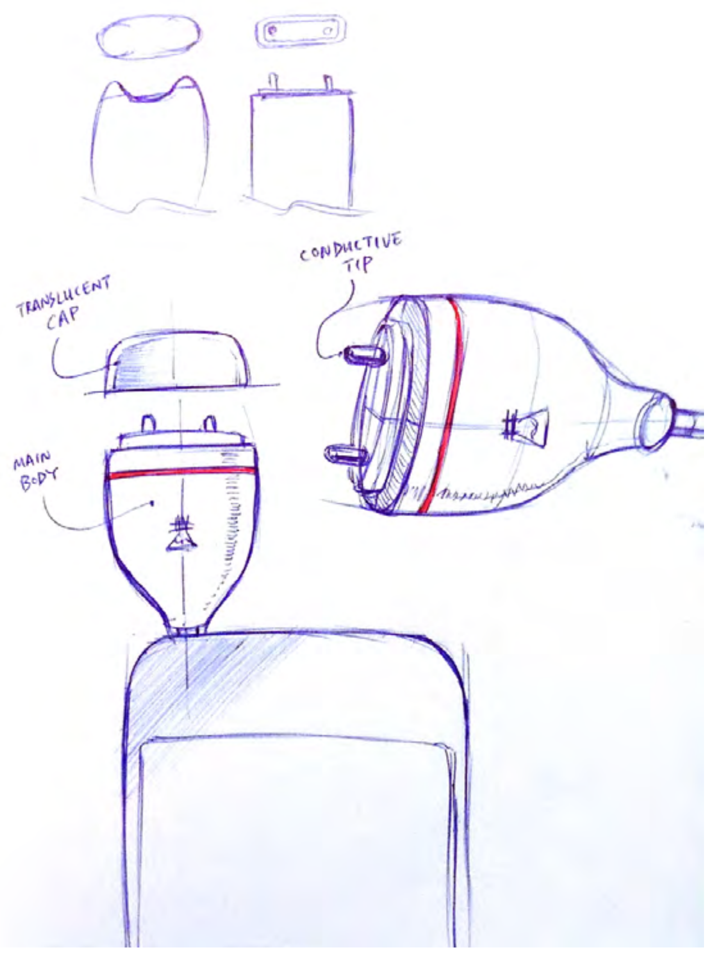


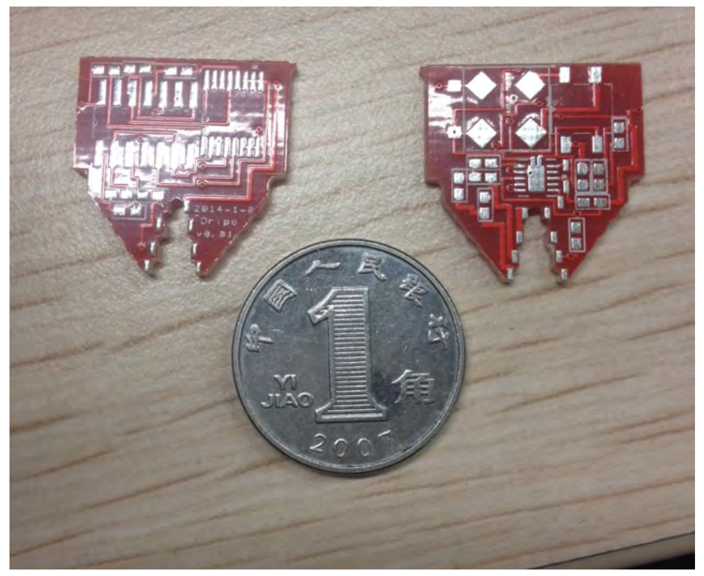


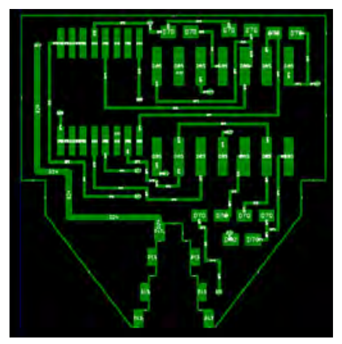
Electrochemical analysis for skin parameter measurement.

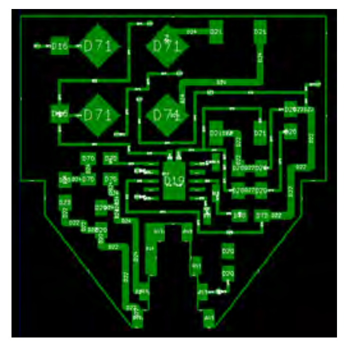
I constructed two resonant circuits and connected the skin to these circuits through two adjacent electrodes. By measuring the resonant frequency, we can indirectly measure the skin's resistance and capacitance values, which are related to the skin's moisture and oil content.

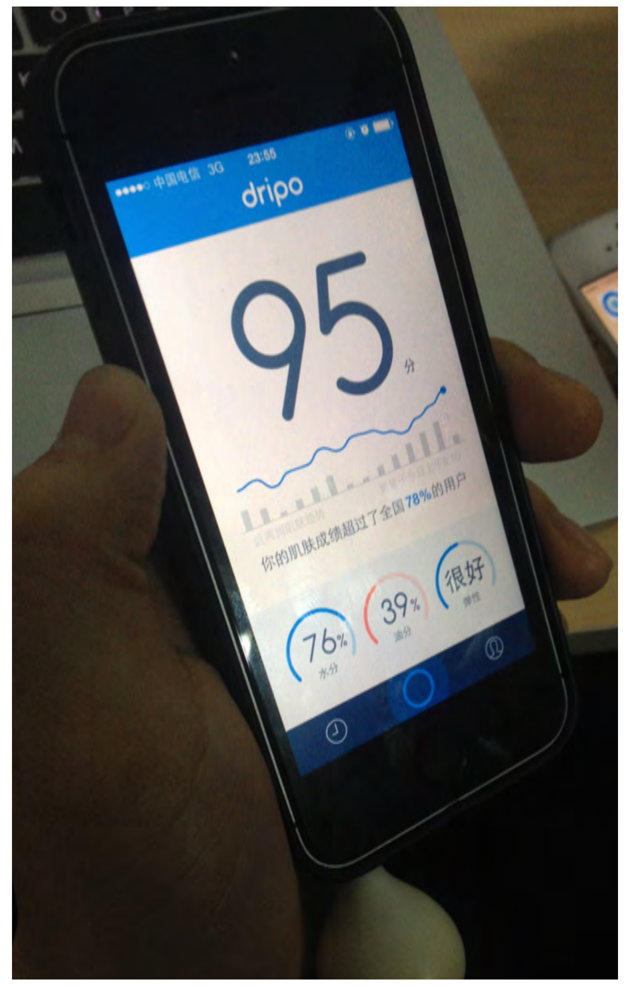
I use customer surveys and skin photos as initial data. By correlating these with subsequent changes in moisture and oil content measured by dripo, I can model skin characteristics and accomplish continuous monitoring of the skin.











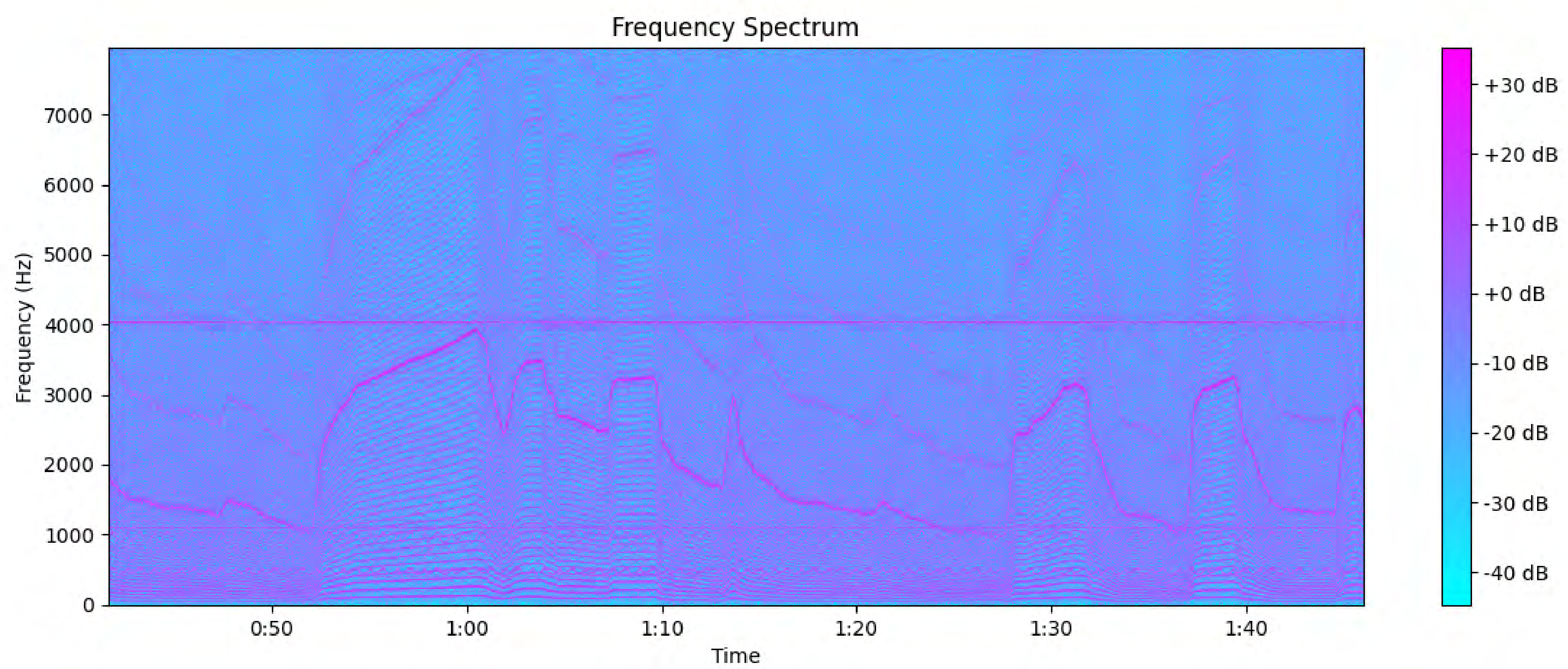
Dripo Introduction Video

BatteryX (2018)

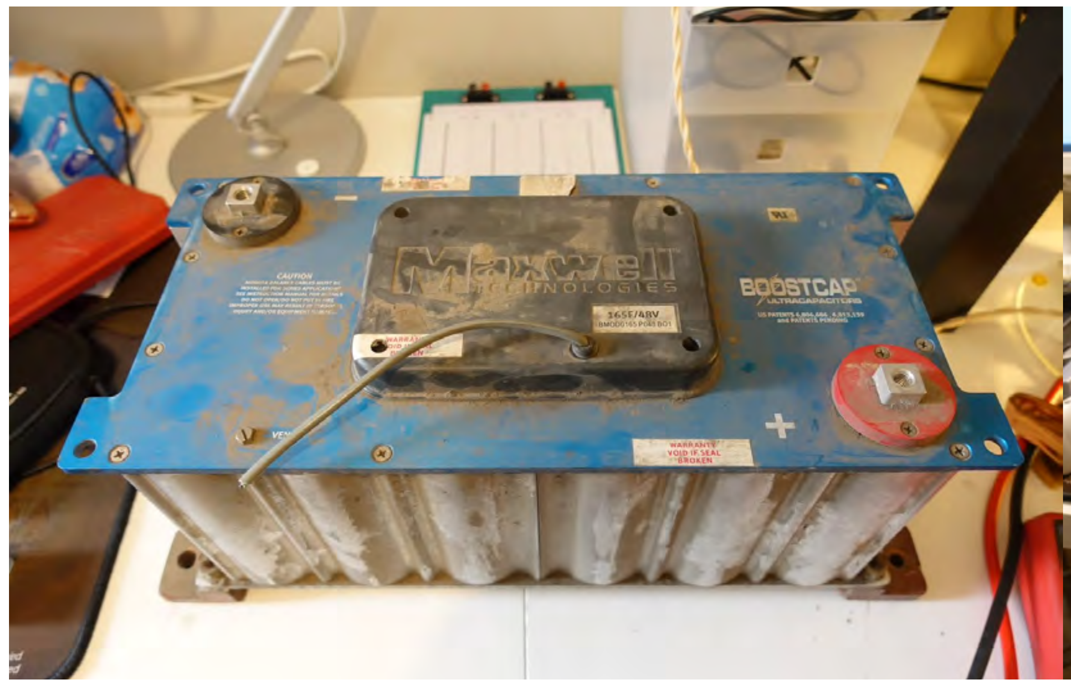
Project Type: Personal Project

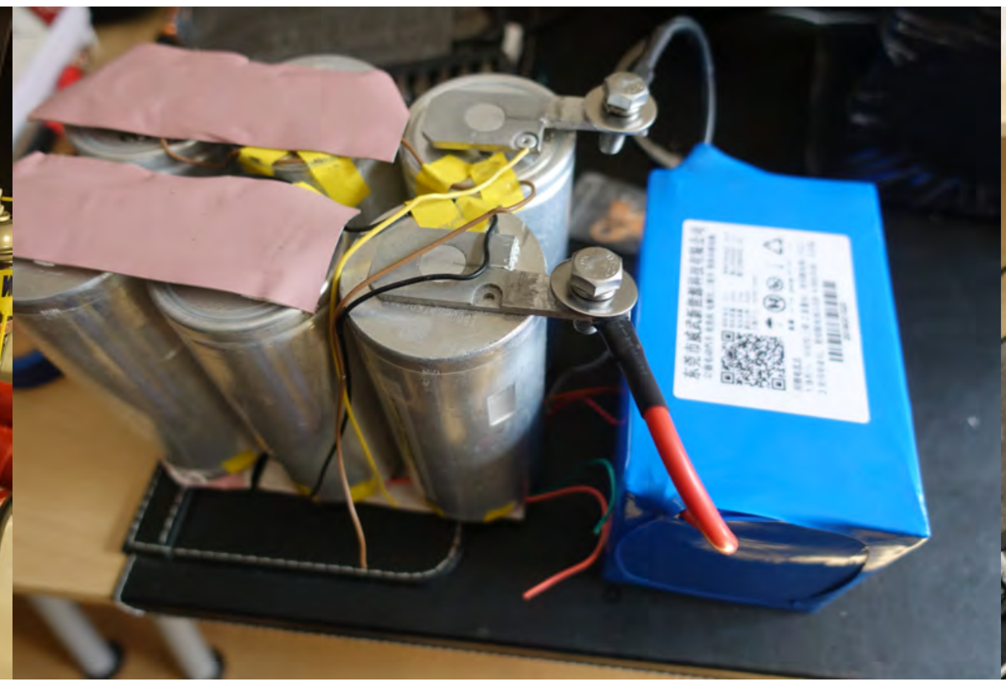
My Role: All

Impact and Results: Supported my off-road expedition and data logging; recycled material [osonic/BatteryX (github.com)]

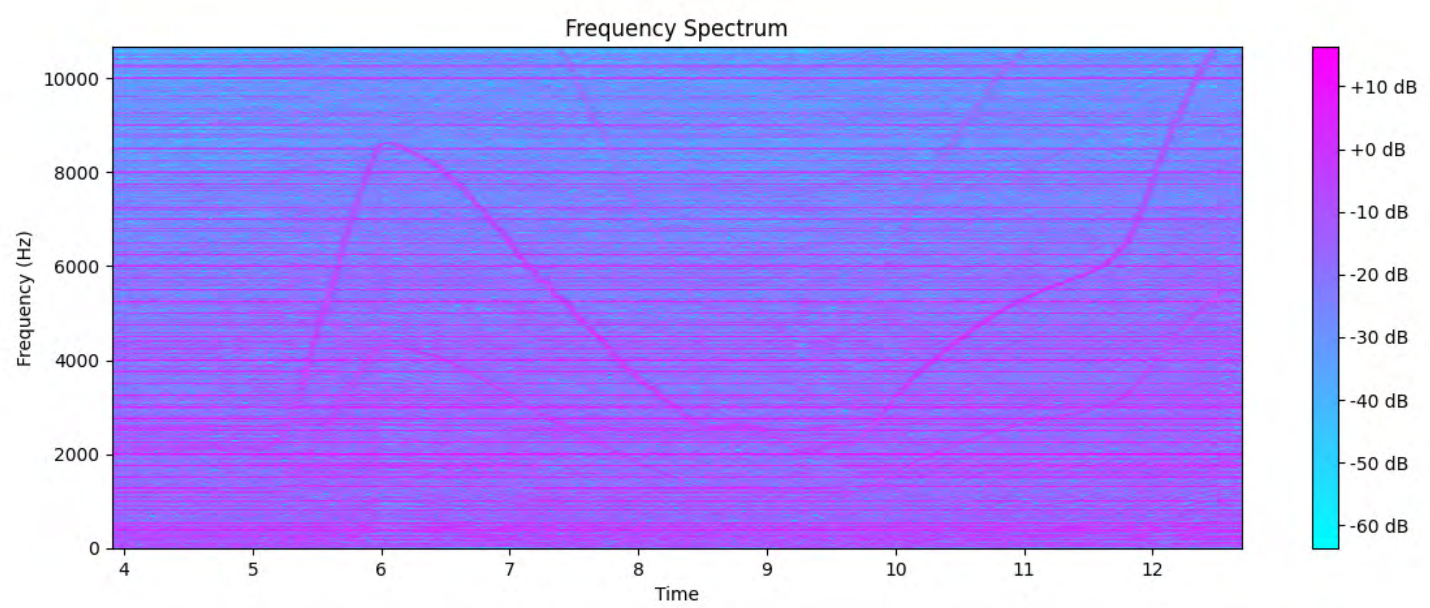


I am an off-road enthusiast and I enjoy driving into cold regions for adventures. Car batteries significantly lose performance in low temperatures, and I often encounter difficulties in starting the engine. Therefore, I thought of using **a hybrid system composed of supercapacitors and lithium iron phosphate batteries**, combining the advantages of both. The supercapacitors provide high current for car ignition, while the lithium iron phosphate batteries compensate for the self-discharge of the supercapacitors and supply power to the ECU.

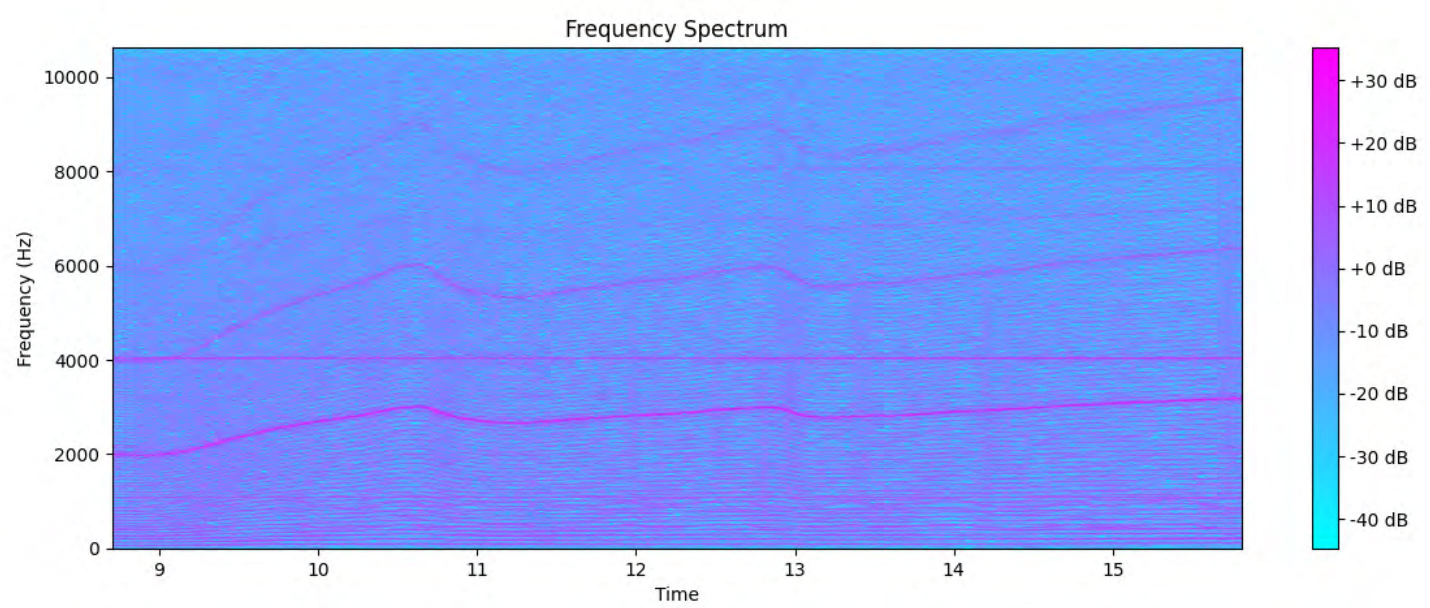




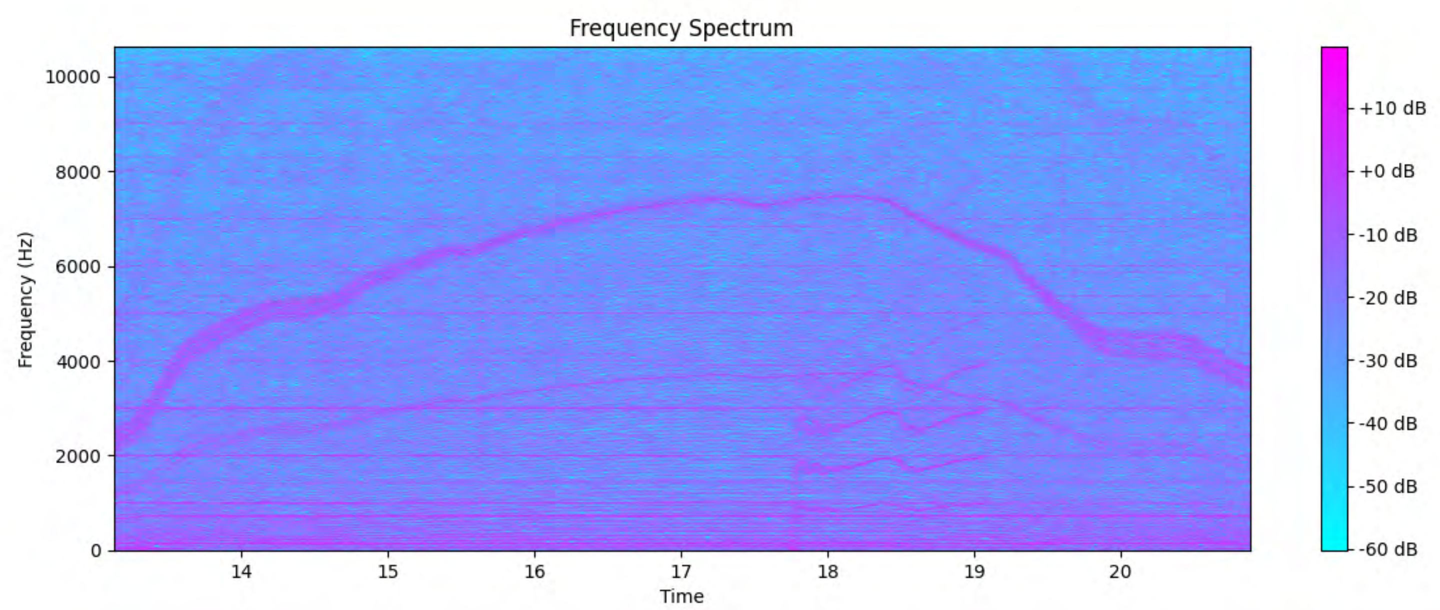
BatteryX (2018)



Jeep Compass, V4 Turbo Engine



Misubishi Pajero, V6 Engine



Honda Jade, V4 Engine

This system still works perfectly to this day, with a **lifespan far exceeding that of lead-acid batteries**.
Interestingly, when I was using an oscilloscope to observe the discharge curve of the supercapacitor during startup, I noticed a lot of noise. This immediately made me think that the noise signals could contain more information about the engine's operating condition. My initial thought was that the momentary ignition of the spark plug would release electromagnetic waves, which would then be reflected in the car's electrical system. This way, the engine's exact RPM could be intuitively measured, further allowing for the analysis of the engine's working condition. **This is somewhat analogous to pulse diagnosis in traditional Chinese medicine**. I connected an MCU to the hybrid battery system for signal collection and then conducted spectral analysis on the signals collected by the MCU. As expected, a clear fundamental frequency curve was visible. However, the fundamental frequency obtained from the spectral analysis was not directly equivalent to the engine speed but showed a very clear linear correlation. Therefore, through simple parameter calibration, I was able to accurately determine the engine speed.
Additionally, I observed that different car models, apart from the fundamental frequency, have many of their **own characteristic spectra**, similar to a car's fingerprint. Perhaps this fingerprint could be used to confirm the car model, engine type and conduct more complex analysis.

This hybrid system surpasses the functionality of lead-acid batteries. The supercapacitors used are sourced **from scrapped energy recovery units**, with a total weight of only 7.7kg. There is also ample space to **embed sensors and computing units**. It represents an interesting exploration in upgrading traditional fuel vehicles.

THE END

Dec. 2023, Updated

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