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Team 6 Individual Component Analysis: Sensor Systems .

Project Description:

The Tecture- Creative Art Installation project is to design and fabricate a kinetic architectural/art piece to introduce motion and new technology to static art features. At the moment, Tecture Inc, the sponsor, relies on traditional tools such as woodworking and metal manufacturing to create still art to various clientele such as corporate companies or art enthusiasts. By introducing motion to art, this can bring a new level of captivation from the audience to feel immersed and bring a new level of clientele. The installation we are focusing on is to create a wall composed of modular panels capable of moving with one degree of freedom (up and down) in a controlled and automated environment. The purpose of this is to create an experience with the user where the system responds to their dynamic movement to increase engagement in which they are the input and the output is the motion generated from the art. To create this system, we will need a grid of microcontrollers connected to a mechanical system that creates linear motion whether that is through linear actuators, stepper motors or even DC motors that are triggered by sensors. To achieve this goal, the installation will integrate all elements of mechanical, electrical, and software components that work together to detect the user, interpret interaction, and drive panel motion hence the input/output behaviour. Understanding and selecting the appropriate sensing methods through research is critical to having the responsiveness, precision, and safe operation within the overall design.

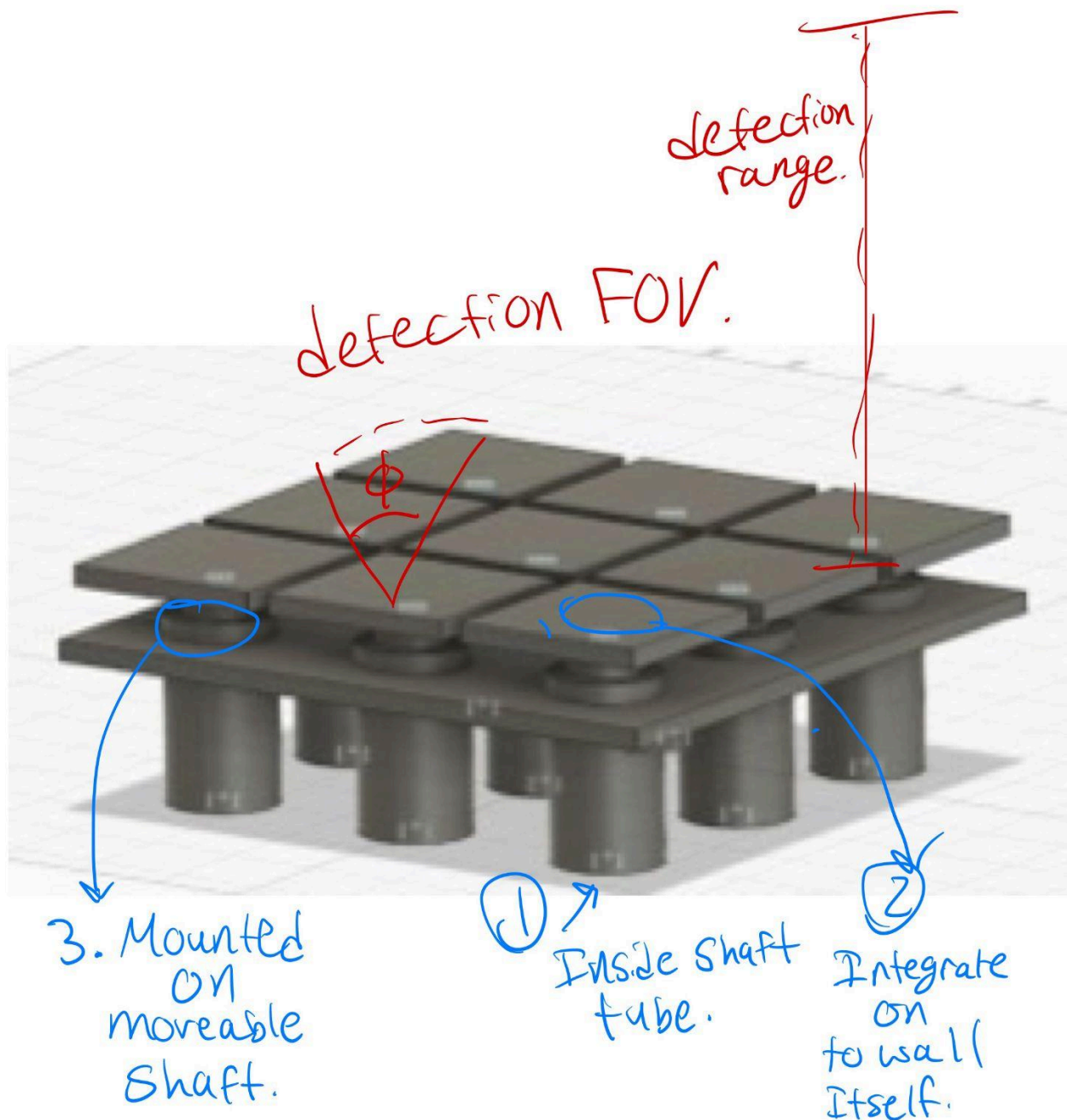


Fig 1: CAD model of the proposed design of the kinetic wall as well as showing detection range, FOV zone, and possible locations of sensor.

Functional Requirements:

The sensing system in the creative art installation must meet several functional requirements to ensure the goal for the total project as it plays a critical role and it provides the automation detection within the whole system. The most important functional requirements that I decided to focus on and can measure of the

efficiency of the sensor systems are as follows:

- Detection Accuracy and Sensitivity
- Response Time and Data Collection
- Microcontroller Integration
- Durability, Cost, Availability

Firstly, a sensor must be able to properly detect motion accurately and not be disturbed by small disturbances or unintentional movement. There has to be a proper range within the sensor to detect the motion that is meant specifically for this art piece. Secondly, when it is able to detect an input, the sensor has to accurately relay the information to the microcontroller in a quick response time to ensure the movement is not delayed. As mentioned above, this system will work with a grid of microcontrollers such as an arduino or raspberry pi, the sensor selected must be able to integrate properly with them and be able to be programmed for the desired motion needed. Lastly, since this model is a prototype, cost is not of importance however when reaching the final product and when Tecture Inc creates more of these kinetic projects, the sensors will be mass used and so they need to be somewhat a reasonable cost, available to buy a large amount at one time and durable so that the project does not break over time due to unavailable detection. Below will be a comparison of three options with quantitative analysis. It is important to consider the limitations or failure that can occur with these sensors in the kinetic wall environment. Ultrasonic sensors, for example, can have angled or soft surfaces that do not reflect sound well as given from their product description above. IR sensors are more sensitive to lighting conditions, reflectivity and dark materials, which can affect distance readings or reduce accuracy in inconsistent lighting. PIR sensors, while good for broad motion detection, can be unintentionally triggered by unrelated heat sources or temperature changes and cannot distinguish between users who use this art at different distances which can affect how precise this sensor works.

Component Options

Option 1:

Ultrasonic Sensor: An ultrasonic sensor is a great, affordable and reliable option to use in this system. Firstly the sensor works by having a transmitter and a receiver, the transmitter emits a short burst of sound waves which then reflect off an object and the returning echo is read by the receiver which measures the time of the sound wave. The time is then converted to distance internally using the speed of sound equations. The reason that this sensor is ideal and applicable to this project is due to the fact that it is reliable, can work with an arduino, non-contact detection, reasonable accuracy, cheap as well as the team is familiar with it from previous MAE labs. The typical detection range for the HC-SR04 is about 2–400 cm, with an accuracy of the order within a few millimeters when used in ideal conditions such as minimizing noise with reasonable temperature and humidity. The response time is roughly 20–30 milliseconds, and it usually operates around a 15 to 20 Hz sampling rate, which is viable to detect human motion in front of a wall. The field of view is relatively narrow around 15 degrees, so it focuses on a specific area in front of each of the modular panels which can lead to error over time. The operative voltage is 5V DC with an operating current of 15mA.

Product Proposal: Ultrasonic Sensor HC-SR04: [Link](#)

Option 2:

IR Sensor: An infrared sensor is also a great option for this system as it uses infrared light to detect the presence and distance of nearby objects, offering a quick response time and reliable performance in mostly indoor environments. In active infrared mode, the sensor emits an infrared beam that reflects off a nearby object, and the receiver detects the change similar to an ultrasonic sensor which then enables quick detection of the user approaching the wall. These sensors are common in robotics or even automatic garage doors. This is also applicable to this project as the automatic detection can be used as an input trigger with various linear motion mechanisms that are driven by motors. The range depends on the exact model but is roughly 10–80 cm for the one linked below, with accuracy that is good in that short range but more sensitive to surface properties and outside light. The response time is around 30–40 ms, and the field of view is narrower than ultrasonic, closer to 10 and 15°, which gives more localized detection and could be viewed as less immersive for the user. The voltage supply needed to power this is also 5V but with an operating current of 40mA as given from digikey.

Product Proposal: Sharp IR analogue sensor: [Link](#)

Option 3:

PIR Sensor: While a PIR sensor is similar to an infrared sensor the difference is that the passive configuration does not emit infrared light but relies on detecting fluctuations in heat radiation from moving people. This makes the PIR sensor effective for motion detection and are used in various applications such as motion activated lighting or even security systems used in homes. This is ideal and applicable to this project as the trigger input could be better for motion detection and automation for this kinetic wall. This can limit errors and be more accurate when the motion activates as subtle changes will not affect it and have higher effectiveness overall. The detection range is usually in the 3–7 m range with a wider field of view than the previous 2 which is around 90–120°. With an operating voltage DC of 4.5V - 20V and 50mA operating current usage.

Product Proposal: HC-SR501 PIR Sensor : [Link](#)

Summary Table:

<u>Component</u>	<u>Detection Range</u>	<u>FOV</u>	<u>Response Time / Sampling Rate</u>	<u>Operating Voltage</u>	<u>Operating Current</u>	<u>Price</u>	<u>Shipping</u>
HC-SR04 Ultrasonic Sensor	2–400 cm	15°	20–30 ms / 15–Hz	5V	15 mA	\$4–\$7	3–7 days
GP2Y0A21YK0F IR Sensor	10–80 cm	10–15°	30–40 ms	5V	40 mA	\$7–\$15	3–7 days
HC-SR501 PIR Sensor	3–7 m (motion)	90–120°	<100ms	4.5–20V	50 mA	\$3–\$10	3–7 days

<u>Component</u>	<u>Pros</u>	<u>Cons</u>
HC-SR04 Ultrasonic Sensor	Reliable, good long-range detection, fast response time, easy Arduino integration, familiar from MAE 170	Narrow field of view accuracy affected by temperature, humidity, and angled surface.
GP2Y0A21YK0F IR Sensor	Compact size, fast short-range detection, precise local sensing, and strong indoor performance.	Non-linear output; affected by lighting and reflectivity; reduced accuracy on dark surfaces; shorter range.(more possible ways for error not outside friendly)
HC-SR501 PIR Sensor	Wide coverage, strong general motion detection, long range, and low cost for given ranges.	No distance measurement and has a cooldown period; can trigger from unrelated heat sources (also not outside friendly) and also draws more amps.

Contextual Justification:

The sensor choice directly affects several other parts for the overall design of the kinetic wall since the sensing system sets the foundation for how the kinetic wall detects user movement. For example, selecting a distance-based sensor such as the HC-SR04 or the IR sensor requires microcontrollers that can handle continuous data at higher sampling rates, which influences how many panels each controller (arduino or raspberry-pi) can manage and how quickly the motors must respond to that input signal. The more precise sensor allows for the design to have motors and control systems capable of smoother motion and more controlled linear motion, while a simpler motion only sensor like a PIR can limit the user interaction to activate at random times when someone walks by. The operating voltage and current of each sensor also impact power distribution and wiring across the total kinetic wall, meaning the electrical layout must accommodate whichever sensing method is chosen. Overall, the sensor selection affects the responsiveness, precision, and practicality of the overall mechanical system, ensuring that it remains aligned with the intended input/output behavior of the kinetic installation and the sponsor needs and constraints. For example choosing a sensor with high operational amperage usage can lead to the system shorting and overall failing the total design. All these considerations need to be taken into the design criteria. Also, mounting the sensors can be difficult for the overall design as each modular panel needs to have its own sensor, knowing where that can fit whether it is on the panel itself, on the shaft, or in the encasing of the overall system. This can affect how the design looks visually which for an art project, is very important for the customer. Since the sensor works directly with a microcontroller and the motors (both other ICA of other team members) choosing a motor with an input signal that can connect it with the sensor is very important (Addressed with Delson).

Appendix

“Active Infrared vs. Passive Infrared.” *Gst-Ir.net*, 2021,

www.gst-ir.net/news-events/infrared-knowledge/491.html.

Dejan. “Ultrasonic Sensor HC-SR04 and Arduino Tutorial.”

HowToMechatronics, 4 Aug. 2018,

<http://howtomechatronics.com/tutorials/arduino/ultrasonic-sensor-hc-sr04/>.

<https://www.sparkfun.com/ultrasonic-distance-sensor-hc-sr04.html>

Used for gathering electronic Spec information:

https://www.digikey.com/?gclid=aw.ds&gad_source=1&gad_campaignid=120498675&gbraid=0AAAAADrbLlg0UXAWqEwNHVXIFTZM8t03z&gclid=Cj0KCOiA_8TJBhDNARIsAPX5qxQqEEyPEiLzlmyTbhyreQWEFu-WAdzfdY2BmfdT4pCsacJWK27G3IkaA11JEALw_wcB

Types of sensors and how they work.

<https://eshop.se.com/in/blog/post/what-is-a-sensor-how-does-it-work-and-what-are-the-various-types-of-sensors.html?srsltid=AfmBOop8wVe4Nq60uGx7bg5HaLz-cWtiRYRLgqdFLfHwu9b1uDxF1z4b>

<https://www.vergesense.com/resources/blog/why-pir-sensors-are-no-longer-enough>

Pros and cons of sensor technology

<https://www.mcpconsultinggroup.com/blog/pros-and-cons-of-sensor-technology>

USE OF AI:

CHATGPT: Prompt: Please give me a table summary of these 3 given sensors (gave it links from digikey and sparkfun of given sensors) and output columns of components, detection ranges, response time, cost, shipping time and field of view). (I added the operating voltage and current myself to table above)

Output: **Component | Detection Range | Field of View | Response Time / Sampling Rate | Price | Shipping Time**

HC-SR04 Ultrasonic Sensor | 2–400 cm | 15° | 20–30 ms / 15–20 Hz | \$4–\$7 | 3–7 days

GP2Y0A21YK0F IR Sensor | 10–80 cm | 10–15° | 30–40 ms | \$7–\$15 | 3–7 days

HC-SR501 PIR Sensor | 2–4 m (motion only) | 90–120° | <100 ms | \$3–\$10 | 3–7 days

Prompt: I also asked it to give me the sources it used to get these numbers which output:

Digi-Key Electronics

SparkFun Electronics

Adafruit Industries

Amazon Electronics (Prime shipping estimates)

Sharp Microelectronics Official Datasheet

HowToMechatronics – HC-SR04 Tutorial

ELEGOO / KeyStudio / Generic Manufacturer Datasheet

(This LLM output was checked and verified by looking at all these 3 products on amazon, going through the links in the appendix to check the actual response time, detection ranges and etc... to make sure that they were correct. 1 error was found when I saw that originally it said PIR sensors have a range of 2-4 meters but it was actually 3-7 meters. The range of the prices was accurate looking online for example the HC-SR501 PIR Sensor was \$6.50 which is in the given range)

Technical Call

Call duration: 13:23 Minutes

Tech Sales Representative: Nick

I decided to call digikey technical support to describe to them my application and my overall MAE 156 project. I spoke to a sales representative named Chance Wilinski (not sure if last name was spelled correctly) who was very kind and helpful who said that he has been working there for about a year so far after being a manufacturing associate for General Mills. After explaining the purpose of the art installation and how the panels rely on sensor input to trigger linear motion (I told him we are probably thinking about using linear servo motors). I told him that I was down to 3 sensor choices, PIR, IR and Ultrasonic. He explained the main trade offs between the sensors and to me it seems like all this information was readily available and I already researched it online however. Nick said that the Ultrasonic is usually the most reliable for indoor distance detection but warned about when using many of them together it could lead to issues and concerns such as overlapping echo patterns and timing interference when one sensor picks up another sensor's returning pulse which has not even occurred to me when writing this ICA (very helpful information). Overall, he recommended that I use a PIR sensor (I asked him which would be the best but he pretty much said that he does not know my design limitations so he cannot help unless I email a specialist my designs directly) because a PIR sensor is best at detecting overall user presence. However I disagree with him as my research shows that a PIR sensor is not accurate or precise and if I were to use this in a multigrad modular panel, they would all activate and interact all at once. I also asked him what his background was as an engineer and he said he was a mechanical engineer who graduated from Michigan State. Those were the key takeaways from the call.