CHAPTER 3

DNA Splicing System in Chorale Music

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3.1 INTRODUCTION

In the study of macromolecules, Head (1987) introduced splicing as the language produced from biochemical systems together with operation on strings of deoxyribonucleic acid (DNA), followed by Păun (1996) who introduced other operations in the same field. Adleman (1994) solved a directed Hamiltonian path problem, namely a directed graph from a start vertex to an end vertex and visiting each node exactly once, by utilizing DNA strings. Also, genetic algorithm has been shown to work on music by some researchers, for instance, Horner and Goldberg (1991) on thematic bridging, Biles (1994) on Jazz solos, and Jacob (1995) on human intervention genetic algorithm.

The other field mentioned in this research is music, in which it is an art and cultural activity which is used for a variety of purposes, be it aesthetic pleasure, religious activities, or just as a form of entertainment which includes singing. The genre of music used in this study is the chorale music which is known as a metrical hymn tune used in church.

Recently, De Felice et al. (2017) proposed a new system by using bio-inspired strategy specifically to build an automatic music composer for chorale music. Before that, De Felice et al. (2015) proposed the same system using a general approach. Thus, this research aims to investigate and relate the model of

DNA splicing system and music spicing system. Here, chorale music splicing system is analysed using note representation and tonality-degree representation approaches.

This research emphasised on the mathematical model of DNA splicing system in chorale music by using specifically Păun's splicing system model. Hence, this research shows the relation between DNA splicing system and chorale music. The development of a new system for algorithmic composition by using splicing system can be used as the basis for composition in music. Thus, this research contributes to the development of biological systems with music composition.

3.2 MATHEMATICAL MODEL

In this section, some concepts and theories which include some basic knowledge and components related to this entire research are presented.

The notation of splicing system, namely Păun's notation, is presented with its own condition and rules. Păun (1996) presented a new notation of splicing system in a simpler way which is $S = (A, I, R)$ and this notation is used in this research. The notation A represents the set of a finite alphabet, I represents the set of finite initial strings and R represents the set of rules. Since the splicing operation was introduced to work on the genetic recombinant, hence a finite set of alphabets has the form of $A = \{a, c, g, t\}$.

In formal language theory, a word consists of alphabets, so as a language in mathematics. An alphabet $\sum$ is known as a finite nonempty set of symbols (Linz and Rodger, 2023). However, a finite sequence of symbols from an alphabet produces strings. For instance, if $\sum = \{a, b\}$, then

$abab, aabb, aaabbba$ are strings on $\sum$. Normally, the lower-case letters $a, b, c, \ldots$ denote the elements of an alphabet $\sum$.

A subset of $\sum$ is known as a language L. The string formed by the language is called a sentence of L. The union ($\cup$), intersection ($\cap$), difference and complement ($\bar{L}$) are defined since languages are considered as sets. Thus, the operations are defined as

$$L_1 \cup L_2 = \{x: x \in L_1 \text{ or } x \in L_2\},$$
$$L_1 \cap L_2 = \{x; x \in L_1 \text{ and } x \in L_2\},$$
$$L_1 - L_2 = \{x: x \in L_1 \text{ and } x \notin L_2\},$$

and $\bar{L} = \{x: x \in U, x \notin L\}$ where U is a universal set and $\bar{L} = \sum^* - L$.

Some studies on music notation used in this research are given in Piston and Devoto (1987). Firstly, a scale is an ordered set of musical notes in the range of an octave and tonality refers to a group of chords in the arrangement of a scale. Two kinds of tonalities are major and minor. The major and minor tonalities differ by the third essential note of chords and scales.

Next, a chord is a formation of three notes based on the degrees of the scale in the tonality used (as in major or minor), in which the degree is denoted using roman numerals. Capital letter is used for a major chord while small letter is used for a minor chord. Then, an octave indicates the range of frequencies between two different sounds which are often obtained by using doubling or halving.

Furthermore, chorale music, also known as chorus or choir, is the music written specifically for an ensemble to perform. Johann Sebastian Bach wrote for chorale music and he was also a great composer and performer during the early 18th