Chapter 1. Introduction

1.1 Background and Motivation

A tsunami wave can be defined as the resulting wave movement that is caused by a displacement of a large mass of water in a relatively short time (Cartwright & Nakamura, 2008). Numerous natural and non-natural phenomena can cause this displacement of a large mass of water. Some well-known examples of this cause are earthquakes, subsequent effects of volcanic eruption, and landslides in the water body. Since it is a natural phenomenon, it is tied with the geographical condition of the earth. Earth is dynamic since some of its tectonic plates underwater are constantly moving. This movement of tectonic plates is especially constant on the locations of the earth called the Pacific Rim (Hinga, 2015). Pacific Rim (also called the Ring of Fire) is associated with more natural disasters due to the level of activity of the earth in this area. In the past couple of decades, tsunamis have occurred more frequently around this area. A couple of notable tsunami events in Indonesia are Aceh (2004), Mentawai (2010), Sulawesi, and Sunda Strait (2018). These events brought significant casualties to the population's welfare that lived in the affected area.

As such, it is then apparent that a way to anticipate a tsunami event is required to have a chance to lower casualties and mitigate the impact of the tsunami. Thus, a tsunami forecasting model can serve as a primary method to understand and describe tsunamis. The numerical method can be used to solve complex equations for predicting natural events that consider the underlying physics (Epperson, 2013). One method to forecast tsunami is by using a numerical method as a basis of which the tsunami’s wave propagation equation is solved by taking into account its fluid flow and propagation characteristics. This modeling can be done by taking advantage of the historical data of past tsunami events that is publicly available and easily accessible. With the development of a good model, it is possible to replicate a past tsunami event with relatively good accuracy. With recent development in artificial intelligence and machine learning, developing a data-driven model that allows a faster and higher accuracy of tsunami forecast has become feasible. The output of the data-driven model can be utilized together with numerical methods of tsunami forecasting to generate an early warning system that serves as an evacuation prompt in a real-time manner.
Currently, the existing complex numerical modeling of tsunami is generally faced with the challenge of requiring a sizeable computational resource and limited applications (Synolakis et al., 2008). A numerical model requiring sizeable computational resources is a disadvantage for real-time applications and immediate warning of evacuation systems since it may require a long duration to complete its computation. It is possible to speed up this computational process by using a pre-computed model; however, speeding up only reduces the lengthy computational time to a certain extent (Titov et al., n.d.). In this case, data-driven modeling offers its best benefits. In this case, the numerical model can be simplified. The computational time required is short, and the data-driven model can immediately process the result of this computation. With a prediction system built using a machine learning algorithm, it is possible to develop a prediction system where future tsunami events are forecasted with high accuracy.

By developing a model that takes advantage of both numerical modeling and data drive modeling, it is possible to achieve a less demanding computational resource model and attain desirable accuracy of the result of this model. The result can then be utilized to develop a complete early warning system of the tsunami. With an operational early warning system, it is possible to lower the risk and mitigate the impact of this natural disaster.

1.2 Research Scope

This research is conducted in the following scope:

1. Building physically based numerical model for tsunami predictions in a particular location, for instance, tsunamis in Aceh, using appropriate software that included a base model with adjustable parameters,

2. Understanding, describing, and adjusting the physically-based numerical model and data-driven models,

3. Building a data-driven model for tsunami forecast based on the output of the numerical model and,


The following points are not the focus of this research:
1. Collecting data directly from the measurements on the sea, the source of the data included in this research will be based on pre-existing research or publicly available sources,
2. Developing a mathematical equation for numerical modeling and,

1.3 Research Objective

This research focused on developing a tsunami forecast model with the aims and objectives as follows:

1. Develop and review tsunami modeling using physically-based tsunami modeling software, namely Delft3D and Delft Dashboard,
2. Explore and apply several machine learning algorithm that is used to forecast tsunami modeling,
3. Develop a data-driven model of tsunami forecasting and,
4. Evaluate the accuracy of the model used in tsunami forecasting.

1.4 Main Benefits

An accurate tsunami forecasting model is beneficial for nations, governments, and institutions that minimize the impact of natural tsunami disasters on society’s welfare. With an accurate tsunami forecasting model, it is possible to attain these benefits:

1. Provide a data-driven forecasting model that can be further developed and used to anticipate and prevent the impact of potential future tsunamis
2. Develop a data-driven model that can serve as a foundation for an early warning system.
3. Demonstrate the capability of machine learning algorithms when applied to tsunami forecasting and other fluid dynamics problems
1.5 Thesis Structure

Chapter 1: Introduction
This chapter describes the research's scope, aims, benefits, and structure.

Chapter 2: Literature Review
This chapter elaborates on the definitions, concepts, and theories of tsunami forecasting. Similar research is discussed and reviewed. This chapter builds the preliminary knowledge and understanding of the methodology used in the subsequent chapter.

Chapter 3: Methodology
This chapter describes the methodology involved in building a model for tsunami forecast. It includes a practical step-by-step example that can be reviewed and replicated for those interested in building a tsunami forecast.

Chapter 4: Results
This chapter describes the result obtained by completing the methods in the previous chapter. A discussion will follow directly after each statement of the result.

Chapter 5: Discussions
This chapter includes an in-detail discussion regarding the results from the previous chapter. In addition, comparisons, evaluations, and reasoning of the related result are shown here.

Chapter 5: Conclusions & Recommendations
This chapter concludes the research and gives recommendations for tsunami forecasting.