CHAPTER I
INTRODUCTION

1.1 Background Problems

Radar systems using Frequency Modulated Continuous Wave (FMCW) technology have been widely employed for monitoring human activities and moving objects due to their ability to capture micro-Doppler signatures—fine-grained frequency patterns generated by dynamic parts of a target, such as swinging arms or rotating propellers [1], [2]. These micro-Doppler features are essential in applications such as activity recognition, security surveillance, and intelligent sensing systems [3], [4].

Despite their advantages, building an FMCW radar system for research or real-world deployment often requires expensive hardware, complex calibration procedures, and controlled testing environments[5]. In addition, collecting large-scale radar datasets is resource-intensive, posing challenges for developing data-driven models such as deep learning systems that require significant amounts of labeled data [6].

On the other hand, monocular RGB cameras offer a low cost, portable, and widely available alternative. They are already commonly used in motion tracking, human activity recognition, and augmented reality applications. However, unlike radar, monocular cameras do not capture frequency domain information such as Doppler shifts. Therefore, there is a growing need for methods that can transform visual data into radar like signal representations, particularly micro-Doppler spectrograms.

Recent advancements in deep learning, especially in Generative Adversarial Networks (GANs), have shown promising capabilities in cross-domain translation. Several studies have successfully synthesized micro-Doppler spectrograms from diverse input modalities such as skeleton sequences and motion data [7], [8].

In this context, the present study aims to develop a micro-Doppler simulator that takes monocular video input and uses GANs to synthesize depth map estimation to generate FMCW radar signals. This simulation framework is expected to offer a cost-effective alternative for generating radar data synthetically, especially in environments where actual radar hardware is unavailable or impractical. Although this research initially focuses on the FMCW waveform only, the proposed architecture can be extended to support various other radar signal types in future work.

1.2. Problem Formulation

Based on the background that has been explained, the identified research problem is:

1. How monocular camera and depth estimation can give depth of human joints.
2. How can depth information convert into 3D coordinates while the object still moving.
3. How to makes the 3D coordinates can used as the model of waveform echo signal from a human target.

1.3. Objectives

The objectives of this thesis design are:

1. To investigate the use of monocular camera combined with depth estimation algorithms for estimating the depth distance of human joints from 2D RGB images or video.

2. To develop a method for converting estimated depth maps into 3D joint coordinates, even when the human subject is in motion, by leveraging distance estimation.

3. To construct a pipeline that transforms the 3D motion data into synthetic radar waveform echoes, modeling how FMCW radar would respond to such human movements using micro-Doppler signal simulation techniques.

1.4. Benefits of Research Results

The advantage of this thesis lies in its ability to simulate various radar signal modulations using a monocular camera instead of depth camera, thereby facilitating the use of other modulation types with simpler equipment.

1.5. Scope of Problem

Based on the background and problem statement, the scope of the study is as follows:

1. The system will only use monocular RGB video as input. No stereo vision or depth sensors.
2. Human joint positions will be estimated using existing 2D pose estimation models (e.g., MediaPipe).
3. The research subject is limited to signle target due to models limitation.
4. The target distance ranges from 1.5 to 10 meters from the sensor due to radar sensor capability and minimum camera to capture of full human posture.
5. This study does not cover the process of radar manufacturing.
6. This study focuses solely on signal modeling using existing programming algorithms.
7. Analysis of signal radar using monocular camera as a ground truth.

1.6. Research Method

This research method such as literature review, modeling, empirical measurement, statistic analysis.

1. Literature Review

   This research involves collecting and analyzing various journal sources and relevant literature related to Depth Estimation, Radar Signal Processing, and Image Processing. The reviewed literature includes discussions on basic concepts and recent developments in converting images to depth images and using radar for human activities. This literature study aims to gain a deep understanding of the concepts used, while also identifying the strengths and weaknesses of existing systems.

2. Empirical Measurement

Empirical measurements were conducted to collect data on human movements using radar and a monocular camera, which were then transformed into depth estimations. The collected data includes information such as the distance and angle of objects detected by the radar. This measurement process was carried out indoors to ensure that the collected data accurately represents actual conditions. The measurement data will then be used in the radar signal modeling process.

1.7. User Projection

The model developed in this thesis will serve as an initial step for modeling complex radar signals, not only for FMCW-based signals but also for other types of signals. Radar signal model (Radar Waveform) can be simulated to obtained from human as a target so this systems can obtained micro doppler with the cheapest devices and cost reduction. This model creation serves as a cost-effective comparison and can be used as a database for human activities.