Virtual Computer Mouse using mmWave Radar (TI)

Oscar Chavez Araiza

Greyson Heath

Daniel Lu

Zane Meikle

**Concept of Operations**

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Concept of Operations

for

Virtual Computer Mouse using mmWave Radar (TI)

Team <71>

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Prof. Kalafatis Date

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# Executive Summary

This project aims to create a virtual mouse using Texas Instrument’s (TI) mmWave radar. Using the mmWave radar, the system will track the user's hand and convert those movements into mouse movements on the computer. Additionally, it will recognize different gestures and convert those into mouse actions. This solution stands out based on its lower power and processing requirements, and a variety of environments in which it can easily operate.

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# Introduction

This project aims to make effective use of TI’s mmWave radar technology to eliminate the need for a mouse by tracking the user’s hand movements. A virtual mouse would improve a multitude of computing tasks, as opposed to using a mouse, in ways such as the following: enhanced multitasking, improved accessibility leading to a ‘hands-free’ interaction, increased ergonomics, and hygiene management. The performance of the virtual mouse will not be impacted by variations in ambient brightness or pollutant levels, as the signals can transmit usable data regardless of the environmental conditions.

## Background

Common virtual mouse systems used today rely on technology referred to as computer vision. Computer vision uses machine learning and neural networks to extract important data from video or digital images, and further analyze and compute tasks. A crucial component of the success of these systems involves the storage of countless videos and images. The system will continuously run analyses and train itself using the stored data, to the point where it can distinguish minute differences and learn to recognize patterns. Massive databases store heavy amounts of data used to execute computer vision, which requires vast resources and a significant amount of computing power.

The virtual mouse using TI’s mmWave radar technology aims to replicate the same successful results seen using computer vision, but meanwhile address and correct various technical and privacy issues. The mmWave radar does not rely on the following for meaningful data: visual data extracted from videos or photos, sufficient ambient lighting conditions, and high air transparency. The mmWave radar will consume much less power as compared to a traditional camera, and enable an even lower-latency detection and tracking of gestures. Eliminating the need for a camera resolves the growing privacy concern regarding potentially sensitive user data.

## Overview

The mmWave radar uses short wavelength electromagnetic waves, detecting the gestures in this project. The data from the radar will be communicated as frames. A gesture-detecting Machine Learning model will process the data to detect hand gestures. Detected gestures corresponding to assigned commands will have a gesture ID which will later be used to map the gesture to the mouse input. Another algorithm will track the hand and map its movements to mouse movements. A radar system can determine the range, velocity, and angle of the objects, with two electromagnetic waves transmitting and reflecting signals. Our radar system is operating at 57-64 GHz with error in a fraction of a millimeter. When the data processing unit receives the reflected signals, signals will be transferred to data plots. The computer will recognize the data plots, and convert plots to mouse commands.

## Referenced Documents and Standards

* 60GHz mmWave Sensor EVMs User’s Guide
* IWR6843, IWR6443 Single-Chip 60- to 64-GHz mmWave Sensor datasheet
* DCA1000EVM Data Capture Card User’s Guide
* Texas Instruments mmWave Radar Academy
* IEEE Xplore: An FCNN-Based Super-Resolution Mmwave Radar Framework for Contactless Musical Instrument Interface

# Operating Concept

## Scope

The virtual mouse using mmWave Radar is a proof of concept that will simulate the functionality of a simple computer mouse. A virtual mouse has been implemented using computer vision, thus this project will test the effectiveness of radar in tasks already done using computer vision. The virtual mouse will be able to control the cursor’s position, right-click, and left-click.

## Operational Description and Constraints

**3.2.1 Operational Description**  
To operate the virtual mouse, the user will connect TI’s mmWave radar and data-processing circuit boards, referred to as the mmWave radar package, to the computer. The mmWave radar package will be recognized as an I/O device and will be continuously monitoring for gestures to interact with the computer mouse. The user should ensure that the mmWave radar package is properly oriented so that it is able to detect and capture hand gestures. Additionally, the computer program that interacts and interprets the radar output should be executed and running prior to using the mmWave radar package.

**3.2.2 Constraints**Correct mouse functionality is expected when the user's hands are within a range of ten meters from the mmWave radar package, and only one hand is facing the radar. The algorithm will not recognize small hand movements as inputs.

## System Description

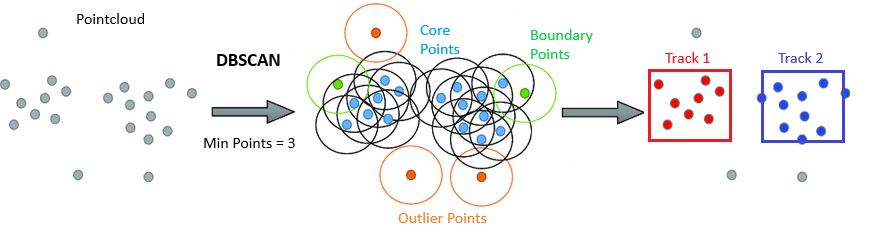
The mmWave Radar mouse is divided into 4 different subsystems: Chirp Optimization and Data Collection, Mouse Positioning, Gesture Recognition, and Input Mapping to the Computer.



**Figure 1**: Functional System Diagram

**Chirp Optimization and Data Collection**The Chirp Optimization and Data Collection subsystem is responsible for establishing a sufficient chirp signal and outputting useful data to be used for processing. A chirp signal is a pulsed signal that increases frequency over time, and further allows for an accurate range resolution and target detection to be observed. Heavy trial-based experiments and research will be conducted to yield an accurate target resolution for gestures using the chirp signal and will be continuously modified as needed. Following the optimization of the chirp signal, the output data will be collected and transmitted to the computer in a meaningful format for further processing.

**Mouse Positioning**The Mouse Positioning subsystem is responsible for calculating a 2D unit vector in the direction of movement of the hand. By creating a group tracker module, which utilizes clustering and gesture recognition in order to identify and monitor the existence of objects in an environment, a 2D position plot of point cloud will be created. The gesture recognition unit will detect the viewing and remove the return signal data from the surrounding environment.



**Figure 2**: Prediction state and measurement state

**Gesture Recognition**The Gesture Recognition subsystem is responsible for producing a gesture ID representing a right click or a left click. This subsystem will use a Machine Learning(ML) model to identify a hand and discern between two gestures, left and right click. The AI model will be sensitive enough to have less than 10% chance of false positives occurring. The Machine Learning Algorithm used is CNN. The Convolutional Neural Network has been used for the Computer Vision implementation, which will make the output of the mmWave Radar implementation more predictable.

**Input Mapping to Computer**The Input Mapping to Computer subsection is responsible for taking the vector from the Mouse positioning subsection and converting that to corresponding mouse movements on the computer. As well as taking the gestures recognized by the Gesture Recognition and converting those to mouse actions on the computer.

## Modes of Operations

**Active**

The mouse is in active mode when a hand is recognized by the Gesture Recognition system. When the mouse is in active mode it will operate normally with full functionality.

**Idle**

The mouse is in idle mode when no hand is recognized. In this mode, the mouse is on standby and will produce no mouse input. Once a hand is recognized, there will be a second of delay to allow for a comfortable positioning of the hand. The mouse will then enter the active mode.

## Users

The targeted users of the mmWave Radar mouse are people who prefer to have a hands free option to controlling their computer. Basic computer literacy is all that is required to operate the mouse. The mouse will contain a manual for operation, and the gestures will reflect actions done in a physical mouse.

## Support

To help the customers install and use the radar mouse, two instruction manuals will include standard gestures and provide information on installation and self-optimization settings.

# Scenario(s)

## Presentation

The virtual computer mouse will be an excellent resource when presenting. Navigating slides with the mouse will be easy and convenient. It would be comparable to a presentation clicker/pointer in functionality.

## Medical

The hands free operation of the mouse is very useful for maintaining a clean and sterile environment in a hospital. Doctors and nurses could use the virtual mouse to control a monitor during surgery, eliminating the need for physical interaction.

# Analysis

## Summary of Proposed Improvements

* The mmWave radar package is more power efficient than a camera based virtual mouse.
* The mmWave radar package will be less processing intensive due to the computer only processing a simple point cloud format, instead of a video or photo data format.
* The mmWave radar package can successfully operate in dark and hazy environments without impacting performance.
* The mmWave radar package is hands-free making it more hygienic than a regular mouse.

## Disadvantages and Limitations

* The mmWave radar package has a lower ability to discern finer gestures due to a lower resolution when compared to a camera.
* The mmWave radar package is bigger than a conventional computer camera.
* The mmWave radar package has a low polling rate ~ 20Hz.
* The mmWave radar package is more expensive compared to a camera based solution.

## Alternatives

* **Virtual Mice -** Virtual mice would be a camera based solution. They would be more power and processing-intensive, and also would not function in the dark. However, they would be more accurate in determining gestures, have a smaller physical footprint, and would be significantly cheaper than our solution.
* **Physical Mouse -** A standard mouse would be far more accurate for recognizing inputs, tracking position, and running at a higher polling rate. On the other hand, it requires physical contact, making it less hygienic.
* **Touch Screens -** Physical finger inputs are able to interact directly with the screen, and would be more accurate for movement and for recognizing inputs. Nevertheless, they would be unhygienic as the user must physically touch the screen.

## Impact

This product will likely have very little impact on the environment other than the environmental impact of manufacturing it, though all devices of this type would have a similar impact. There is not likely to be any major societal impact as this will replace a device that is commonly used by society.