Build Your Own Arcade Machine with Tinycade

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ABSTRACT

Tinycade is a platform designed to help game designers build their own mini arcade games by hand. With this platform, one can craft functioning game controllers out of everyday materials such as cardboard and toothpicks. By utilizing computer vision markers, we can create a variety of inputs without a single wire. In this pictorial, we discuss the functionality of Tinycade and showcase three games that demonstrate the variety of controls possible with this platform.

Authors Keywords

Cardboard Prototyping; Tangible Interaction; Alternative Control; DIY

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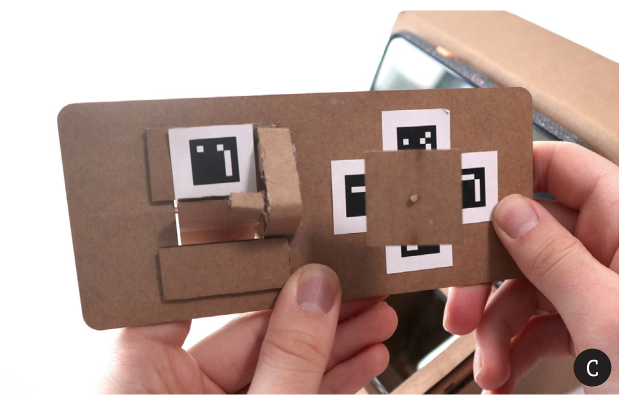


A – Iterations of tinycade designs.
B – Tinycade with control panels for Lightcycles, Cyber Hockey, and CLAW
C – Inspecting the back side of the Lightcycles control panel. CV markers are visible when the inputs are used

INTRODUCTION

We want to empower game designers to creatively explore the design space of tangible game interactions. Currently, designers are often limited to either a mouse and keyboard or a dual stick gamepad for their game interactions. Recently we have seen the rise and celebration of Alt Ctrl (alternative controller) games by the game developing community. These games offer a fertile testbed for Tangible Interface research. Alt Ctrl game designers focus on crafting new and fun interactions with novel physical interfaces.

One Alt Ctrl example is HOT SWAP [8], which divides the tasks of operating a ship, like steering and managing the sails, into individual inputs that must be swapped during play. Or Octopad [13], which turns a classic Nintendo Entertainment System (NES) controller into eight distinct parts. This transforms any game for the NES into a real time co-op strategy game. There are also Alt Ctrl games that put narrative context directly into the interface. Cook Your Way [14] educates players on how the immigration process strips people of their culture with its faux kitchen controller, complete with a knife and pot. Similarly, The Book Ritual [2] requires players to commit the taboo of destroying actual books while they feed torn out pages to a “living” paper shredder who takes them on a journey of self-reflection. Alt Ctrl games celebrate the creativity, craft and design of game controllers while also experimenting with tangible user interfaces.

Games like HOT SWAP and Cook Your Way would likely not be possible without advancements in digital fabrication such as 3D printing or laser cutting. Most Alt Ctrl games make use of interface prototyping platforms, like Arduino and Makey Makey, to facilitate these interactions. Both fabrication tools and interface prototyping tools are active topics in the tangible interface research community [9, 22, 23]. We see an opportunity to address some of the challenges Alt Ctrl game designers face. Such as the need to gain the technical expertise required to operate digital fabrication tools like 3D printers. Another challenge is that most Alt Ctrl games are shown exclusively at festivals such as ALT.CTRL.GDC [4] and Indiecade [10]. This leaves out the entire audience of players who cannot attend such events. By using common materials and simple crafting approaches, we hope Tinycade games can bridge this gap. If a designer can build their game from spare cardboard, then all they need to do is share the crafting instructions with potential players. Furthermore, by using these materials we encourage the design of controllers that can be easily disassembled, repurposed, and replaced.

In this paper we present Tincyade, an approachable platform for Alt Control games. With this work we explore how to help designers overcome the skill and knowledge barriers of physical computing and simplify the production of Alt Control games. Our aim is to create a Tangible User Interface platform that supports at-home, low-cost fabrication of Alt Controls.

UNPACKING TOOLS FOR PROTOTYPING

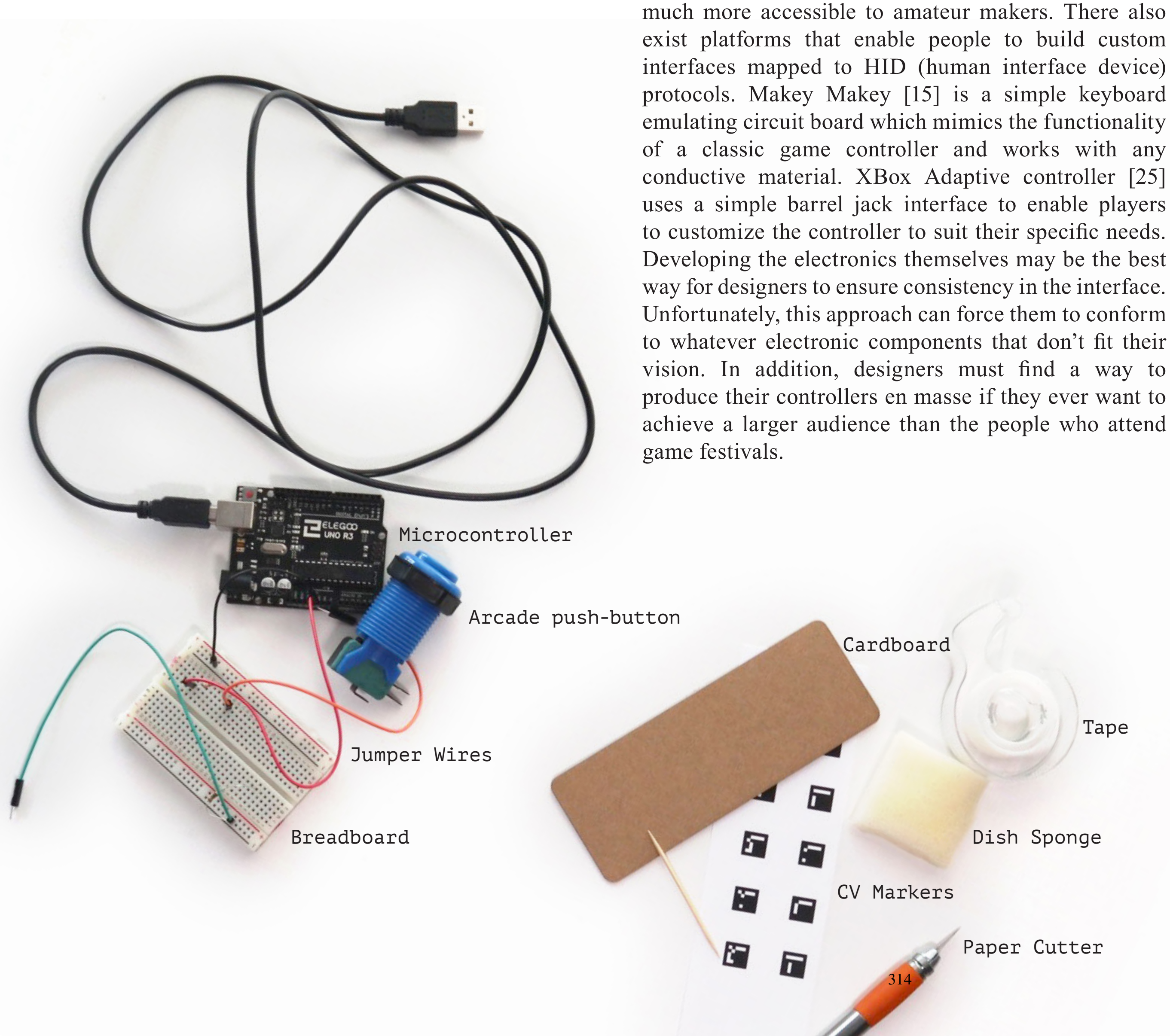
Electronics Based Tools

A common approach to prototyping a novel tangible interface is to build the electronics from the ground up. Microcontroller platforms such as Arduino[5] and Micro:bit [16] have made interactive circuit design much more accessible to amateur makers. There also exist platforms that enable people to build custom interfaces mapped to HID (human interface device) protocols. Makey Makey [15] is a simple keyboard emulating circuit board which mimics the functionality of a classic game controller and works with any conductive material. XBox Adaptive controller [25] uses a simple barrel jack interface to enable players to customize the controller to suit their specific needs. Developing the electronics themselves may be the best way for designers to ensure consistency in the interface. Unfortunately, this approach can force them to conform to whatever electronic components that don't fit their vision. In addition, designers must find a way to produce their controllers en masse if they ever want to achieve a larger audience than the people who attend game festivals.

Computer Vision Based Tools

Utilizing computer vision (CV) as a functional component of an interface has a rich history in tangible interface research. Toolkits such as Reactivision [11, 20] bundle everything a developer would need to create an interactive tabletop. Projects such as Sauron [21] use an infra-red (IR) camera to detect the internal movements of 3D printed controls to determine the state of multiple inputs. In the game industry, a similar technique is used by Nintendo Labo [17], a kit of cardboard templates which are assembled into a variety of physical interfaces. Labo interfaces use the IR camera on the device for CV-enabled inputs. Another CV approach can be seen with Printed Paper Markers [27], which leverages the properties of fiduciary markers to create functional interfaces out of just paper. Controllers made with computer vision can be relatively agnostic about the physical materials involved in their construction as long as the webcam sees the same thing.

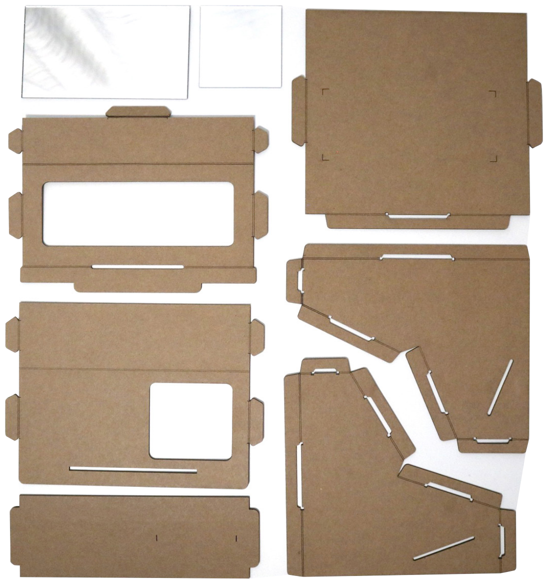
We decided to use CV as the basis of the Tinycade platform because it enables us to use accessible materials without requiring knowledge of how electricity works. We are inspired by all of these projects to use CV as a basis for an Alt Ctrl game prototyping platform. In particular, Tinycade extends Printed Paper Markers, which demonstrated how CV markers can be used as a material alongside simple paper crafting for functional physical interfaces.



BUILDING A TINYCADE

While developing Tinycade, we challenged ourselves to use only materials easily found around our homes. Due to this restriction, a smartphone is the only electronic component we use. This promotes our design goals of ease of distribution, low barrier to entry, and rapid prototyping. The profile of Tinycade is designed to evoke the shape of an actual arcade cabinet. All of the interfaces shown in this pictorial are made using only cardboard, toothpicks, paper, foam, and magnets.

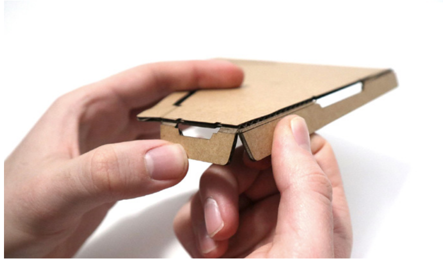
Once the body is assembled, players then need to build the controller for their game. After that they just need to slot their smartphone in and launch the game. While the screen displays the gameplay, the smartphone's rear-facing camera facilitates the computer vision that makes the controls function. We were inspired by projects like Acoustruments [12], which use the phone as a sensor and a display.

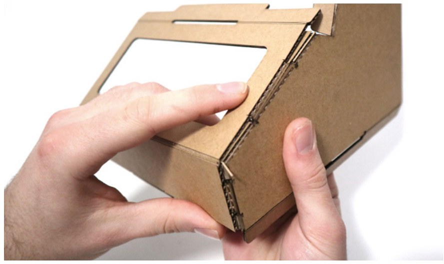


All the components of a Tinycade
Lasercut for easy assembly

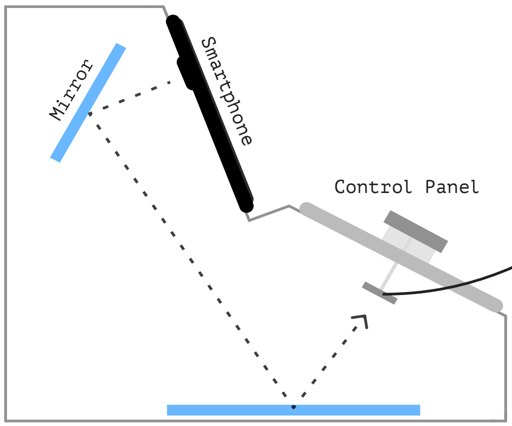
Assembled Tinycade

Assembling Tinycade (left to right):
Fold the parts along the scored lines, insert the tabs in the proper slots, and glue mirrors to the inside.

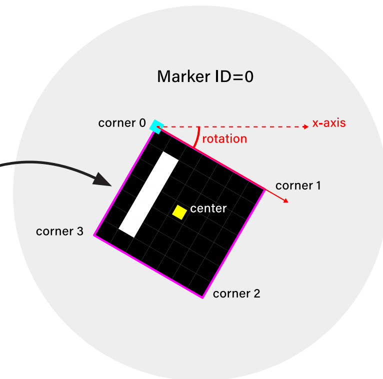




A diagram of the inner workings of Tinycade.



A diagram of a marker with all of its tracked properties.



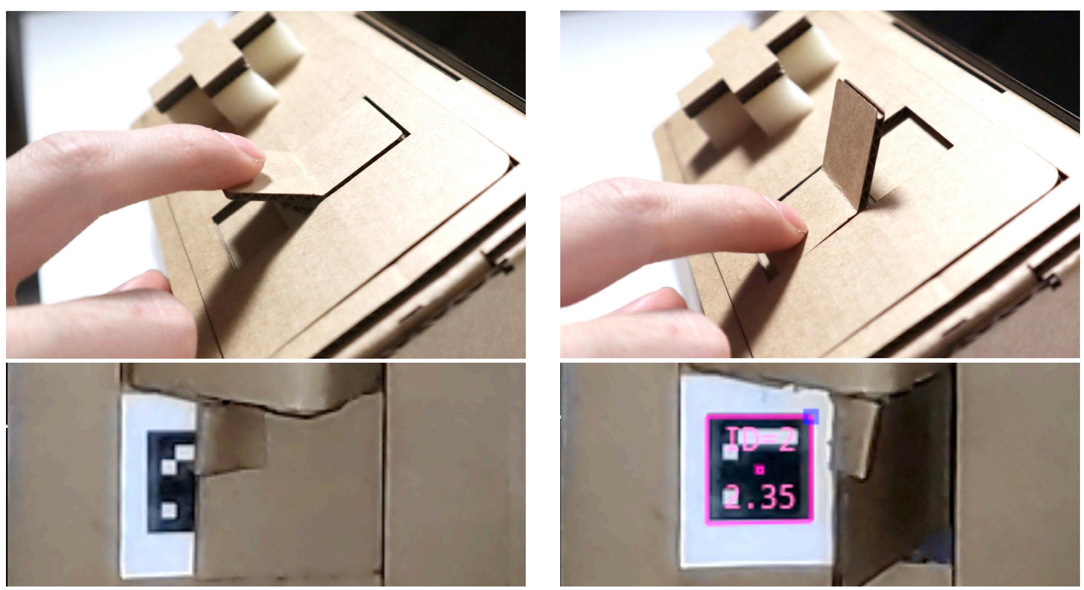
HOW IT WORKS

Inside, Tinycade's cabinet is almost completely empty. By using the rear-facing camera of the phone, we are able to run marker detection on the video feed and render the game for the player to see. The mirrors create a periscope that aligns the camera view with the back of the control panel, enabling the controls to function without any additional electronics. The control panels are also interchangeable, which enables a wide variety of interfaces to work on the same platform. The computer vision component of Tinycade is built with a JavaScript port [7] of the original 5x5 ArUco [6] marker dictionary. For each marker identified, we can calculate its unique id, x and y position in the camera feed, rotation, and each corner. These properties are used to make each controller function. Using Javascript also enabled us to rapidly iterate on games without worrying about build times or operating system restrictions. This approach means that Tinycade is not bound to a specific hardware or system, unlike the Labo.

IMPLEMENTING AN INTERFACE

To support Tinycade, we developed a Javascript library specifically for creating interfaces with computer vision. Once the library is initialized on a webpage, it automatically initiates everything needed to run marker detection as well as injecting an optional debug overlay that shows the output of the ArUco algorithm. This library also tracks additional information on each marker enabling developers to add rotation and position smoothing, as well as account for when the detection fails or flickers momentarily.

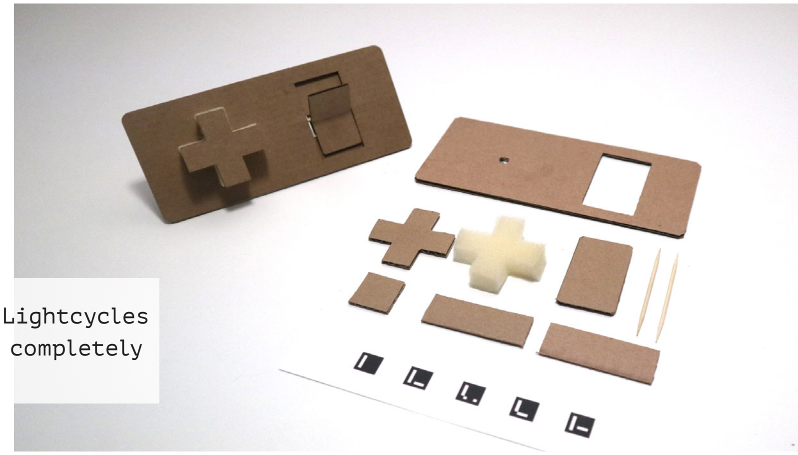
For example, in the game Lightcycles we use a toggle input for the control of when the trail is being created by a player. This functions physically by simply having a switch that snaps into place with attracting magnets and a flap that can cover a marker. When the marker is covered the trail is off, and the trail is on when revealed.



The toggle input in its two states with computer vision view.

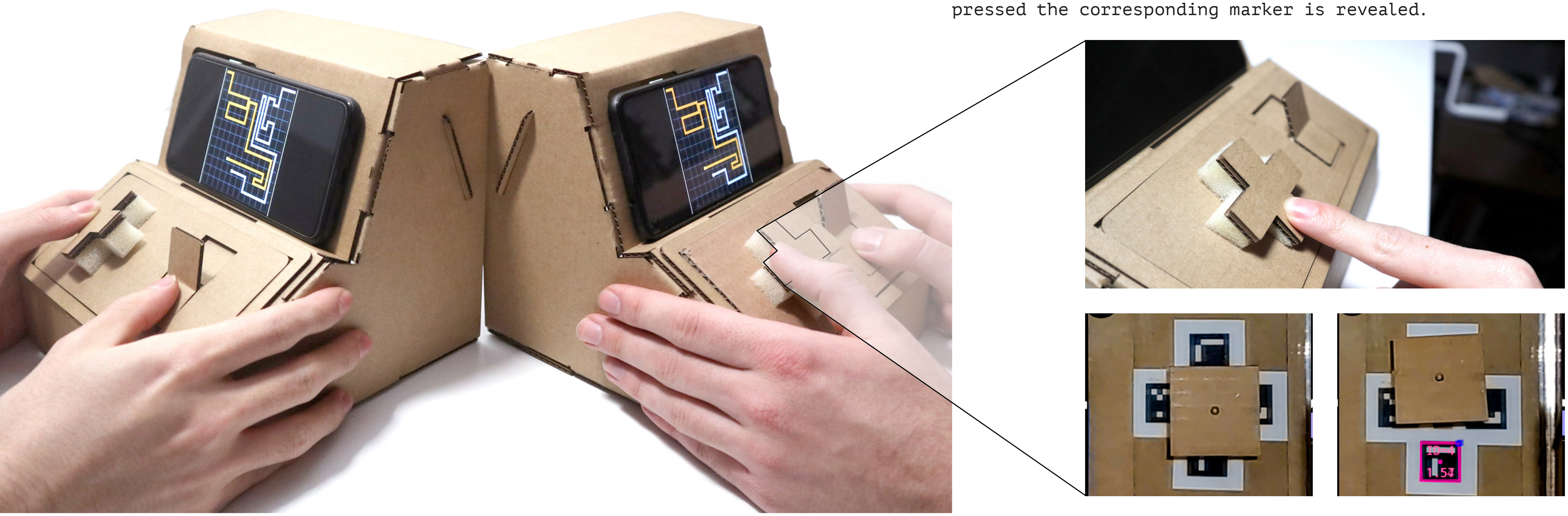
GAME: LIGHTCYCLES

Lightcycles is a wi-fi multiplayer game inspired by TRON. We were inspired by arcades where multiple racing game booths are lined up next to each other. In Lightcycles, players try to be the last one standing by driving around on the grid and leaving walls behind them to cause other players to crash. You win when all other players are eliminated. The controller is a simple d-pad, used to steer the lightcycle and a switch to toggle its trail on and off.



The components of a Lightcycles controller next to a completely assembled one.

The d-pad for Lightcycles detects the presence of four markers hidden behind a blocker. When a direction is pressed the corresponding marker is revealed.

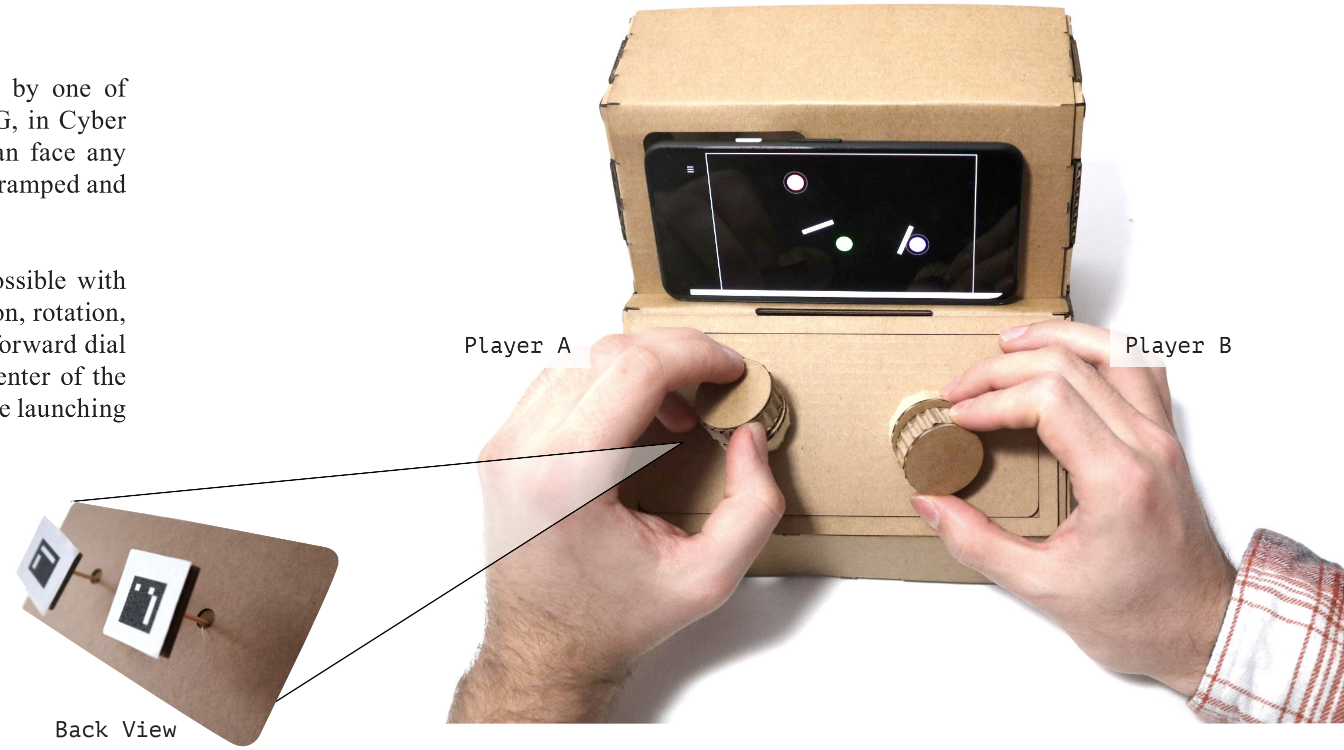


GAME: CYBER HOCKEY

Cyber Hockey is a competitive two-player game inspired by one of the oldest arcade games, PONG [3]. However, unlike PONG, in Cyber Hockey, players can move freely around the screen and can face any direction. We wanted the fun of this game to come from its cramped and frantic nature.

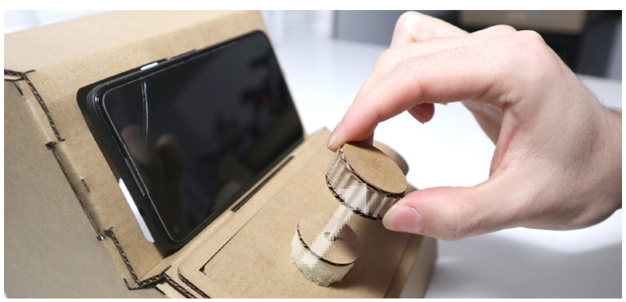
We packed as much functionality into a single input as possible with this controller. With their knob a player controls their position, rotation, and paddle. This opposes the simplicity of PONG's straightforward dial controls. To score a point, you must hit the ball into the center of the other player's character. But you must also be careful, because launching your paddle to hit the ball leaves your own goal vulnerable.

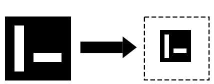
CV View



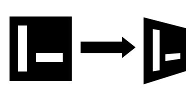
Back View

Pulling the knob moves the marker away, this changes the marker's perimeter which launches the player's paddle.

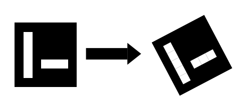




Tilting the knob like a joystick moves the marker. This offset determines the player's movement vector.



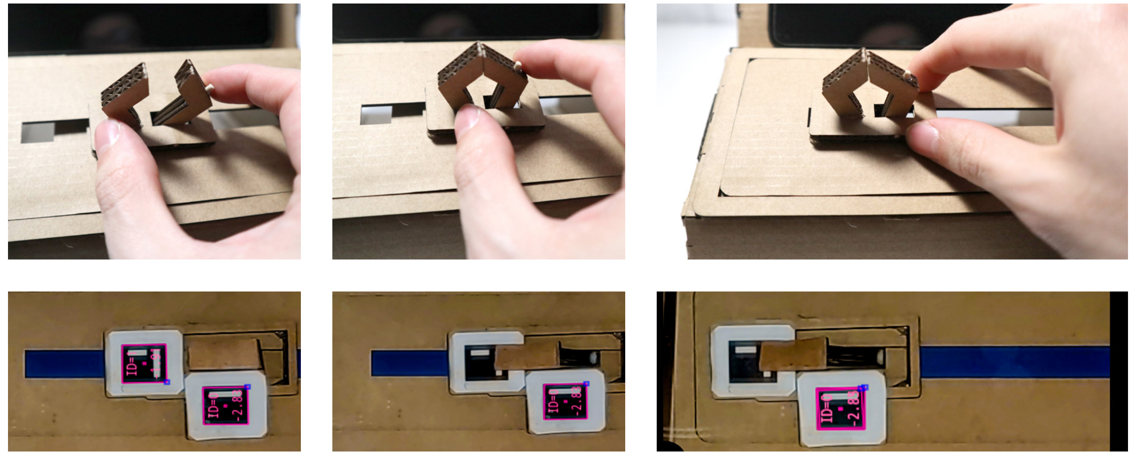
Twisting the knob rotates the marker which is mapped to the rotation of the paddle in the game.



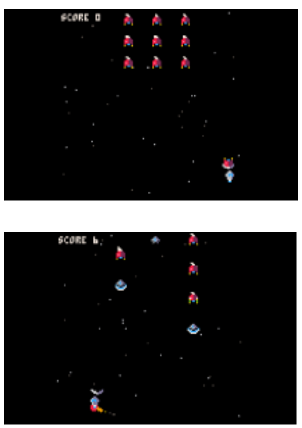
GAME: CLAW

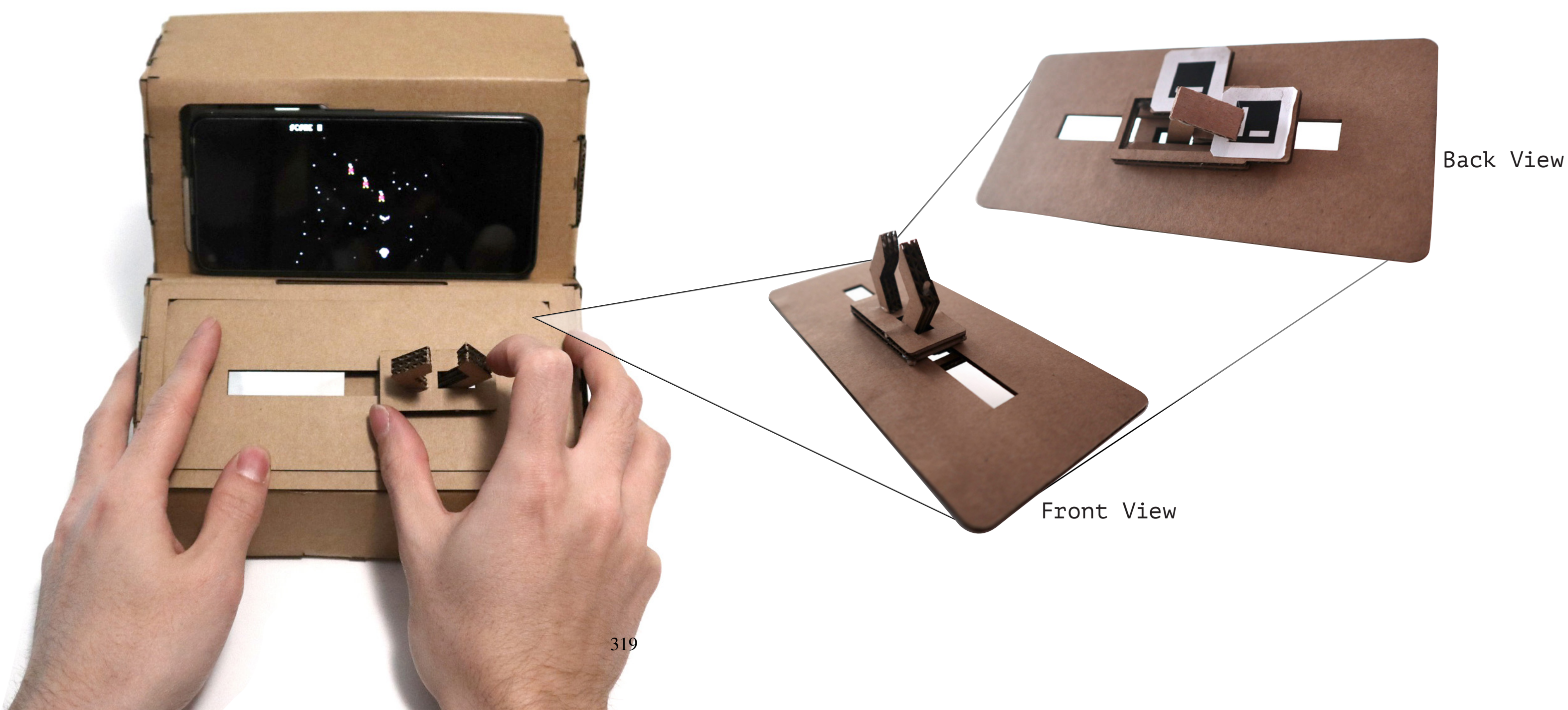
CLAW is inspired by “Shoot em ups” such as Galaga [26] in which players aim to survive for as long as possible as enemies bombard them. In lieu of players having their own weapons, they must instead use their claw to steal enemy ships along with their powers. To get a high score, players must grab a variety of different enemies and use their powers to stay alive.

In order to capture the interaction of grabbing hold of an enemy, we designed the controller as a claw itself. When a player closes it, their in-game claw launches out to grab an enemy. Once they have an enemy in their clutches, pinching the claw activates that ship’s weapons. The claw input is also attached to a slider, which maps directly to the position of the ship on the screen.



The core action of CLAW is mimicked by the interface, with a sliding pincer as the central component. When you pinch the claw, a tab moves to block a marker which the in game ship’s claw. A pair of attracting magnets snap the claw into an open state when let go. Sliding the claw along the track, moves a second marker with it. This marker’s position maps directly to the position of the ship.





DISCUSSION

Debugging at a Glance

One of the biggest advantages of working with CV markers is how straightforward debugging can be. Even without the camera on, you can tell if the interface is going to work . As long as you understand how markers work, it becomes apparent if your input will work in most cases.

"Sketching" functional Controllers

A common workflow we employ while designing controllers with CV markers is to hack together a rough structure and tack on some markers to make it functional. Supporting the art and craft of design and creativity approach is an important goal of Tinycade. This also extends to the ability to repurpose any material you have access to into a functioning interface as long as you can find a good camera angle.

Limitations of CV Markers

One of the greatest limitations we faced while working on Tinycade has been the high CPU load of computer vision. Even on modern smartphones you can expect to see an average latency of 0.2 seconds. This unfortunately prevents designers from creating controllers that are as responsive as a player might expect. The camera's view also limits the design space. Your canvas for the interface is determined entirely by the field of view of the camera that is observing the markers. Given these factors, Tinycade is still not in a place where all potential players can print a controller template and play its games. Yet it is at the stage where hobbyist makers can begin crafting and sharing their own custom arcades.

Conclusion

We are excited about the opportunities for Tinycade going forward. We hope to see game designers exchanging Alt Ctrl games in an easy to recreate format such as a PDF. We envision Game Controller Hackathons where anyone with a phone can participate. The standardized format of Tinycade has the potential to expand the community of Alt Ctrl designers, making it easy for players to experience unique games with unique controls. Tinycade may also serve as an onboarding tool for aspiring interface designers without a technical background.

ACKNOWLEDGEMENTS

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A – Making refinements to the CLAW controller.
B – A dozen controller explorations including basic inputs (i.e. knob, slider, button)
C – Prototype swappable control panel.

REFERENCES

[1] Adams, B. (1982). Tron. Bally Midway.

[2] Aitcheson, A. (n.d.). The Book Ritual. Itch.Io. Retrieved August 2, 2021, from https://agaitcheson.itch.io/the-book-ritual

[3] Alcorn, A. (1972). Pong. Atari.

[4] alt.ctrl.GDC Archive. (2019, September 11). Game Developers Conference. https://gdconf.com/alt-ctrl-gdc/archive

[5] Arduino - Home. (n.d.). Retrieved August 2, 2021, from https://www.arduino.cc/

[6] Garrido-Jurado, S., Muñoz-Salinas, R., Madrid-Cuevas, F. J., & Marín-Jiménez, M. J. (2014). Automatic generation and detection of highly reliable fiducial markers under occlusion. Pattern Recognition, 47(6), 2280–2292. https://doi.org/10.1016/j.patcog.2014.01.005

[7] GitHub - jcmellado/js-aruco: JavaScript library for Augmented Reality applications. (n.d.). GitHub. Retrieved August 2, 2021, from https://github.com/jcmellado/js-aruco

[8] Gyory, P., Zheng, C., Leithinger, D., & Do, E. Y.-L. (2019). HOT SWAP: Probing Embodied Game Interfaces With Reconfigurable Controllers. Companion Publication of the 2019 on Designing Interactive Systems Conference 2019 Companion, 183–187. https://doi.org/10.1145/3301019.3323901

[9] Hill, C., Schneider, M., Eisenberg, A., & Gross, M. D. (2021). The ThreadBoard: Designing an E-Textile Rapid Prototyping Board. Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction, 1–7. https://doi.org/10.1145/3430524.3440642

[10] IndieCade. (n.d.). Retrieved August 2, 2021, from https://www.indiecade.com/

[11] Jordà, S., Geiger, G., Alonso, M., & Kaltenbrunner, M. (2007). The reacTable: exploring the synergy between live music performance and tabletop tangible interfaces. Proceedings of the 1st International Conference on Tangible and Embedded Interaction, 139–146. https://doi.org/10.1145/1226969.1226998

[12] Laput, G., Brockmeyer, E., Hudson, S. E., & Harrison, C. (2015). Acoustruments: Passive, Acoustically-Driven, Interactive Controls for Handheld Devices. Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, 2161–2170. https://doi.org/10.1145/2702123.2702414

[13] Lemieux, P. (n.d.). Octopad. Retrieved August 2, 2021, from http://patrick-lemieux.com/projects/Octopad/

[14] Llagostera, E. (n.d.). Cook Your Way. https://enric.llagostera.com.br/cookyourway/

[15] Makey Makey. (n.d.). Joylabz Official Makey Makey Store. Retrieved September 23, 2020, from https://makeymakey.com/

[16] Micro:bit Educational Foundation. (n.d.). Retrieved August 2, 2021, from https://microbit.org/

[17] Nintendo LaboTM for the Nintendo SwitchTM home gaming system - Official Site. (n.d.). Retrieved September 23, 2020, from https://labo.nintendo.com/

[18] Oh, H., Hsi, S., Eisenberg, M., & Gross, M. D. (2018). Paper mechatronics: present and future. Proceedings of the 17th ACM Conference on Interaction Design and Children, 389–395. https://doi.org/10.1145/3202185.3202761

[19] Oh, H., Hsi, S., Klipfel, K., & Gross, M. D. (2017). Paper Machines. Proceedings of the Eleventh International Conference on Tangible, Embedded, and Embodied Interaction, 771–774. https://doi.org/10.1145/3024969.3025050

[20] reacTIVision. (n.d.). Retrieved August 2, 2021, from http://reactivision.sourceforge.net/

[21] Savage, V., Chang, C., & Hartmann, B. (2013). Sauron: embedded single-camera sensing of printed physical user interfaces. Proceedings of the 26th Annual ACM Symposium on User Interface Software and Technology, 447–456. https://doi.org/10.1145/2501988.2501992

[22] Tokuda, Y., Sahoo, D. R., Jones, M., Subramanian, S., & Withana, A. (2021). Flowcuits: Crafting Tangible and Interactive Electrical Components with Liquid Metal Circuits. Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction, 1–11. https://doi.org/10.1145/3430524.3440654

[23] VirtualWire: Supporting Rapid Prototyping with Instant Reconfigurations of Wires in Breadboarded Circuits | Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction. (n.d.). Retrieved August 3, 2021, from https://dl.acm.org/doi/abs/10.1145/3430524.3440623

[24] Weiss, M., Wagner, J., Jansen, Y., Jennings, R., Khoshabeh, R., Hollan, J. D., & Borchers, J. (2009). SLAP widgets: bridging the gap between virtual and physical controls on tabletops. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, 481–490. https://doi.org/10.1145/1518701.1518779

[25] Xbox Adaptive Controller | Xbox. (n.d.). Xbox.Com. Retrieved August 2, 2021, from https://www.xbox.com/en-US/accessories/controllers/xbox-adaptive-controller

[26] Yokoyama, S. (1981). Galaga. Namco.

[27] Zheng, C., Gyory, P., & Do, E. Y.-L. (2020). Tangible Interfaces with Printed Paper Markers. In Proceedings of the 2020 ACM Designing Interactive Systems Conference (pp. 909–923). Association for Computing Machinery. https://doi.org/10.1145/3357236.3395578

[28] Zheng, C., Kim, J., Leithinger, D., Gross, M. D., & Do, E. Y.-L. (2019). Mechamagnets: Designing and Fabricating Haptic and Functional Physical Inputs with Embedded Magnets. Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction, 325–334. https://doi.org/10.1145/3294109.3295622