

**MULTI-MODAL ASSOCIATION LEARNING USING  
SPIKE-TIMING DEPENDENT PLASTICITY (STDP)**

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## Abstract

We propose an associative learning model that can integrate facial images with speech signals to target a subject in a reinforcement learning (RL) paradigm. Through this approach, the rules of learning will involve associating paired stimuli (stimulus–stimulus, i.e., face–speech), which is also known as *predictor-choice* pairs. Prior to a learning simulation, we extract the features of the biometrics used in the study. For facial features, we experiment by using two approaches: principal component analysis (PCA)-based Eigenfaces and singular value decomposition (SVD). For speech features, we use wavelet packet decomposition (WPD). The experiments show that the PCA-based Eigenfaces feature extraction approach produces better results than SVD. We implement the proposed learning model by using the Spike- Timing-Dependent Plasticity (STDP) algorithm, which depends on the time and rate of pre-post synaptic spikes. The key contribution of our study is the implementation of learning rules via STDP and firing rate in spatiotemporal neural networks based on the Izhikevich spiking model. In our learning, we implement learning for response group association by following the reward-modulated STDP in terms of RL, wherein the firing rate of the response groups determines the reward that will be given. We perform a number of experiments that use existing face samples from the Olivetti Research Laboratory (ORL) dataset, and speech samples from TIDigits. After several experiments and simulations are performed to recognize a subject, the results show that the proposed learning model can associate the predictor (face) with the choice (speech) at optimum performance rates of 77.26% and 82.66% for training and testing, respectively. We also perform learning by using real data, that is, an experiment is conducted on a sample of face–speech data, which have been collected in a manner similar to that of the initial data. The performance results are 79.11% and 77.33% for training and testing, respectively. Based on these results, the proposed learning model can produce high learning performance in terms of combining heterogeneous data (face–speech). This finding opens possibilities to expand RL in the field of biometric authentication.

**Keywords:** *spiking neural network, feature extraction, spike-timing-dependent plasticity, association learning, reinforcement learning.*

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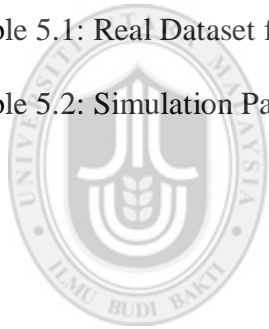
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# CHAPTER ONE

## INTRODUCTION

### 1.1 Introduction

In general, human being depends on five senses to interact with the surrounding environment which are; sight, hearing, touching, smell, and taste. These senses enable the person to capture a huge amount of information to the brain. Then the brain analyzes, classifies, and recognizes this information in a way that is incredibly fast and accurate [1]. It is amazing for the brain to have such great capabilities to comprehend substantial physiological and behavioral biometric traits as well as to process the coming information in terms of human recognition. In computer systems, there are two methods that normally used to perform the authentication which are the traditional systems and the biometric systems.

Traditional person authentication approach can be knowledge-based like the password or PIN code, it also can be token based like an ATM card, credit card, and ID cards. This approach is less reliable and insufficient in terms of security performance [2, 3] because, it is difficult to differentiate between the genuine person and an imposter one. Furthermore, authentication elements like passwords or cards can be borrowed, stolen, and forgotten. That makes this approach suffers from a number of limitations which make it undesirable in terms person authentication [4].

Biometric identification approach is constraining on how to identify the individuals based on their physiological or behavioral characteristics. It based on what the person is, and what the person do. Biometric traits include fingerprint, iris,

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