Universität Bremen

Bachelor Thesis – Digital Media

# An alternative shape for a game controller with specific visual feedback

## Designing a gamepad with new exterior design, while taking ergonomics of face buttons into account


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# 1 Preface

Ich möchte mich an dieser Stelle bei all denjenigen bedanken, die mir während meiner Bachelorarbeit zur Seite gestanden oder ihre Hilfe angeboten haben. Ich danke euch von Herzen!

Für meine Mutter, der ein ganz besonders Dankeschön gebührt, für die immerwährende Unterstützung in meinem gesamten Studium. Danke, dass du immer für mich da bist und mir diesen Weg ermöglicht hast.

In Gedenken an meinen Großvater.

# 2 Introduction

Regardless of how good a game is, it's definitely not enjoyable with a bad gaming controller. There is a huge number of aspects that need to be considered when developing a game pad. The conception of a design that works for every game, is ergonomic, enjoyable and especially intuitive to use, is a complex task.

Some people build their own gaming controller to fulfill exactly the aspects that are important to them. Mostly their form look almost similar to that classic form like the GameCube controller, Sony PlayStation controller or Xbox controller. They all have one thing in common: Their underlying shape.

The development of this shape took years and left behind some astonishing gaming controllers. Some of them were just a box with two knobs and one analogue stick. Particularly inspiring was the Sega Genesis controller, because it was the first that featured small downward extensions and a curved and therefore very ergonomic shape. This kind of different shape led to the idea which is considered in this bachelor thesis.

Creating a gaming controller with an alternative shape for playing retro games or emulator games with the feeling of a matching gaming controller instead of a mouse and keyboard. In addition, this thesis dealt with the idea of producing a gaming controller that was reduced to the most important aspects and is still pleasurable to the user. The four face buttons allow for all the necessary inputs that are required to interact with these games. The scope of this thesis are only the upwards facing elements of such a controller. Shoulder buttons, triggers and similar inputs will not be included.

The directional pad is usually present in retro controllers but not integrated in my controller. Reason for this is that two joysticks allow more movement and freedom, since not only up, down, left and right are given as directions, but also diagonal movements. Therefore, I decided to leave out the directional pad and integrate two joysticks instead, similar to the GameCube controller. Of course, one of these joysticks is used for the movement itself and the other as a kind of C-Stick (GameCube) or as an environment viewer.

This thesis is focused on the ergonomics of my own gaming controller. Not only the shape of the game pad, but also the placement of the buttons. One of the major aspects considered here are the thumb muscles.

## 2.1 Problem definition

Another question is to find an option to build a gaming controller that is in addition to being efficient, ergonomic and requires minimal muscle effort from the thumb. Research into this question is conducted in this thesis and the gaming controller is designed. This includes, of course, the thumb muscules as well as typical movements of the human body.

Jinghong Xiong's study "An ergonomics study of thumb movements on smartphone touch screen." examined thumb movements on smartphones and targeted six muscles in the thumb and forearm to record muscle fatigue from individual movements. They say that

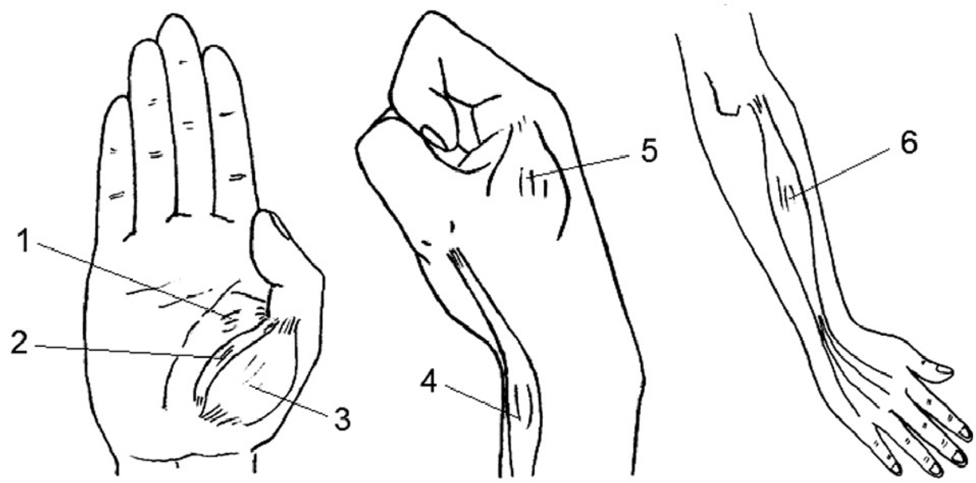



Figure 1: The six targeted thumb muscles: (1) AP – adductor pollicis, (2) FPB – flexor pollicis brevis, (3) APB – abductor pollicis brevis, (4) APL – abductor pollicis longus, (5) FDI – first dorsal interosseous, (6) ED – extensor digitorum [**Xiong**, **2014**]

six muscles in the right thumb and forearm were targeted. (Figure 1), namely adductor pollicis (AP), flexor pollicis brevis (FPB), abductor pollicis brevis (APB), APL, first dorsal interosseous (FDI) and extensor digitorum (ED). [**xiong2014ergonomics**]

In this illustration, the muscles of the thumb and forearm are visualized to clarify understanding of the subject.

A number of tasks had to be completed by the participants in the study. The first was the tapping task, in which they had to press four different buttons on the prototype. The photos show that they had to stretch or bend their thumbs.

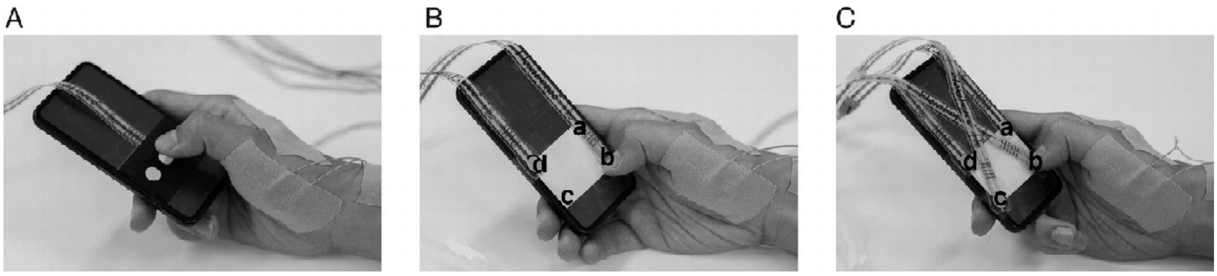



Figure 2: Tasks in three tasks: A. Tapping task: large button task – button diameters of 9.0 mm, small button task – 3.0 mm; B. Moving task: adduction–abduction task – orientation between a and c, flexion–extension task – b and d; C. Circling task: clockwise task – direction a-b-c-d, counter-clockwise task: a-d-c-b [**Xiong**, **2014**]

In the next task, the participants had to make a kind of circular movement while pressing the different buttons in the given order. Clockwise up-right, down-right and then down-left, up-left.

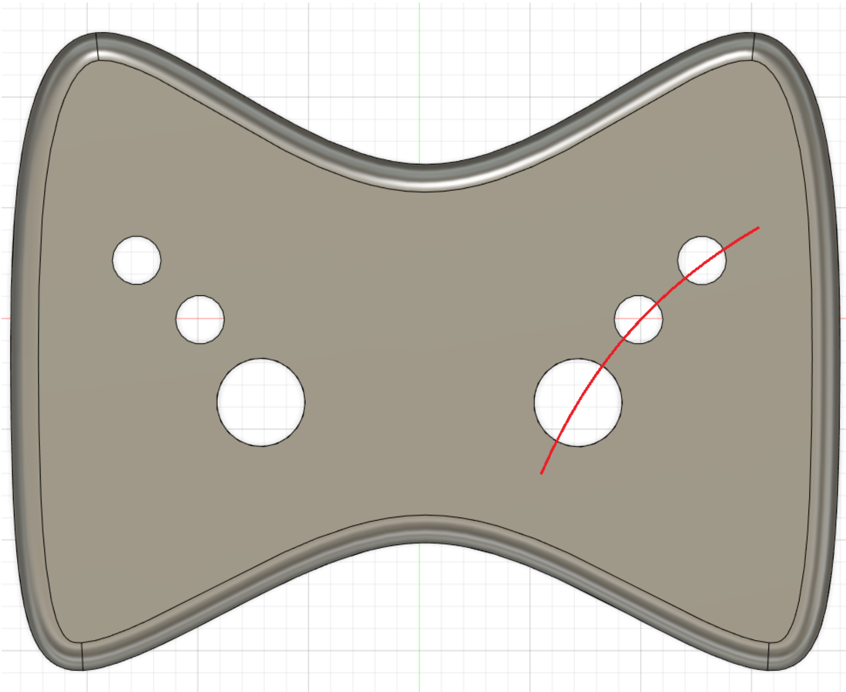


Figure 3: Curved Button Arrangement

My arrangement of the buttons would be a movement from bottom-left to top-right or vice versa. Depending on what buttons the user wants to press, the order changes for me. But the movement remains constant, because my buttons are arranged in a curve.

As can be seen in 3, indicated with a red line, all three buttons on both sides lie on a slightly angled line. This curve is the main focus of the controller, as it ensures that the thumb only has to act laterally and does not have to be expanded or contracted. Furthermore, the keys are kept low profile to minimize vertical movements of the thumb. It is not necessary for the user to lift the thumb very far to reach the keys. Therefore, the user only has to make a swiping motion, as intuitively known from smartphones. This is a significant aspect in the production of gaming input devices. The ability for people to use a game or even a game pad intuitively and comfortably is crucial. These are devices that should increase the fun and not frustrate the user with overly complicated inputs.

Furthermore, the controller also supports the AC Grip. This is also possible and common with lots of other controllers, but this one has a better handle because no shoulder buttons interfere by requiring the player to hold the device in a particular way.

## 2.2 Aim of thesis

It is not the purpose of this thesis to design a gaming controller which has the most evolutionary technical implementation and design. The idea here is to develop an interesting gaming controller that has a completely different shape but is still ergonomic and efficient. Of course the latest gaming controllers have much more modern functionalities and highly finegrained technology inside.

The challenge was, to design and develop a gaming controller whose shape is different from all conventional models and yet ergonomically fits in the hands of the user. Since this gaming controller was designed for this kind of games, the retro design was an important aspect in this work.

User experience is the most important thing for me, which means that the shape and placement of the buttons and joysticks influence the design the most. It is about exceptional handling and intuitive operation of a simplified retro controller. The new way of arranging the buttons in a single curve is meant to be easy on the muscles and should allow the user to enjoy playing for extended amounts of time. For further stimuli of visual effects, I have included LEDs that illuminate the buttons and joysticks. Visual stimuli, as well as the feel of the buttons and the general shape of the controller, I feel is the main task and have adapted this gaming controller exactly to my own requirements.

Over the course of this thesis I will design a gaming controller that will feature a new and audacious exterior design, while accounting for placement of face buttons and joysticks in accordance to thumb muscle ergonomics.

# 3 History of Gaming Controllers

- Brown Box (1967)
- Magnavox Odyssey 100 (1972)
- Magnavox Odyssey Shooting Gallery (1972)
- Atari Home Pong console (1975)
- Fairchild Channel F (1976)
- Coleco Telstar Arcade (1977)
- RCA Studio II (1977)
- Atari 2600 (1977)
- Atari 5200 SuperSystem (1982)
- Casio PV1000 (1983)
- Nintendo Entertainment System (1983)
- Sega Master System (1985)
- Atari 7800 (1986)
- Sega Genesis/Mega Drive (1988)
- Commodore 64 Games System (1990)
- Super Nintendo Entertainment System (1990)

- Philips CDi (1991)
- Sega Activator (1993)
- Atari Jaguar (1993)
- Sega Saturn (1994)
- Neo Geo CD (1994)
- Sony PlayStation (1994)
- Nintendo 64 (1996)
- Apple Bandai Pippin (1995)
- Microsoft Sidewinder Force Feedback Wheel (1997)
- Sony PlayStation DualShock (1997)
- Sega Dreamcast (1998)
- Nintendo GameCube (2001)
- Microsoft's 'Fat' Xbox (2001)
- Nintendo Wavebird (2002)
- Microsoft Xbox 360 S (2005)
- Nintendo Wiimote and nunchuck (2006)
- Microsoft Kinect (2010)
- PlayStation Move (2012)
- Nintendo Wii U Gamepad (2012)
- Microsoft Xbox One (2013)
- Sony PlayStation DualShock 4 (2013)
- Xbox One Elite Controller (2015)
- Nintendo Switch Joy Cons (2017)
- Sony PlayStation 5 DualSense (2020)

Game Controllers have come a long way. The Atari Joystick was the main controller for the Atari 2600, officialy called the Atari cx-10 joystick which was a very simple nine pin controller with a joystick and a single button.

Over the intervening years, game controllers have been tested extensively and have changed significantly with the launch of each new game system console. The most significant modification in recent times has been the consideration of multi-dimensional motion capabilities.

Figure 4: Atari Joystick

As video games have become one of the most lucrative and influential forms of entertainment in both the United States and globally, the importance of the design is a major concern. It must be ensured that the buttons can be reached easily. Players quickly find a game frustrating if the muscles in their fingers and thumbs have to be strained too much in order to play the game. It is therefore very important for the user experience to take these things into account when designing the controller.

Another very interesting study is focused on the assignment and labeling of buttons on gaming controllers. Among other things, Wagner[1] poses the following question:

> "Can the layouts of gaming controllers be placed in a historical lineage that reveals an evolutionary history of the need for certain keys or key combinations?"

The Form of Gaming Controllers has changed over the decades and three major producers of gaming controllers survived: Sony, Nintendo and Xbox.

It is easily noticeable that motion control units are usually placed on the left side of the game pad. This includes all control crosses, all individual sticks except the centrally located N64 stick, and one of each sticks in two-stick configurations.

In the case of two sticks or one stick and another control medium (trackpad of the Steam controller, yellow C-buttons of the N64 pad), one of them is located on each of the two halves of the controller. The N64 controller is an alternative with its three control media like cross, stick, C-buttons, but nevertheless fits into the traditional geometry, since the cross is on the left, the C-buttons are on the right and the stick is in the center. The GameCube controller, as a logical advancement of the N64 controller, is placed between this and the layout that is common today: The C-buttons turned into a C-stick, which takes over the functionality of the right analog stick, but is different in design from the

[1] Die Motivation des Gamepad-Layouts: Eine diachrone bildlinguistische Betrachtung der Knopfbelegung und -benennung

| *Generations* | *Example Consoles* |
|---|---|
| First (1972-1977) | Pong, Magnavox Odyssey |
| Second (1976-1983) | Atari 2600, Intellivison |
| Third (1983-19987) | NES |
| Fourth (1987-1993) | SNES, Sega MegaDrive |
| Fifth (1993-1998) | PlayStation 1, Nintendo 64, Sega Saturn |
| Sixth (1998-2005) | Sega Dreamcast, PlayStation 2, Nintendo Gamecube, Xbox |
| Seventh (2005-2012) | PlayStation 3, Xbox 360, Nintendo Wii |
| Eighth (2012-today) | PlayStation 4, Xbox One, Nintendo Wii U, Nintendo Switch |

Table 1: The Eight Console Generations

one on the left.

Throughout, all face buttons can be found on the right side of the game controller, irrespective of if they are two like in the NES and N64, three like on the MegaDrive or four like most other game pads. The concept of four face buttons has been established in the evolution so far like all PlayStation, all Xbox, SNES and the Nintendo Switch. Also, the dimensions of the face buttons on the controller have mostly remained constant: only the GameCube controller, with the large A button increased compared to the B button, and the semi-circular X and Y buttons, is an exception. The original Xbox controller the "Duke", is also worth mentioning. It had two additional, smaller buttons above the face buttons, which were excluded when the Xbox controller was created new to the design still used today. Every menu and system button is located either directly above the face buttons like the MegaDrive, precisely centered on the controller like the PlayStation, NES, SNES, N64, or both (Xbox, Switch Pro). Only the triangular menu button of the Dreamcast controller is centered, but beneath the other buttons. Instead, the space above it is taken up by a small screen that displays the game title of the game that's currently running.

A historical order of the controller designs is established in order to determine the evolution of the design. The controller designs are determined by how the console was designed and developed. Therefore, the consoles are subdivided into different generations. This procedure is already known and is used not only for gaming consoles but also graphics cards and more.

It is important to consider the way in which consoles should be classified into generations. It would be possible to focus the specification on the controller layout and classify the generations that way. Certainly, one can also proceed according to release date or computing power. Wagner split the consoles into eight generations.

Classyfing the generation in relation to the number of joysticks is the core idea because this layout type provides a strict line through the different designs. Joystick addition is one of the most important changes to the layout and general design of a game pad.

As compared to digital control pads, Joysticks allow for more degrees of freedom. They have digital keys only; no analog keys or joysticks. Over time the number of buttons increased: The NES controller consists of a directional pad, two face buttons and two menu buttons, while the SNES controller from the next generation was designed in such a way that it already had four face buttons with the familiar designation A, B, X and Y and two shoulder buttons. The Sega MegaDrive was rather unusual in that it had a directional pad, three face buttons and a menu button.


Figure 5: Only Buttons Layout

Games that were compatible with this layout are more like retro games where the user controls the avatar from a bird's eye view or side view. Just as my layout of the game pad is intended for certain generations of games. Although my controller has two joysticks.

One stick layout can be seen on the Nintendo 64. The joystick is located directly above the third handle in the center of this controller. Similarly, the Sega Dreamcast includes a joystick to the left of the display. They are based on the previous version of the button-only controllers and not only provide more motion options, but they also allow for additional camera control. This means that not only the avatar can get moved, but also the environment is adjustable.

This method of layout is now an intermediate step between the button-only layout and the two-stick layout. Through the two stick layout, the user achieves a smoother control over the avatar and environment adjustment, in a more precise and more comfortable way. The arguably most popular layout form for game pads is to feature two analog control sticks, a digital directional pad, two digital menu buttons, four digital face buttons and four shoulder buttons. Especially the shoulder buttons have a lot in common. Controllers that have been desined with shoulder keys feature an even number of them in an axis-symmetrical arrangement.

Buttons play an essential part, because my game pad has this kind of distribution and number of buttons due to certain aspects. In the following, I will go into more detail about the designation of the buttons in general, in order to explain later how my controller corresponds to the layout and why the structure is designed this way.


Figure 6: One Stick Layout

Similarities in the naming of the buttons are apparent as well. The joysticks, as well as the directional pad and the C stick are quite consistent in their naming, which is the reason I want to focus on the face buttons here. Nonetheless some differences emerged over time: Nintendo declared the designations for two face- buttons as A and B with the NES controller. This schema is still used on all Nintendo controllers until today and was even applied by Sega for the Sega MegaDrive and extended by the C.

Since the SNES, Nintendo has introduced the four face buttons and also used a consistent naming convention for them, which was also used by Sega for the Dreamcast controller. Both additional face buttons are declared with X and Y. Thus the four face buttons have constant identifiers in A, B, X and Y.

Although Sega has adopted the names for the buttons, they have been adjusted as follows: The positions of A and B and X and Y have been swapped and color-coded. The A button is now red and at the bottom, the B button is now blue and on the right, X is on the left and yellow, and finally Y is green and at the top.

Xbox also adopts the labels but changes them completely so that they no longer have anything to do with the original layout. A at the bottom and green, B on the right and red, X on the left and blue, Y at the top and yellow.

Sony PlayStation, has only taken over the layout of the buttons and changed the image designation. X is at the bottom, the circle on the right, the square on the left and the triangle at the top.

I do not refer to any other buttons than the face-buttons, since they are not relevant in the scope of this thesis.


Figure 7: Two Stick Layout

Especially the designations of the A and B buttons have established themselves over many gaming controller generations and console manufacturers as the final designations of the face buttons, in addition to the X and Y buttons, which were also added by Nintendo in the fourth generation. Since there are no official design documents from nintendo, the question arises where the designations came from.

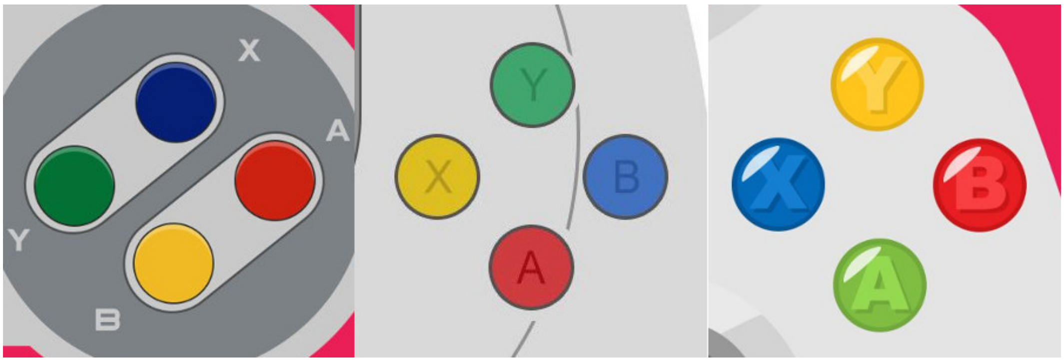



Figure 8: Nintendo Buttons

A conjecture would be if there are several buttons with a similar function or one wants to keep the option open to add more (as happened from NES to SNES), a sequential numbering by numbers or letters is a good idea. A and B as the first two letters of the Roman alphabet, which is also used in Japan when writing Romaji (the romanized spelling of Japanese Hiragana and Katakana) and especially on the international market, lends itself here as well as the numbers 1 and 2[2] The derivation of those face button names when considering X and Y becomes more complex here. The focus could be on the fact that two letters from the end of the alphabet would make sense from A and B at

[2] [**Wagner2019**]. Die Motivation des Gamepad-Layouts: Eine diachrone bildlinguistische Betrachtung der Knopfbelegung und -benennung

the beginning of the alphabet when adding two new buttons in the generation change to clearly differentiate the two button duos. The game Secret of Mana (1993, Square Soft) shows that the A and B buttons are intended for direct interaction in the game and that X and Y were designed for opening different menus.

A Button: Press and hold the A button to dash.

B Button: Press the B button to perform an attack.

Y Button: Press the Y button to summon the ring menu for your currently controller character.

X Button: Press the X button to summon the ring menu for a computer controller character.[11]

Figure 9: Secret Mana,1993 Square Soft

Initially, the two additional keys X and Y served as administrative infrastructure during gameplay and were not considered as additional interaction keys like A and B. The games become more complex from the fifth generation onwards. With the change to the sixth generation, and the two additional keys X and Y therefore no longer serve as an administrative infrastructure.

Due to the complexity of the 3D games, it was foreseeable that the button layout would have to evolve and consequently, not only X and Y would find new applications, but Nintendo even introduced the Z shoulder button on the N64 controller.

The Sony PlayStation controller is an exceptional case in the designation of the buttons, as Sony has chosen symbolic designations: Triangle, Circle, Cross and Square. Arrangement and color are as mentioned above. Teiyu Goto, the designer of these characters, carries out the referencing function:

> ”I gave each symbol a meaning and a color. [. . . ] The triangle refers to viewpoint; I had it represent one's head or direction and made it green. Square refers to a piece of paper; I had it represent menus or documents and made it pink. [. . . ] The circle and X represent ‚yes‘ or ’no‘ decision-making, and I made them red and blue, respectively. People thought those colors were mixed up, and I had to reinforce to management that that's what I wanted.” [**Goto, 2010**]

# 4 State of the Art

With the DualSense, the DualShock 4 has taken over as the PlayStation controller. The changed name refers to the new technology that is supposed to make various gaming experiences even more intense. New haptic triggers are supposed to simulate the pull of a bow, for example. One new feature added to the DualSense controller is deep haptic feedback. Instead of the simple rumble pack, the DualSense includes actuators that give players more tangible, customizable feedback to better immerse them in a game.

Figure 10: DualSense PS5 Controller

Even the smallest effects in the game can give the player more precise feedback via the controller. This includes the fact that the surface the player is on also feels different. For example, a distinction is made between gravel or ice. In addition to the haptic feedback, the new controller has adaptive triggers for the L2 and R2 buttons, which can resist the fingers and provide even more immersion, i.e. the effect caused by the virtual reality of the game.

These represent the controller's greatest technology, with different levels of force feedback available for developers to implement in their games. For example, when a bowstring is pulled to fire an arrow, the trigger may be easy to press at first, but become harder and require more pressure as the string tightens. This results in the player getting an even stronger feel for the game.

Furthermore, the new PS5 controller has an integrated microphone, adaptive trigger buttons and haptic feedback in a whole different manner. The integrated accelerometer and gyroscope provide intuitive motion control in supported games. The integrated rechargeable battery runs via USB Type-C®4.

Astro's Playroom is a 3D platformer from Team Asobi! Actually, it's the first next-gen game, as it is preinstalled on every PlayStation 5. This game is a constant for all the PlayStation generations over 25 years. Although Astro's Playroom focuses on the new PlayStation 5, it draws strong references to past console generations and focuses on the greatest PlayStation titles of all time.

First of all, the swipe functions on the DualSense remind us of the predecessor controller. Furthermore, the test even shows that the built-in microphone is used to blow a fan, which then rotates.

In addition, the audio effects streaming from the controller have more range and connection to what's happening on the screen, while even supporting the haptic feedback. In this example, Astro's steps can be heard and the haptic feedback differentiates whether he is walking on ice or a smooth surface. The DualShock 4 Wireless Controller's sound effects have thus been optimized for the new hardware.

# 5 Idea

The concept of the Sega Genesis controller has slightly inward curved handles. I chose it to serve as one of the base inspirations. It features outward curved handles on the top of the controller. Key to the idea was the designing of a gaming controller that was highly simplified but at the same time supported ergonomic aspects and intuitive use for playing retro games or emulator games.

Thumb movements are a very important aspect in the development of a gaming controller. As with smartphones, it is very important to pay attention to the ergonomics in order to not tire the thumb muscles unnecessarily. On this controller, the thumb movement is exactly the same for both sides. The buttons have been arranged in such a way that the user can reach all keys within a certain range without having to move the thumb differently. All buttons and joysticks lie on one curve. This leads to an intuitive and muscle-friendly movement of the thumb.

The musculature of individual fingers and the thumbs, which are needed to use the game pad, must be taken into account, so that the thumb does not have to be stretched or bent to reach the buttons. A quick transition from the joystick to a button is just the completion of the movement on the joystick. I call this arrangement of buttons "one curve motion" (OCM). For the user experience, it is of significant importance how much strain is put on the finger or thumb muscles when playing. If it's too strenuous, playing will only become more tiring for the user. That's why I decided to arrange all buttons and joysticks in a curve to protect the user's thumb muscles as much as possible by placing each button on the curve. Because this controller does not have shoulder buttons, the hand position has changed slightly and the buttons that are on top of the controller can be used in new ways. The thumbs are more protected, because the natural thumb position was integrated and thus uncomfortable movements are reduced to a minimum.

My idea arose from the fact that I wanted to induce the use of thumb movements. With smartphones and the PlayStation controller, people are used to performing a kind of swipe gesture with their thumbs. Nowadays it is fair to assume that most test subjects instinctively understand swipe gestures. This is obviously connected to the ubiquitiousness of smartphones and tablets. Exactly out of this thought, the curves arrangement on my game pad was created. First I created a prototype out of cardboard and held it in my hands with the current shape to think about how to arrange the buttons. I found the swiping gesture particularly easy to execute after performing a large number of possible thumb movements and decided to arrange the buttons accordingly.

I wanted to create and develop a Retro Controller which is shaped like no other common controller and requires very little thumb muscle effort, either while holding the controller, pressing the buttons or moving the joysticks.

# 6 Implementation

A core problem was finding a shape that does not yet exist among conventional controllers and is still ergonomic for the user. The inner workings of a gaming controller are much more extensive than I had anticipated. This led to some problems with minor details. Working with Fusion360 was a new experience and it took me some time to get aquainted with the program and instrumentalize it.

A mockup to visualize my ideas was created on my tablet's drawing program.

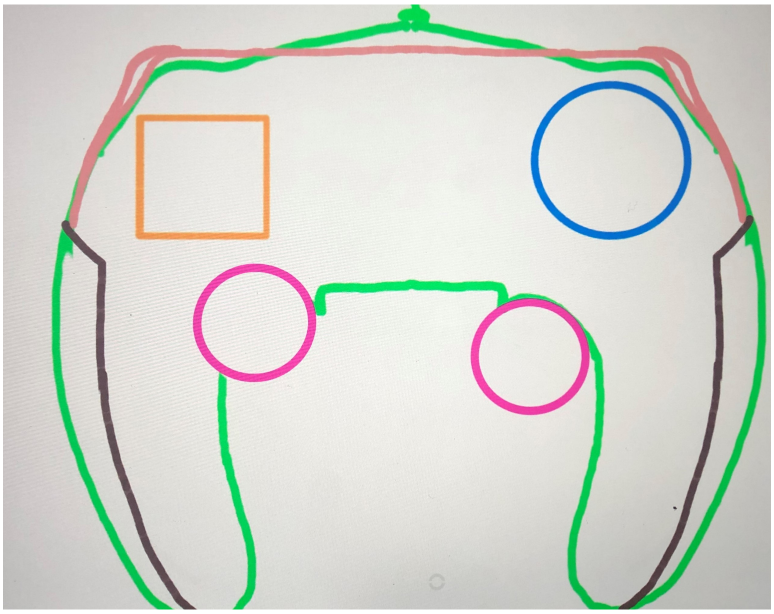


Figure 11: First Sketch

The first iteration turned out to be quite clunky and could not serve as a good base shape for a game pad. The 3D model of the controller also looked very massive and bulky, so I decided to make a test print. I only printed the exterior shape so I had a grid protoytpe. The controller was way too large and unwieldy and it became clear that this shape definitely does not work even if it looks similar to familiar shapes. In addition, the shape of the controller appeared more like the conventional game pads and not as special and retro as it was meant to be.

The next step was to create a new design for the controller in the 3D modelling programm Fusion 360. My prototypes were first used to get a feel for the dimensions I had in mind. Of course, I had many controllers in hand and played with them myself to see which one I liked best. This allowed me to refine the prototypes and think about the general rounding and thickness of my controller. These measurements were then applied and evaluated in

Figure 12: Grid Prototype Of Fist Design Idea

Fusion 360.

Initially the new design was created with new demands. Based on the created sketch, a body was generated by extruding and shaping the sketch. The shape is reminiscent of a retro controller, which puts a new kind of focus on the most important parts. This aspect is considered to be important, because for me user experience is key.

This game pad suggests the shape of a bow or a butterfly. A simple but ergonomic shape. The idea behind it is that this is not a complicated controller but clearly shows that these six inputs, four face buttons and two joysticks, are everything the player needs. To further reduce them would be a loss in user experience and would lead to the intuitive use no longer being effective.

There are different ways to form a sketch into a body and therefore also different possibilities. Depending on which variant is used, the more complicated or simpler the shaping and designing of the body can turn out to be. There were several attempts and versions of this game pad to find the perfect variant in the end. For the 3D printing, it was very important to avoid using a free form as a basis, as this cannot be symmetrical. Minimal deviations can cause the offset plane to shift so much that the upper and lower shells of the controller no longer fit together.

In addition, many details had to be kept in mind. The diameter size of the holes for the buttons turned out to be one of these details. Using a caliper gauge, I measured the caps of the buttons that the user touches at the end and set the size of the holes to 11 mm.

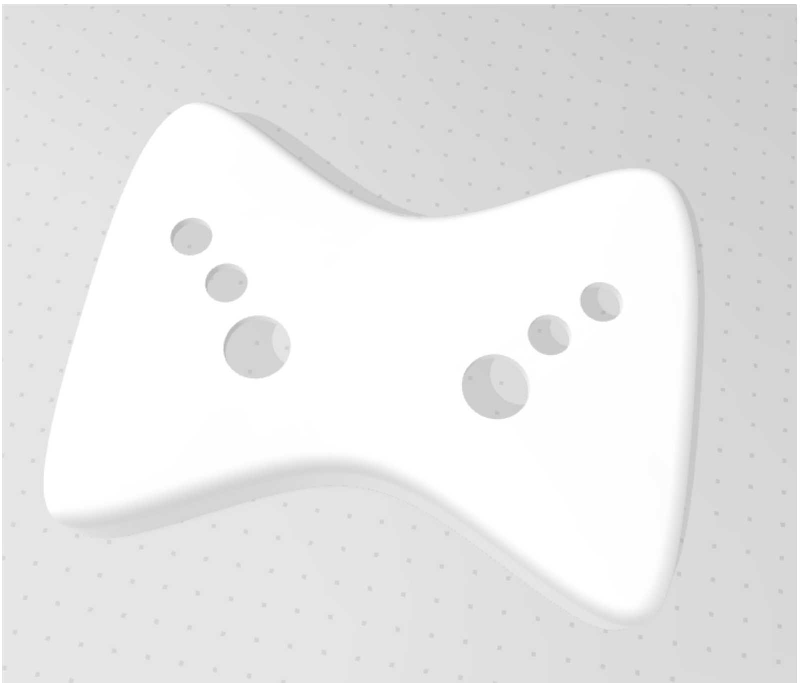


Figure 13: 3D Model Of Final Gamepad

The caps themselves have a diameter of 8 mm, plus the 3 mm of additional space, since the 3D printer does not produce to the millimeter. The height was set to 187.1958 mm, the width to 144.08 and the length to 23.8796 mm.

Many conventional controller measurements served as comparison and inspiration. The size of this controller is similar in width to the Xbox controller and the length to the Game Cube controller. Of course, all conventional controllers have similar measurements, but it depends on the shape if the proportions make sense. In this case, I wanted to combine the conventional dimensions with my new shape to ensure a new handling and button distribution.

The arrangement of the buttons and joysticks was the primary focus and allows for a new way of using thumb inputs. All buttons and joysticks are accessible on one curve. Because the controller itself is very simple, it has no shoulder buttons or paddles. The major reason for this is that the controller is intended for retro games on the self-built retro pi or for emulator games, in which shoulder buttons were not yet used. The four buttons and the two joysticks show that these are the six most important inputs a game pad needs to give the user fun. On the atari there was only one button and one joystick to play e.g. Space Invaders. I did not want to simplify my controller that far so I settled in the middle and decided to use the six most important inputs.

Since the intuitive use of a game pad is essential, I made multiple attempts to find a design. Once I had decided on my design and modeled it in Fusion360, I had to 3D print it. On the first printing, the holes for the front buttons were 2mm too small, which meant that the button caps wouldn't fit through, meaning that the entire controller had to be reprinted after adjustments.

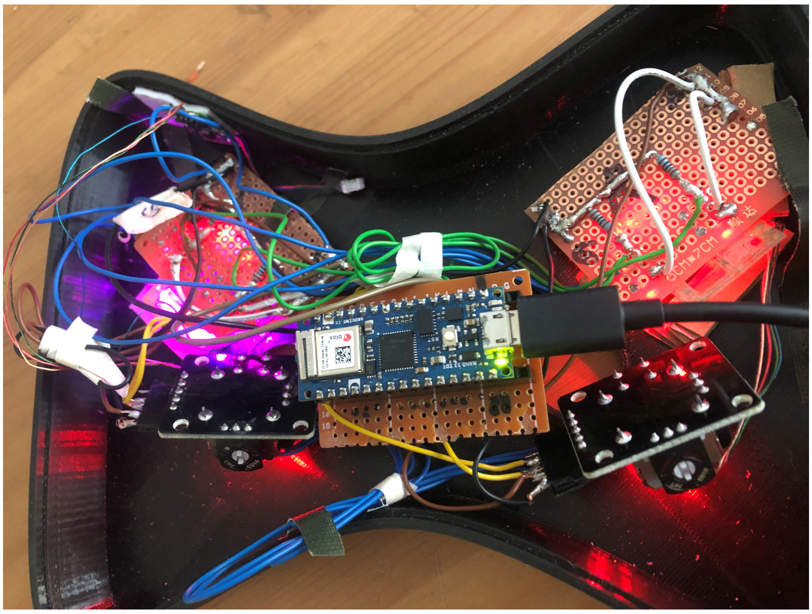
Figure 14: My Gamepad

Holding the new model in my hands, I noticed that my game pad was very thick and massive. This is why the bottom shell had to be rebuild after I reduced the thickness in Fusion360 to 1cm. As a result, the controller was more ergonomic and comfortable to hold.

Furthermore, I have been occupied with electrical engineering in order to wire and install the individual buttons and joysticks. I used two circuit boards and cut them to size. Then I placed the tactile switches on it and inserted them through the controller holes to ensure a good positioning for the board. I proceeded in this way for both sides. Once I figured out a good position, I soldered the tactile switches from the bottom side. On each sides of both boards, I created two bridges with solder. One for volt and one for ground. This was very important, because it was not possible to connect everything directly to my Ardunino Nano 33 IoT as there is just one 3.3 volt pin.

The bridges I had created were meant to give me more options to connect the cables. Because there was volt and ground on both of my breadboards, I only had to solder one cable to my arduino volt pin and connect it to the corresponding bridge on my breadboard. Although I did not solder the Arduino directly, but soldered a pin strip and plugged it into the Arduino. Each connection was checked and verified with a voltmeter.

Planning turned out to be insufficient though. A few cables have been laid and soldered in very unfortunate locations. The left breadboard is connected to the right one via the volt and ground bridge by cable. Resistors have been soldered in such a way that they are located between the tactile switch and ground.



As I have used the joysticks, first small pin connectors, female to male, were plugged to my joystick connectors and the cables for volt, ground, X and Y were soldered to them. For X and Y I soldered the yellow cables to the pins of the Arduino board and defined them with A1 - A4.

In addition, I bought LEDs that were actually intended for the PlayStation4 controller as a modification. Despite this, I ordered these LEDs and wanted to install them. The only problem was that the cables didn't have enough range that I could install them well without the joysticks being on very strong tension. so I unsoldered the very thin wire cables of the LEDs and replaced them with my own. The blue cables are used to get more range. What I didn't take into account is that they are much thicker than the original cables, and therefore rub against the transparent cap of the joystick, reducing its flexibility.

After installing this, I dealt with the distribution of the individual buttons and joysticks. Since the shell is quite tight for the breadboards and my cables, it turned out to be more difficult than I expected to get all of this sorted and in position. Inserting and supporting the buttons so that they are functional as I had planned created new challenges. Since I never worked with mechanics like this before, I had to improvise. I considered cardboard could be a very good material to build or support the different things with.

For this reason, I used cardboard and placed it under the two breadboards to find the spacing from button to board that would work best for the mechanics. I subsequently glued it in place to ensure that nothing could be moved. The circuit board on which the Ardunio is plugged was also glued into the shell. Furthermore, the Arduino remains removable, which I consider extremely important.

The next problem arose when I realized that I had not installed any supports or anything else in my case to support the entire contents from the top. The boards were attached to the surface, but not supported from the back, meaning that when the buttons were pressed, everything was pushed into the controller, as I had not built in any support. So I came back to the cardboard and filled the bottom of the controller with cardboard that has the same shape and create another shape that should only lay over the circuit boards on which the buttons are. I left the joysticks out of it to get everything on one level. This was very important for the mechanics. Despite this, I discovered that because of the support, the two shells have to be glued or screwed together to hold this in position.

Finally, I have realized that there is some type of short circuit in my electrical system, but I can't identify it with a voltmeter. There seem to be no false bridges or connections. Nevertheless, I have managed to develop an alternative shape of a retro gaming controller, as planned with LEDs underneath the joysticks and buttons, so that the mechanics still work and the controller supports the ergonomics and the muscles of the thumb.

# 7 Circuit Diagram

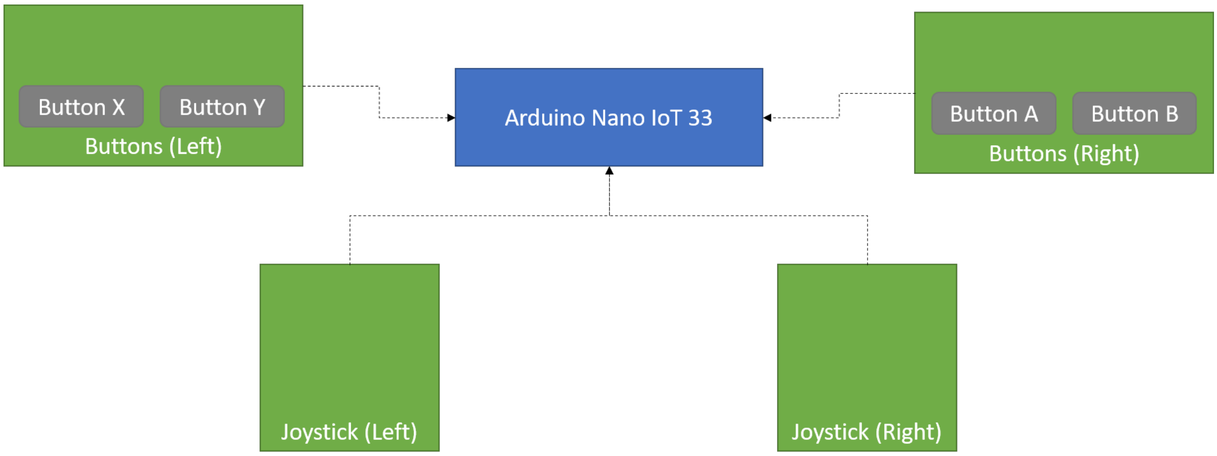



Figure 15: Data Connections of the Gamepad

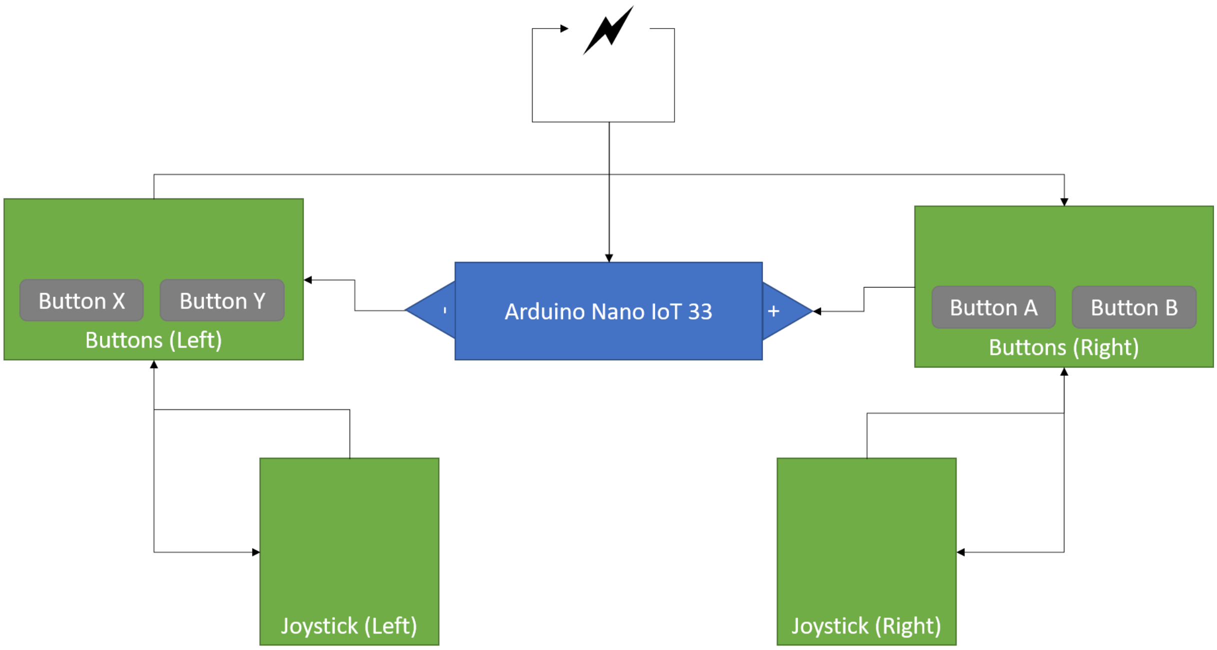



Figure 16: Electrical Input Of Buttons

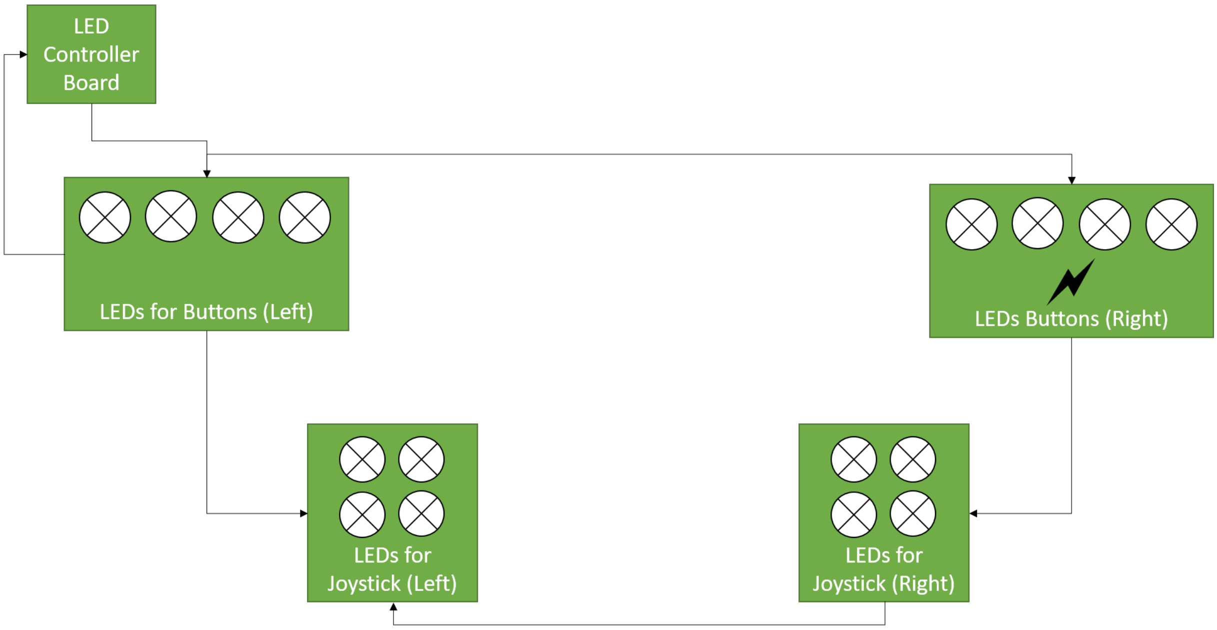



Figure 17: Electrical Connection Of LEDs

# 8 Source Code

```
#define JOYSTICK_ONE_Y A1
#define JOYSTICK_ONE_X A2
#define JOYSTICK_TWO_X A3
#define JOYSTICK_TWO_Y A4

#define BUTTON_LEFT_C_PIN 11
#define BUTTON_LEFT_D_PIN 12
#define BUTTON_RIGHT_A_PIN 7
#define BUTTON_RIGHT_B_PIN 8

#include "Mouse.h"
#include "Keyboard.h"

const int PAUSE = 250;
long lastAction = -1;

int buttonLeftCState;
int buttonLeftDState;
int buttonRightAState;
int buttonRightBState;

void setup() {
  Serial.begin(9600);
  pinMode(BUTTON_LEFT_C_PIN, INPUT);
  pinMode(BUTTON_LEFT_D_PIN, INPUT);

  pinMode(BUTTON_RIGHT_A_PIN, INPUT);
  pinMode(BUTTON_RIGHT_B_PIN, INPUT);

  Mouse.begin();
  Keyboard.begin();

  buttonLeftCState = digitalRead(BUTTON_LEFT_C_PIN);
  buttonLeftDState = digitalRead(BUTTON_LEFT_D_PIN);
  buttonRightAState = digitalRead(BUTTON_RIGHT_A_PIN);
  buttonRightBState = digitalRead(BUTTON_RIGHT_B_PIN);
}

void update_joysticks() {
  int one_x = analogRead(JOYSTICK_ONE_X);
  int one_y = analogRead(JOYSTICK_ONE_Y);

  int two_x = analogRead(JOYSTICK_TWO_X);
  int two_y = analogRead(JOYSTICK_TWO_Y);

  //JOYSTICK ONE
```

```
  int mouse_move_x = one_x - 512;
  int mouse_move_y = one_y - 512;

  Mouse.move(mouse_move_x, mouse_move_y, 0);

  Serial.print("analog stick one (x,y): ");
  Serial.print(mouse_move_x);
  Serial.print(", ");
  Serial.print(mouse_move_y);

  Serial.print(" two (x,y): ");

  Serial.print(two_x);
  Serial.print(", ");
  Serial.println(two_y);

  //JOYSTICK TWO
  int arrow_move_x = two_x - 512;
  int arrow_move_y = two_y - 512;

  //LEFT
  if (arrow_move_x < 0) {
    Keyboard.press(123);
    Keyboard.release (124);
  }

  //RIGHT
  if (arrow_move_x > 0) {
    Keyboard.press(124);
    Keyboard.release (123);
  }

  //UP
  if (arrow_move_y < 0) {
    Keyboard.press(126);
    Keyboard.release (125);
  }

  //DOWN
  if (arrow_move_y > 0) {
    Keyboard.press(125);
    Keyboard.release (126);
  }

}

void update_buttons() {
  int buttonLeftCInput = digitalRead(BUTTON_LEFT_C_PIN);
```

```
int buttonLeftDInput = digitalRead(BUTTON_LEFT_D_PIN);

int buttonRightAInput = digitalRead(BUTTON_RIGHT_A_PIN);
int buttonRightBInput = digitalRead(BUTTON_RIGHT_B_PIN);

//BUTTON C
if (buttonLeftCInput == 1 && buttonLeftCState == 0) {
  Keyboard.press('c');
}

if (buttonLeftCInput == 0 && buttonLeftCState == 1) {
  Keyboard.release('c');
}

//BUTTON D
if (buttonLeftDInput == 1 && buttonLeftDState == 0) {
  Keyboard.press('d');
}

if (buttonLeftDInput == 0 && buttonLeftDState == 1) {
  Keyboard.release('d');
}

//BUTTON A
if (buttonRightAInput == 1 && buttonRightAState == 0) {
  Keyboard.press('a');
}

if (buttonRightAInput == 0 && buttonRightAState == 1) {
  Keyboard.release('a');
}

//BUTTON B
if (buttonRightBInput == 1 && buttonRightBState == 0) {
  Keyboard.press('b');
}

if (buttonRightBInput == 0 && buttonRightBState == 1) {
  Keyboard.release('b');
}

Serial.print("button left c ");
Serial.print(buttonLeftCInput);
Serial.print(",  left d ");
Serial.print(buttonLeftDInput);
Serial.println("");

Serial.print("button right a ");
```

```
  Serial.print(buttonLeftCInput);
  Serial.print(",  right b ");
  Serial.print(buttonLeftDInput);
  Serial.println("");

  //update button state
  buttonLeftCState = digitalRead(BUTTON_LEFT_C_PIN);
  buttonLeftDState = digitalRead(BUTTON_LEFT_D_PIN);
  buttonRightAState = digitalRead(BUTTON_RIGHT_A_PIN);
  buttonRightBState = digitalRead(BUTTON_RIGHT_B_PIN);
}

void loop() {
  update_buttons();
  update_joysticks();
}
```

# 9 Result

Focusing on the mechanics and the design, the ergonomic conditions and the general shape of the game pad are fulfilled. The Arduino Nano IoT33 keeps repeatedly crashing, though, which is probably due to a short circuit. Therefore, the controller can unfortunately not be used for gaming. This was only a partial aspect, since the focus of this work is on the shape and ergonomics, but I was able to test the gaming controller nevertheless. I concentrated mainly on the mechanics and performed the tests on the basis of the thumb muscles.

Question XY was researched and analysed in this bachelor thesis with a self-built controller. The arrangement of the buttons requires little movement of the thumb in relation to stretching or squeezing. This is a single curve on which all the buttons and joysticks lie. As a result, the thumb does not have to move as much to reach the inputs.

## Evaluation

I did not do a proper study, but an open survey for my game pad, which was primarily about how the controller generally feels in the hand and how tiring it is to use the buttons and joysticks. For the evaluation of this game pad, I made use of Jinghong Xiong's study [3] and strongly reduced them to fit my questioning and applied it to my own game pad. Since this type of study is very meaningful for my analysis, I decided to invite 5 participants [4] to hold my gaming controller in their hands and perform certain movements over a given period of time. Since this was intended to be no more than a brief questionnaire and therefore not a proper study I did not research any muscle measurements. Therefore, I told the participants to say when pressing the buttons starts to get a little strenuous and to stop when it gets too strenuous.

[3] An ergonomics study of thumb movements on smartphone touch screen

[4] Due to the covid-19 pandemic, I reduced the number of probands as much as feasible.

The participants were given different tasks to perform. Of course, I changed the participants' posture, since they were not holding a smartphone as in Jinghong Xiong study, but rather my gaming controller. Each participant was asked to sit on a chair without an armrest and hold the game pad as they would normally do when playing.

Figure 18: Usins buttons

**Task: 1**

The participants were first asked to use only the buttons by pressing the A, B and X, Y buttons alternately with the respective thumb.

They should simultaneously use the buttons from the bottom to the top with both hands and do this as fast as they can.

**Task: 2**

The second task was to move the joysticks and generally get a feel for the controller. The hand position did not play a role, as I wanted to let the participants determine the position themselves and intuitively.

**Result**

It was discovered that the low-lying buttons are comfortable for the muscles, but not very effective for real playing. Of course, this could only be determined theoretically, as the controller has a short circuit and could therefore not be play-tested. Otherwise, the shape was very comfortable to hold, even if it was unusual at first. The controller is fun to use and makes people curious to play with it.

# 10 Conclusion

As has been demonstrated, the face-button and joystick positioning is one of the major considerations of a gaming controller. Therefore this theis focused on the question if there is a way to built a gaming controller that has a new and audacious exterior design. And also investigated the placement of the face-buttons and joysticks, as this was a major factor in relation to thumb muscle ergonomics.

In addition, studies on the topic of ergonomics were taken into account in order to be able to apply them to the controller. The tasks mentioned in Jinghong Xiong study on smartphones and the muscles of the thumb and forearm, which the participants were asked to complete, proved essential for the research on my own controller and its ergonomics as well as the sensible arrangement of the face buttons in relation to the thumb muscles.

The tasks I took from Jinghong Xiong's study and adapted showed that the muscles of the thumb are not less strained, but that less muscle groups are involved. This suggests that my gaming controller ergonomically requires less muscle groups.

The shape of the controller had a limited effect from a strictly ergonomic point of view. On the other hand, the gamepad can be held well in the hand and the face buttons are easy to reach. But the shape doesn't have as much of an impact on ergonomics as the placement of the buttons. Furthermore, it can be said that the shape and the design support the user experience and the user enjoys handling this gamepad.

The objective of the work was achieved in a different and new way, in that the positioning of the face buttons turned out to be a key point. The development of this position, based on ergonomics, has been achieved by making it possible to build the controller in such a way that only one muscle group needs to be used for playing and the user experience is improved.

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