RelaxU: A Wearable Massage Tape

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ABSTRACT
Project RelaxU is to design and test a prototype of a smart massage tape, which is a portable and wearable massager for pain relief and muscle recovery. It has an adjustable design that allows different users to easily wear on their arms, legs, or waists. The design mainly includes a power adapter, a ESP32 microcontroller to control vibration based on user input, and 4 direct current motors with 2 L298N driver boards to generate vibration. Aside from the hardware, we also developed an Android APP to control the massager. RelaxU is targeted to almost everyone, it is reliable and easy to use, which makes it a perfect choice for daily health care.

Keywords
Health, embedded system, motor control, Android APP, massage, Bluetooth, portable device, wearable tech

1. INTRODUCTION
Contemporary workplaces have significantly changed the lifestyle of people. The high workload and long working period make people sit in their office for hours without any exercise. This could also happen for students who spend the whole night studying for exams. Over time, muscles will ache due to the lack of appropriate exercise. Our main idea of RelaxU is to offer a solution to those types of people for muscle relief. However, it not only benefits office people and students, but also helps elderlies and even athletes. Our idea of this massage tape is to serve almost everyone for muscle recovery, pain relief, or just pure comfortable massage experience. We are driven to offer a portable and wearable smart massage tape with our embedded and circuit knowledge. This report contains the design decisions, details of the implementation, test, evaluation results, concerns and future improvements.

2. RELATED WORK
Existing massaging devices on the market include massage guns, massage pillows, or massage chairs, and each of them have different strengths and drawbacks. Massage guns can provide deep tissue massage for different positions, but requires users to hold it consistently, which may be hard for older users and distractive for users who are trying to do other things. Massage pillow is hand-free, but is usually shaped specifically for the neck or back. Massage chair usually covers the massage for the entire body but is expensive and not portable.

Figure 1. Overview of the product

Our intention is to keep the features of massage guns such as light-weighted and portable, features of massage pillows such as wearable and hand-free, and the features of massage chairs such as endurable and targets many positions.

Our interested customers are the potential sub-healthy population including people who have to stand or sit for long periods daily which lead to back stiffness, leg swelling, etc., and the athletic groups who exercise regularly but don't stretch properly which may end up in muscle strain and lesion. After investigating different types of massages, we found that sport massage, deep tissue massage, and lymphatic massage seem to work the best for these two populations[1][2]. Sport massage focuses on a specialized position rather than the entire body. It involves finger pressing and kneading on the specific area and gentle stretching. It can help to prevent injuries by reducing fatigue and tension throughout the body. Deep tissue massage uses slow friction and deep pressure to help with persistent muscle tension, pain and aches. Patients from the recovery stage of muscle strain and those who sit most of the day can benefit from it. Lymphatic massage stimulates the lymphatic system of the body and reduces swelling, which may benefit the long-sitting population as well.

3. TECHNICAL DETAILS

3.1 Overview

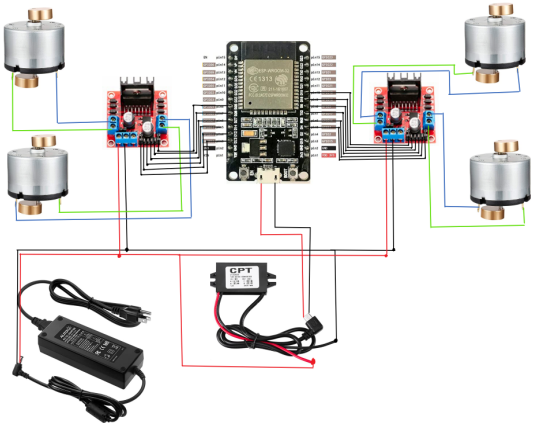


Fig 2. Block diagram of the product

The massager consists of 3 parts: power supply, controller, and fabric case. The user can wrap the massager around the waist, arm, and legs with an Android app to control the mode and strength of the vibration.

Fig 3. Massager wraps on waist

Fig 4. Massager wraps on arm

Fig 5. Massager wraps on leg

Fig 6. Name of RelaxU and Class on product

3.2 Theory of Operation

In order to operate our product, the user needs to install an Android APP to communicate with the microcontroller through the Bluetooth module inside the ESP32 microcontroller. After opening the APP and turning on the power of the massager, the user can tap the black box located in the center of the screen to connect the massager as shown in Fig 7, and then select position, mode, and massage strength as Fig 8 and Fig 9.

Fig 7. Selecting Device

Fig 8. Selecting Position

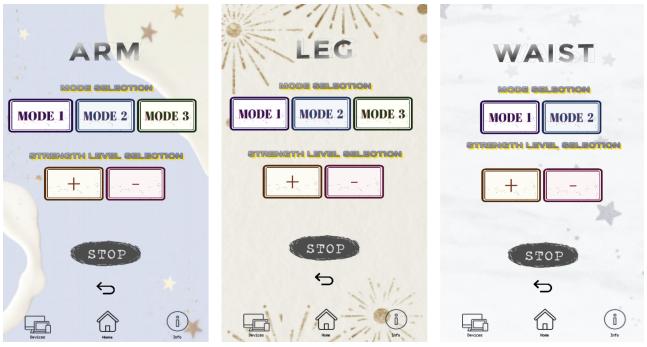


Fig 9. Selecting modes and massage strength

After selecting the mode, the massager starts to work and control motors through PWM. The maximum current and voltage that can be delivered to each motor is 12V 1A.

3.3 Implementation Details

3.3.1 Power

The power of the whole device is provided by an AC to DC adapter that can output 12V and a maximum current of 10A. The output of the adapter is split into three parts. Two of them connect to two L298N motor drive controllers and one connects to a 12V to 5V converter and then connects to ESP32 microcontroller. In addition, we added a power switch to increase safety. The user can power off the power immediately by switching off the power immediately instead of unplugging the adapter from the wall. Initially, we considered using a rechargeable battery as the power supply, but we found that the battery that is large enough to drive four motors for a long time will be too heavy.

3.3.2 Control

The massager consists of one microcontroller and two driver boards: one ESP32 (wrover module) and two L298N motor drive controllers. The reason why we need two L298N is that each L298 can only control two DC brushed motors, while one ESP32 with 38 GPIOs is enough to control two L298N. The ESP32 communicates with the Android APP by using the Bluetooth module to receive and send the data. The motor has 13 adjustable strength levels which the PWM is adjusted from 40% to 100%. (The motor stops working under 40%).

3.3.3 Mechanical and Case

Our group did an extensive design on mechanical parts. We design the case for the motor and control box in Solidworks and print them in the 3D printer in Mill. We also add buffers inside the motor case to avoid the collision between motor and case so that our massager works as quietly as massagers on the market.

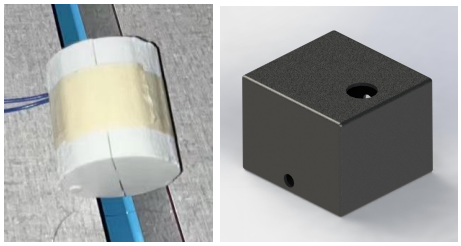


Fig 10. 3D printed motor shell and control box

We sewed a fabric case to provide the most comfortable touch between the motor and body and used a heat shrink tube to wrap eight wires (2 per motor) going from the control box to the fabric case. For all stripped parts (for soldering) of the wire that might be exposed to water, we bind water-resistant tape on them as Fig 11 to increase the safety of the device.

Figure 11 Stripped parts are taped

The fabric case can fit different waist sizes by adjusting the length of velcro being attached. The current design allows a maximum waist measurement of 110cm, which exceeds the average waist measurement of average Americans[3][4]. The user can switch to arm mode and leg mode by closing the velcro in the front together, after each pair of velcro tapes together, the minimum circumference of the massager can be reduced to 16cm, which will fit most of the arm circumference[5].

3.3.4 Software

The massager supports remote control by an android application, and we used MIT App Inventor to develop the app.

Page Viewer. Due to the limitation of the MIT App Inventor, which does not support a cross-screen Bluetooth connection, the page switching happens on the same screen ("page") with manipulation of the visibility of different layout pages.
Transitioning animation and user interaction with buttons or clickable images trigger page switching. Animation-controlled page switching includes switching from the onboarding page to introduction page 1 and switching from the welcome page to the Bluetooth page. The rest of the page switchings are all button-controlled. Buttons for page switching use commonly seen icons such as "next," "return," "stop," or bottom navigators. Examples of introduction page switchings are shown below in Fig. 12.

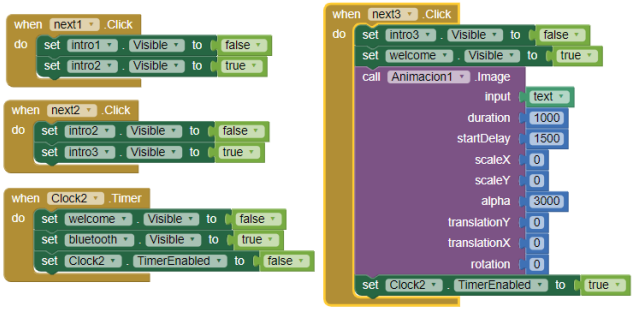


Fig. 12. Introduction page viewer block design

GIF And Animation. MIT App Inventor does not display the gif files as dynamic pictures. It requires developers to use web viewers to display gif. Our design blocks are shown below in Fig. 13.

Fig. 13. gif display using a web viewer

To achieve animations such as scaling and translation, we used a free extension, Animacion, published by Andres Cotes [6]. For the onboarding animation, we set the logo, title, and the gif picture to have a duration of 1000 ms, a start delay of 3000 ms, scale X and Y of 1 (keep as the same size), rotation of 0, a translation X (horizontal translation) of 0, and the translation Y (vertical translation) of 3000 or -3000 to ensure the pictures exit the screen as shown in Fig. 14. The onboarding animation is timed by "clock1" by setting its time interval to 4000 ms to ensure it is followed by page switching. The welcome animation has a duration of 1000 ms, a start delay of 1500 ms, translation X and Y of 0 (stay at the same position), and scale X and Y of 0 to make it gradually diminish and disappear as shown in Fig. 12. The onboarding animation is timed by "clock2" by setting its time interval to 2500 ms to ensure it switches to the Bluetooth page.

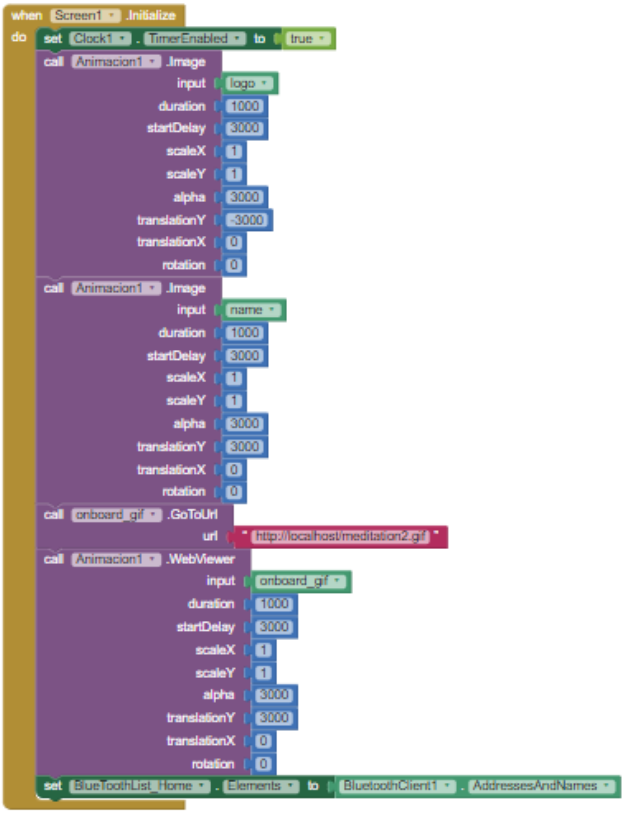


Fig. 14. Onboarding animation parameter setting

Bluetooth. We prompt Bluetooth connection when turning on the application. On the Bluetooth page, users can select their device by tapping on the device name from the Bluetooth device list. Once picked, the Bluetooth on the phone will try to connect to the device. The app will display a message as "Device connected" and close the list if connected successfully. If error number "516" is received, it will show a message as "Device not connected." This is shown in Fig. 15.

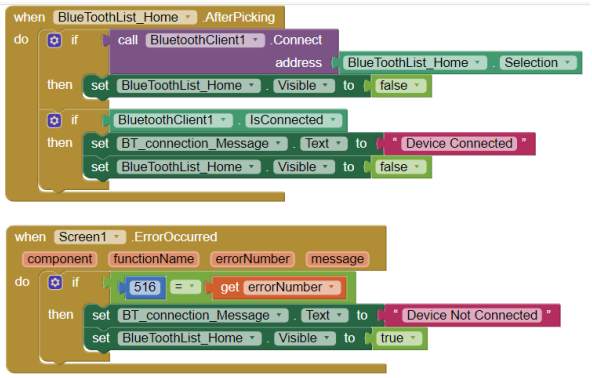
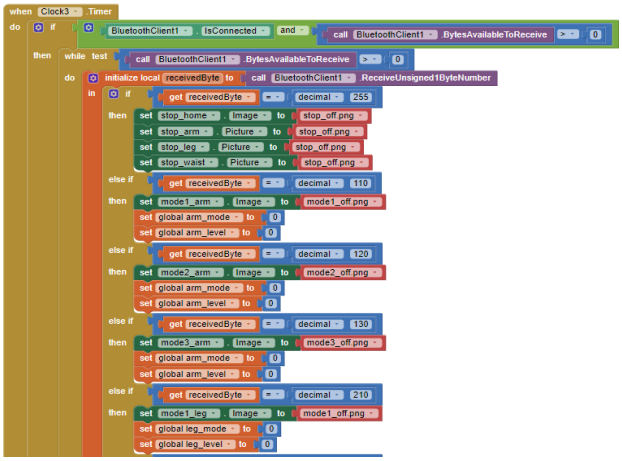


Fig. 15. Bluetooth connection blocks

Data sent. User interaction with buttons or clickable images sends the control signals to esp32 and esp32 provides feedback over Bluetooth. This process is controlled by clock3 with a time interval of 10 ms. We decided to use a fast clock in case user interaction is fast and we want to catch up with the feedback. The data sent to esp32 codes information including position, mode, strength. Therefore, we used six global variables, two ("mode" and "level") for each massaging position, to keep track of each position's mode and strength. When adjusting strength level, plus changes level to 1, minus changes "level" to 2. When choosing modes, mode 1 adds 1 to "mode," mode 2 adds 2 to "mode," and mode 3 adds 3 to "mode." To distinguish the positions, the control signal weighs positions differently: the default for mode_arm is 10, the mode_leg is 20, and mode_waist is 6. The final control signal sent will be 10 * model + level. And for safety considerations, the stop can execute on every page and will send data "255."

Data Received. To ensure the device receives the instruction, we update the mode buttons, the strength buttons, and the stop buttons after the app receive feedback from esp32. Receiving "255" indicates force stop has been executed, and every stop button will be reset. "110" "120" "130" "210" "220" "230" "70" "80" corresponds to each mode button. Receiving these signals indicates that the massaging session has ended, and the app will reset the mode button and the global variables. "111" "112" indicates the strength level increase or decrease for the arm has been performed, and the app will reset the global variable "level" and the strength button. "211" "212" "71" "72" is the same thing but for the leg and waist, as shown in Fig. 16 - 18.



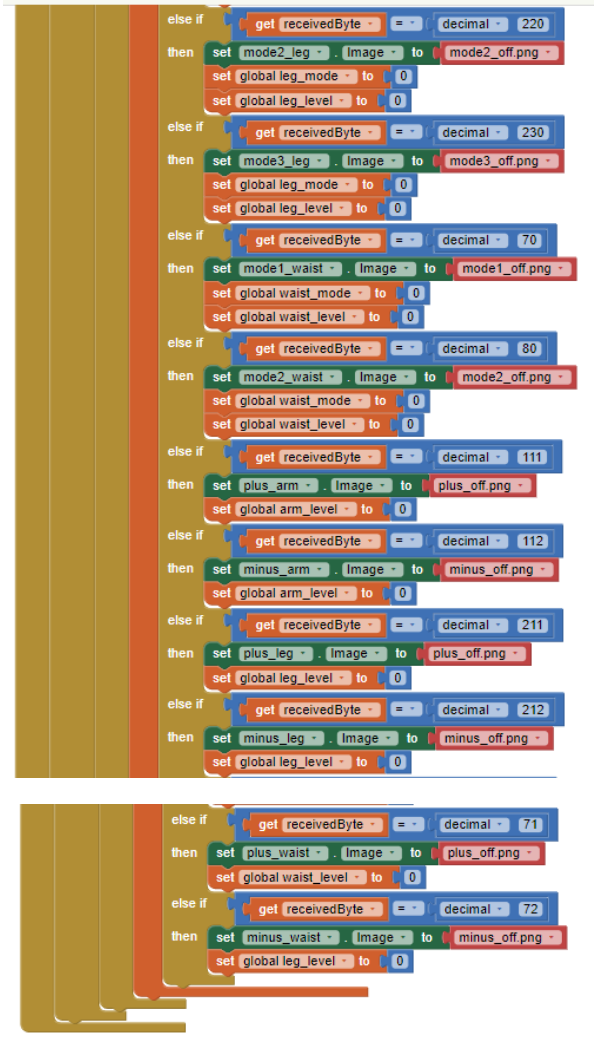


Fig. 16 - 18. Bluetooth data received

Mode And Strength. Only one mode of a position can be selected at a time, and each selection will restart the massaging session. However, if the user selects a mode but decides to use a mode for a different position, it is not supported by our application. We assumed that the users would stop the session, rewrap the massager, and then select a new mode. Once the mode is selected, it will send its control signal. We decide not to send a control signal for position selection for three reasons: 1) users know their target position when they wrap the massager and when entering the position's mode selection page; 2) esp32 do not update to the motors until a mode is selected; 3) the control signal of modes already contains information about position (as discussed under Bluetooth Data Sent). Users can exit the massaging session by tapping on the current mode button again. The mode button will stay as turned on until its session stops or if users tap it again. The implementation is shown in Fig. 19.
Strength can only be adjusted after a mode is selected first. Unlike mode buttons, strength buttons reset fast because users might want to perform strength adjustment multiple times.

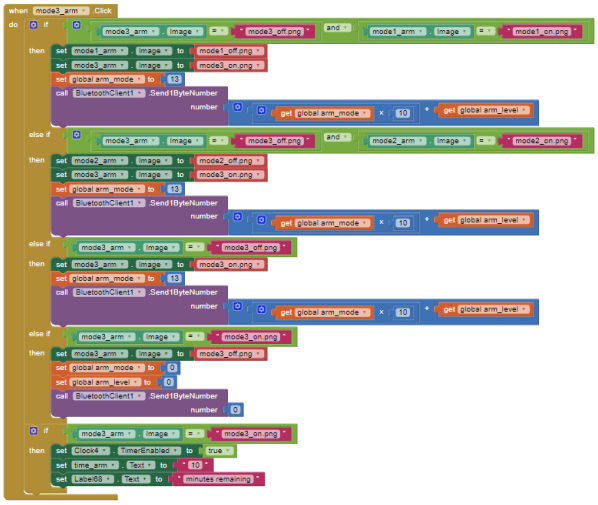


Fig. 19. Mode selection and Bluetooth data sent example

Counting down. When each massaging session starts, a countdown from 10 minutes is triggered. It is controlled by clock4 with a time interval of 60000 ms (1 minute). When the countdown reaches 0, it will turn off clock4 and display the message "Session Ended." If a stop button is pressed, it will display a message as "Session stopped" and stay for 2 s (controlled by clock5). We decided that this message is only displayed shortly because people can feel the massager stopping and the feedback from the stop button as well.

4. EVALUATION AND RESULTS

Table 1. Table of evaluation

Total number of modes	3 arm + 3 leg + 2 waist = 8
Total number of strength	13 Adjustable strength
Circumstance	16cm - 110cm
Maximum distance from the power plug	4m (2.5m of power adapter cable + 1.5m of motor cable)
Overheating	~35 Celsius after 10 min
Connectivity	Very good within the same room
Power Consumption	20W - 50W According to massage strength

5. DISCUSSION

The final product meets most of the original expectations: It provides massage for 3 positions with 2 or 3 different modes; it has a cost of approximately 80 dollars, which is relatively cheap

compared to similar models on the market considering its functionality; it is lightweight and fits the human body shape; it is chargeable over the power adapter. For safety considerations, overheating is reasonably controlled by limiting the massage session to 10 minutes, and the force stop function is implemented effectively. However, clinical statistics on how well the massager helps reduce swelling and muscle soreness at various degrees are not measured. Therefore, it is hard to quantify the effectiveness of the massage.

5.1 Social And Ethical Considerations

Hardware.

- Adjustable strength level. People of different ages and with different weights may have different endurance towards strength. A wide range of adjustable strength levels prevents the mode to be harmful to some people but not sensible to others and provides everyone with a comfortable experience.
- Adjustable length. People with different weights and heights have different measurements over arms, legs, and waists. The adjustable length of up to 110 cm not only facilitates applying the massage to different positions but also to people with different body sizes.
- Hands-free, light, and portable. This feature prevents older people from getting hurt by the strong vibration when holding it, or by lifting it, therefore increasing the accessibility of the product.

Software.

- Every click/tap makes buttons turn to a completely different color, usually also accompanied by warning or error messages. This is aimed to help people with bad visions to see clear feedback from the app.
- Buttons are labeled or using commonly seen icons, such as "next" "return" and bottom navigators. It is easily understandable so even older people who tend to be slower with their phones can use it without a manual.

5.2 Future Expectation

The volunteer hands-on experience suggests that the default mode may be too strong for many people. Therefore, we would decrease the default motor speed for each mode.

Hardware.

- Add rotational massage nodes to provide circular motion and gentle stretch, which is more similar to a human therapist.
- Add inflatable airbags to provide gentle pressure for the message, similar to how we measure blood pressure;
- Add low voltage heating to simulate hot stone massage which relieves tightness from muscles, helps rid toxins, and reduces stress.
- Add gel pads and electrical muscle stimulation feature to simulate geriatric massage to provide passive stretching and lotion, which can help reduce muscle loss and enhance joint mobility for the elderly.

Software.

- Add font changing features. The text on the screen is small for some users (maybe because our phone is small as well). Enabling users to change fonts to bigger sizes would improve the user experience.
- Add read-out features. Enabling read-out features may benefit disabled people or older people with bad visions.

6. CONCLUSION

During 10 weeks of designing the project, the group learns many important skills to be a qualified engineer. Unlike the hard skills, we learned in other courses. The group members learned many important soft skills through the project. The group members collaborate for the whole quarter and each member takes the responsibility for their roles. We are capable of communicating effectively and managing progress and learning the process of designing a product from proposing PRD to final evaluation.

7. REFERENCES

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