Design & Innovation Project (DIP)

Project Charter

Smart Touchless control with Millimeter-Wave Radar Sensor and Artificial Intelligence

Project Group: E047

School of Electrical and Electronic Engineering
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Project Name:	Smart Touchless control with Millimeter-Wave Radar Sensor and Artificial Intelligence
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Project Purpose or Justification:

- In 2021, as recent technology advancements grow like rapid-fire and with the coronavirus impacting our daily lives, sharing handles/buttons/touchscreens has created huge inconvenience and unease when everyone is more concerned about hygiene, sanitation and becoming more health conscious.
- The key to unlocking this issue could live in recent new advances in touchless technology, incorporating millimetre-wave (mmWave) radar and artificial intelligence (AI). Touchless gesture control is a natural, convenient, and hygienic way of human-computer interaction (HCI) and it is considered the Future HCI for the emerging Low Touch Economy. It also should be intuitive so that the user finds it second nature to eg. swipe their palm to flip a menu page.
- The ability of the technology to penetrate materials such as plastic, drywall and clothing also allows the radar sensor to be invisibly integrated into an application. The technology is also impervious to wind and moisture making it a suitable substitute due to its robustness in cases where the camera lens may possibly be stained with dirt, causing distortion or occlusion to the image captured.
- Many big names in technologies are also in the midst or had already incorporated some form of gesture touchless technology, e.g. BMW's BMW 5 Series Gesture Control Feature. Some of its applications are depicted in Figures 1a and 1b below.


Figure 1a (left): Accept a Call – Point to the BMW iDrive Touchscreen [1]
Figure 1b (right): Reject a Call – Swipe Your Hand to the Right [2]

Project Description:

- The main objective of the project is to explore and produce a smart touchless control innovation using low-cost commercial mmWave radar sensor and suitable machine learning/AI algorithms for simple and effective hand gesture sensing and control of a flexible HCI with unlimited applications.
- The product uses a low cost commercial mmWave radar sensor where it is a contactless sensing technology for detecting objects and providing the range, velocity and angle of those objects, which therefore makes it the most common form of no-touch technology where users can do simple gesture to control or interact with devices without physically touching them.

Project Description:

- Figure 2 below depicts some of the possible different hand gestures to be classified by the machine learning/AI classifier.

Figure 2: Examples of different hand gestures [3]

- Gesture recognition is the most common form of no-touch technology. Individuals can do simple gestures to control or interact with devices without physically touching them. Utilising a Acconeer Radar Sensor, we can overcome the unease of many individuals by collecting radar-based hand gesture raw data using I–Q Echo Plot via the Python exploration tool GUI. We will also perform Short-Time Fourier Transform (STFT) and utilising machine learning for gesture classification (image classification) to differentiate the different gestures and to execute and perform its respective functions.
- Figure 3 depicts a rough pipeline of the Smart Touchless control project, starting from the collection of hand gesture raw data to the processing of the data via STFT and into the machine learning classifier to perform gesture classification. The detected gesture will then trigger and perform its corresponding function in real-time.

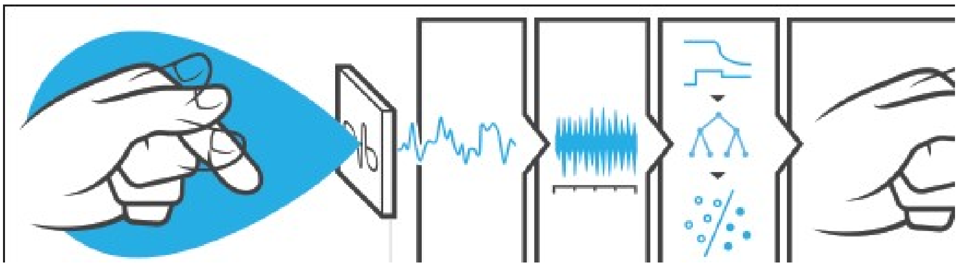

Figure 3: Pipeline of Smart Touchless control project [4]

High-level Project and Product Requirements:

- The project pipeline consists of the following:
  a) Collect radar sensor data (IQ mode) which captures the movements frame by frame including the slices of the depth range specified then exports it as h5 file.
  b) Process extracted h5 files using Python.
  c) Perform STFT on radar data and export an image-based signature based on the hand gesture recorded earlier.
  d) Feed the signature file into a Machine Learning (ML/AI) Model to train it and perform object classification to effectively classify several hand gestures in both seen and unseen cases. Different machine learning techniques or classifiers will be experimented with to yield the best results for the application.
  e) Implement on an edge device with limited computational abilities e.g. Raspberry Pi and integrate into a workable product with applications such as volume control, switching on/off etc.
- Upon project completion, we expect a working machine learning classifier complete with a radar data processing pipeline such that the prototype can detect and distinguish between a pre-set classes of hand gestures. This prototype will also be implemented on a Raspberry Pi to simulate the whole project as a possible HCI or potentially an Internet of Things (IoT) device which has many applications.

Summary Budget:

- S$ 400 – Acconeer radar sensors x2 sets
- S$ 200 – Raspberry Pi x2 sets
- S$ 100 – Miscellaneous including micro-SD card for raspberry Pi and connecting peripherals

As of this project charter, we have purchased the items below:

	Product	Price/unit	Quantity	Cost
Digi-key	XM112	94.13	1	94.13
	XB112	105.84	1	105.84
	XM122	49.8	1	49.8
	XB122	136.38	1	136.38
	XA122	23.88	1	23.88
Cytron	Rasberry Pi 3B+	57.86	1	57.86
	Rasberry Pi 4B (8GB)	119.99	1	119.99
	Raspberry Pi Universal Power Supply 5.1V 2.5A micro B	16.07	1	16.07
	Rpi 15W (5V/3A) PSU USB C UK Plug-White USB c	12.5	1	12.5
Shopee	64GB microSD card	18.9	2	37.8
			Total	654.25

Initial High-Level Risks:

Table 1: Risk Identification & Risk Evaluation								
Risk Identification				**Risk Evaluation**				
1a	1b	1c	1d	2a	2b	2c	2d	2e
No.	**Activity**	**Hazard**	**Possible unwanted consequences and persons affected**	**Control Measures**	**Persons and dateline to act**	**Likelihood**	**Severity**	**Risks**
1	Design & Innovation Project (DIP)	Electronic Devices & Components (Raspberry Pi & Acconeer Radar Sensors)	Overheating of Raspberry Pi/ Acconeer radar sensors	Check and touch the Raspberry Pi/ Acconeer radar sensors periodically to make sure they do not overheat while working on the project.	All group members	2	2	M(4)
			Electrical Hazards	Ensure that no outside food and drinks are brought into the lab. Place water bottles on the floor to avoid accidental spillage.		1	3	M(3)
			Tripping	Ensure that the walking pathway is clear and dry. Avoid placing items like bags and electronic components (Radar sensors & Raspberry Pi) in walkways.		1	3	M(3)
			Low-level Radiation	Avoid looking directly into the radar sensors to minimize radiation.		3	1	M(3)

Summary Milestones	Target Date
Background information and theory	*Week 1-2*
Purchasing and primary testing of radar sensor and Raspberry Pi	*Week 3*
Sample radar signal/data processing in MATLAB with porting to Python	*Week 4-5*
Data collection & Sample ML processing in Python	*Week 6-8*
Radar signal/data processing in Raspberry Pi	*Week 7-8*
ML processing in Raspberry Pi	*Week 8-9*
Finalization, Integration & Testing	*Week 10-12*

References (Image Sources)

[1] https://www.autosofdallas.com/blog/learn-how-to-use-the-bmw-5-series-gesture-control-feature

[2] https://www.autosofdallas.com/blog/learn-how-to-use-the-bmw-5-series-gesture-control-feature

[3] https://www.imagimob.com/blog/the-future-is-touchless-radical-gesture-control-powered-by-radar-and-edge-ai

[4] https://interactions.acm.org/archive/view/january-february-2018/radar-sensing-in-human-computer-interaction