CHAPTER 1
INTRODUCTION

This chapter provides a brief overview of the research. Consist of six sections; the explanation starts with background problem identification and objective, scope of work, research methodology, and structure of this thesis. A more detailed explanation will be later in the next chapter.

1.1 Background

Human is a living creature with different physical endurance [1]. As we age, the changes in human physical shape and endurance decrease, especially in older age (elderly). The age limit is 60 years or more, as set out in the Act No. 13 of 1998 on Advanced Age Welfare. The elderly population according to the Indonesian Central Statistical Authority in 2023 is 11.75% and 53.93% of the older people are still working [2].

Elderly has a more susceptible physical body to health problems, one of which is a stroke. Collisions can occur when falling and cause serious injury to fractures of the spine or back [3]. Falling back injuries are one of the health problems that should be avoided in every human being, especially the elderly, as they can reduce mobility, increase the need for long-term care, and decrease the quality of life. According to the World Health Organization (WHO), approximately 30% of the elderly population suffer at least once a year, and this figure will continue to rise as we age [4]. The impact of falling on the elderly who are still working or engaged in social activities will be more severe as depression reduces productivity and increases dependence on the help of others [5].

The impact of technological advances offers new opportunities to overcome these challenges, thus providing additional protection for the elderly. This extra protection is also balanced with the comfort of its users. So the innovation was found by using the Intertial Measurement Unit (IMU) sensor and artificial intelligence (AI) to detect posture changes in real-time [6].

A study conducted by Sivaranjani, T., et al. (2017) discusses wearable airbag technology designed to prevent injuries from falls in specific positions. The system measures acceleration and angle speed with limits of +3 m/s^2 and 0.52 rad/s, respectively. If the measurement exceeds these limits, it assumes the user will fall, activating the airbag [7]. Sankaran, Sakthivel, et al. (2021) also developed Smart Airbags that not only protect users but send emergency notifications to relatives or caregivers after a fall, facilitating immediate first aid [8].

Li, Junxi (2020) further expanded on the design of airbags integrated into everyday clothing, ensuring comfort and non-interference with daily activities, with airbags located on the hip and head [9]. Research conducted by Zebiah S. Shering et al. (2023) explored the application of machine learning and deep learning techniques for detecting falls using IMU sensors. The study reviewed various methods to classify movements as either falls or normal activities and emphasized the role of advanced algorithms, such as convolutional neural networks (CNNs) and support vector machines (SVMs), in enhancing the accuracy of real-time fall detection [10].

Support Vector Machine (SVM), The study by Hosseini, et al. (2024) explores fall risk assessment using a single IMU (Inertial Measurement Unit) [11]. This approach emphasizes the potential of IMUs in evaluating fall risks by monitoring movement patterns. While effective in detecting fall-prone movements, the method may encounter limitations in accurately distinguishing between different types of risk factors and normal daily activities, which could reduce its precision in real-world fall prediction.

Alanazi et al. (2022) proposed a 3D multi-stream CNN for fall detection, achieving 99.03% accuracy [12]. While CNN excels at recognizing spatial features, it faces challenges in distinguishing transitional movements in IMU data, as fall dynamics often overlap with activities like walking or standing. Fine-tuning with LSTMs can improve its ability to handle sequential data.

Zermane et al. [13] found that the Random Forest model outperformed other machine learning techniques in predicting fatal accidents. It demonstrated superior accuracy and robustness, particularly in handling the complex and imbalanced data typically associated with accident prediction. This model effectively identified key risk factors, providing valuable insights for improving road safety and reducing fatal accidents.

Artificial Neural Network (ANN), as proposed by Li, Junxi (2020) [9], is known for its flexibility in real-time fall detection, capturing temporal dependencies in sequential data. ANN achieved 98% accuracy and low latency, making it the best choice for wearable real-time applications like airbag systems. ANN's ability to learn complex non-linear patterns makes it ideal for detecting rapid motion transitions, such as from standing to falling.

Based on the explanation above regarding the airbag installed on the vest that can be used by the elderly, the following research was obtained "Development of

Intelligent Fall Sensing Algorithm in an Automated Airbag System For Elderly". This vest equipped with an airbag can expand or activate when it detects sudden and significant acceleration, orientation, and rotation of the body. The selection of a vest as a tool that can be used by the elderly aims to provide a sense of comfort, so that it is easy to use along with daily activities.

1.2 Problem Identification

The Identification of the problem to be researched includes:

1. How to integrate a smart airbag system utilizing IMU sensors and artificial intelligence (AI) to detect and prevent impacts on the elderly?
2. How to develop an effective detection and response algorithm based on IMU sensor data to predict falls and activate the airbag before impact?

1.3 Research Purposes

This research aims as follows:

1. To develop a smart airbag system integrated with IMU sensors and artificial intelligence (AI) to detect early changes in the body movement of the elderly, and trigger the activation of the airbag within a response time of 0.1 seconds before the impact phase. This approach ensures that the airbag is activated before the user hits the ground, effectively minimizing the risk of injury.
2. To develop a detection and response algorithm based on IMU sensor data that can predict falls before impact occurs, achieving an accuracy of at least 98%, in line with existing research. This high level of accuracy ensures reliable classification of falls and non-falls, allowing the system to activate the airbag in a timely manner, thus reducing the risk of injury.

1.4 Scope of Work

1. The IMU sensor is placed on the upper back of the vest.
2. The artificial intelligence used is machine learning algorithm.
3. The training data used was only collected indoors with walking, standing, forward falls, backward falls, and lateral falls (right and left).

4. The parameters used were angular velocity, acceleration, and orientation, each with the X, Y, and Z axes.

5. The subjects of data collection in this study consisted of men and women aged 24±2 years, with a height of 152±23 cm and a weight of 45±15 kg.

1.5 Research Methodology

The stages of the research carried out can be described as follows:

1. **Introduction** - Explain the background and urgency of the research. Detailing the research objectives, namely developing an intelligent airbag system that can detect and prevent back impacts in the elderly using IMU sensors and machine learning algorithms.

2. **Basic Concept** - Conducting literature to understand IMU sensor technology, the basic principles of machine learning, and research on fall detection and airbag system development.

3. **System Design and Models** - The airbag system design is made so that it can be used by the elderly which is designed to support the use of IMU sensors and airbags on vests. Integrating IMU sensors and data processing with machine learning algorithms for gait pattern analysis.

4. **Data Collection** - Experiment and collect data in scenarios of normal walking, sway walking, walking falls and static falls. Using IMU sensors to collect acceleration, angular velocity, and position data when in various conditions.

5. **Data Processing** - Data processing obtained from the IMU sensor will be analyzed with the machine learning algorithm to detect potential falls in users (elderly). Train the machine learning algorithm with the collected data to separate normal movements and movements with a risk of falling to have high accuracy. Validate the accuracy and effectiveness of the machine learning algorithm in detecting potential falls based on experimental data.

6. **Field Testing** - The data searches used were normal walking, sway walking, and static falls. Fall simulations are carried out by volunteers to evaluate the system's response in preventing back impacts.

7. **Analysis of Results** - Analyze data obtained from field testing to measure the accuracy and effectiveness of the system in detecting and preventing falls.

Analyze the response time and effectiveness of the airbag in preventing injuries based on machine learning algorithm and IMU sensor data.

8. **Conclusions and Recommendations** - Summarize research findings. Provide recommendations for further development.

1.6 Research Methods

1. Literature Study Searches were carried out on local and foreign papers, textbooks related to IMU sensor and machine learning.
2. Design a vest with specifications that are suitable for installing sensors and airbag systems, as well as control units. This design will consider user comfort for daily use.
3. Conduct simulations with various movement scenarios, including daily activities and situations that will fall, until falling, to test and validate the system's predictions in detecting potential falls.
4. Formulation of conclusions and recommendations. This study will produce recommendations that can be used as considerations in preventing injuries due to impacts on the elderly.