TUTORIAL ON NEGATIVE SELECTION ALGORITHM

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Sonal Singh

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Tutorial on Negative Selection Algorithm

By

Sonal Singh

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Approved:

08/08/2013	Dr. Brian M. Slator
Date	Department Chair

ABSTRACT

The primary aim of this paper is to incorporate the educational objectives of the revised Bloom's taxonomy in the creation of educational material and assessments for teaching the concepts of the Negative Selection Algorithm. Bloom's revised taxonomy makes the learning process easy for learners by dividing the educational material into increasing levels of complexity. Bloom's revised taxonomy identifies six cognitive levels, starting from basic steps in learning to the more advanced steps.

The tutorial material is designed specifically to accommodate the first three cognitive levels of Bloom's revised taxonomy. The material will help students to acquire basic knowledge of the concepts of the Negative Selection Algorithm. This paper also provides a working example and an application that will help students in developing a working knowledge of the concepts of the Negative Selection Algorithm.

ACKNOWLEDGMENTS

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1. INTRODUCTION

1.1. Negative Selection Algorithm

Negative Selection Algorithm is an algorithm that is inspired by the Negative Selection mechanisms of the Biological Immune System. It is an early and inspiring mechanism that has been applied in many fields of the Artificial Immune System to solve various real world problems.

The Negative Selection Algorithm has been successfully used in the creation of a wide range of applications in the field of Artificial Immune System. It was first proposed by Stephanie Forrest et al. in 1994 (Forrest, et al. 1994) to detect a computer virus and after this it has been used in constructions of many applications of the Artificial Immune System, like anomaly detection by Dasgupta in 1998, and network intrusion detection by Kim and Bentley in 2001.

It is essential to develop educational content and assessments to teach the concepts of Negative Selection Algorithm, so that students can make use of these concepts in creation of many other applications in the field of Artificial Immune System.

1.2. Application Implementation

Asp.net with Visual C# has been used to create the complete tutorial website. Microsoft ASP.net is a server-side web application framework designed for web development to produce dynamic web pages (W3schools n.d.). The target framework used for the application is .NET framework 4.0.

C# (pronounced "C sharp") is a programming language that is designed for building a variety of applications that run on the .NET framework (MSDN n.d.). Choosing the C# language as a choice for developing the working example helps in

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taking advantage of the .NET framework, such as easy application development, maintenance and security.

There are several reasons for choosing Asp.net for developing the tutorial website. Compared to other alternatives, it provides or ease of development, provides good performance, and creates safe and secured applications. The Visual Studio .NET framework makes coding quite easy. It can highlight syntax, lets you know when the wrong material is commented, does command completion, and helps you to organize well.

1.3. Problems in Learning

Learners face a number of difficulties when learning new concepts, like not having material focused on a specific topic or not having examples supporting the material. It is difficult to learn complex concepts without having the fundamental knowledge about the basic concepts.

In this paper we develop educational content for the learners to get a good understanding of the fundamental concepts of Negative Selection Algorithm.

1.4. Objectives

The main objective of this paper is to present educational content and assessments for the purpose of teaching the concepts of the Negative Selection Algorithm by applying the revised Bloom's taxonomy principles. The teaching part of the tutorial includes the design and development of course material in such a way that the tutorial satisfies the learning objectives recognized by various levels of the cognitive approach in the revised Bloom's taxonomy.

1.5. Document Organization

The aim of this chapter is to provide the reader with an overview of the Negative Selection Algorithm and its importance in the field of the Artificial Immune System. The chapter has also outlined the need for well-structured course material that can be used by learners to have efficient understanding of the topics.

Chapter 2 presents an overview of the original Bloom's Taxonomy learning objectives and a detailed introduction about the levels in the Revised Bloom's Taxonomy.

Chapter 3 illustrates how the Remember level, the first cognitive level of the revised Bloom's taxonomy, can be supported with tutorial learning material.

Chapter 4 illustrates how the Understand level, the second cognitive level of the revised Bloom's taxonomy, can be supported with tutorial learning material.

Chapter 5 illustrates how the Apply level, the third cognitive level of the revised Bloom's taxonomy, can be supported with tutorial learning material.

Chapter 6 presents a set of conclusions and the limitations related to the work. It also provides recommendations for future work.

2. TAXONOMY OF LEARNING

Learning taxonomy can be described as different stages in the learning process which will help improve our understanding of the subject (Fuller, et al. 2007). It can be used as a way of describing different kinds of learning characteristics that we wish our students to develop.

There are various learning taxonomies and theories developed to assist the creation of educational resources and the development of learning outcomes. The most common and earliest used learning taxonomy technique is Bloom's taxonomy proposed in 1956 by a group of educators directed by Benjamin Bloom (Krathwohl 2002).

2.1.   Bloom's Taxonomy

Bloom's taxonomy is an educational method for the classification and categorization of different levels of critical thinking essential to complete a task. It was first proposed by Benjamin Bloom (Bloom 1956) as a part of his study in educational practices. Bloom along with his group of professors distributed the technique people generally used to learn into three domains of educational activities. The three domains of educational activities are (Wirth and Perkins 2008):

- The cognitive domain: This domain involves attainment of mental skills.

- The affective domain: This domain is demonstrated by behaviors. It involves growth in the feelings, attitudes, emotions and values.

- The psychomotor domain: This domain is demonstrated by physical skills such as coordination, strength and motor-skills.

The Cognitive domain is the most commonly used domain of Bloom's Taxonomy out of the three domains presented above. Within cognitive domain the Bloom taxonomy identifies six levels of understanding in a hierarchical sequence.

The six levels of Bloom's taxonomy, from simple to complex, are (Wirth and Perkins 2008):

- Knowledge: associated to acquisition of facts by recalling facts and using related terminologies.

- Comprehension: associated to understanding the meaning of the facts.

- Application: associated to applying previously gained knowledge in creation of new situations.

- Analysis: associated to drawing conclusion/s from the presented knowledge.

- Synthesis: associated to creating new concepts based on information presented.

- Evaluation: associated to measuring the knowledge presented.

These six levels of Bloom's taxonomy are based on the levels of difficulties, and each level addresses different learning outcomes.

These six levels are interdependent; meaning achieving each level depends upon attainment of lower ones. These levels have become highly important as a guide for educators in planning course objectives.

A structural view of the six levels of Bloom's taxonomy for cognitive domain is shown in Figure 1.
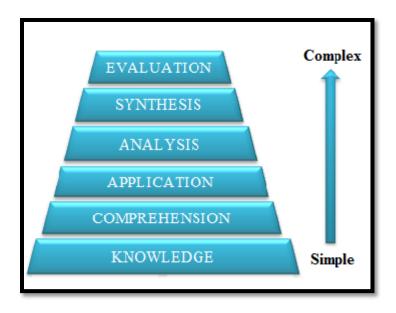
Figure 1: Bloom's Taxonomy

2.2. Revised Bloom's Taxonomy

In 1990 two former students of Bloom's, Lorin Anderson and David R. Krathwohl along with a group of psychologists, revised the original Bloom's taxonomy and referred to it as Revised Bloom's taxonomy (Krathwohl 2002). The scope behind revisiting original Bloom's taxonomy was to add relevance for students and teachers of the present time. In the Revised Bloom's taxonomy, writers emphasized verbs rather than original adjectives to correspond with the ways learning objectives are described (Fuller, et al. 2007). Though the changes in the Revised Bloom's taxonomy are minor, they are quite important and occurred in three categories: terminology changes, structural changes and change in emphasis (Forehand 2010).

2.2.1. Terminology Changes

The terminology change of the six categories of cognitive domain from nouns to verbs is the most recognizable change between the two versions. In the Revised Bloom's taxonomy three categories of original Bloom's taxonomy were renamed, the order of two

categories was substituted, and the categories for which the names were retained were changed to verb form to fit the way they are used in objectives (Krathwohl 2002). Knowledge, which was the first category in the original taxonomy, was renamed as Remember. Similarly Comprehension, which was the second category in the original taxonomy, was renamed as Understand. Application, Analysis, and Evaluation, which are the higher categories of original Bloom's taxonomy, were retained in the Revised Bloom's taxonomy, but in their verb forms as Apply, Analyze, and Evaluate. Synthesis, which was the second last category in the original taxonomy, changed places with Evaluation and was, renamed Create (Krathwohl 2002). The structure of the cognitive process dimension of the Revised Bloom's Taxonomy is provided in Table 1 (Krathwohl 2002).
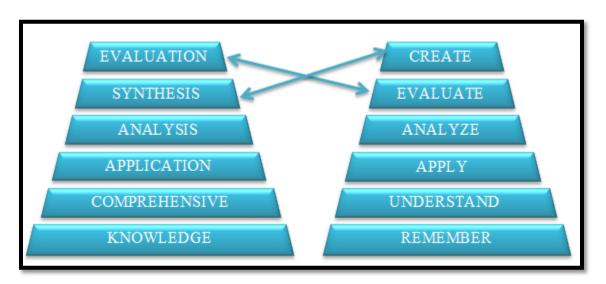
Figure 2: Comparison of Original and Revised Bloom's Taxonomy

Figure 2 provides a comparative view for a better understanding of the differences between the structures of the two versions.

Table 1: Structure of Cognitive Domain of Revised Taxonomy

Categories	Cognitive Processes and Definition
Remember	Retrieving relevant knowledge from long-term memory. *Recalling* *Recognizing*
Understand	Determining the meaning of instructional messages, including oral, written, and graphic communication. *Interpreting* *Exemplifying* *Classifying* *Summarizing* *Inferring* *Comparing* *Explaining*
Apply	Carrying out or using a procedure in a given situation. *Executing* *Implementing*
Analyze	Breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose *Differentiating* *Organizing* *Attributing*
Evaluate	Making judgments based on criteria and standards. *Checking* *Critiquing*
Create	Putting elements together to form a novel, coherent whole or making an original product. *Generating* *Planning*

2.2.2. Structural Changes

The original Bloom's taxonomy was a one-dimensional structure, which means in original Bloom's taxonomy knowledge categories represents both noun and verb aspects (Krathwohl 2002). The verb aspects of original Bloom's taxonomy knowledge category contain multiple activities like define, label, recognize, recall, and so on and the noun aspect was specified in knowledge's extensive subcategories. To overcome the mapping difficulty of these two aspects the revised taxonomy created a two-dimensional structure, providing each aspect, the noun and verb, a separate dimension.

In the Revised Bloom's taxonomy the noun aspects provide the basis for knowledge dimension and the verb aspects provide the basis for cognitive process dimension (Krathwohl 2002). This gives rise to a two dimensional table which is often termed 'The Taxonomy Table'. Table 2 illustrates the structural change in the revised Bloom's Taxonomy (Krathwohl 2002).

Table 2: Two-Dimensional Structure of Revised Taxonomy

Knowledge Dimension	Cognitive Process Dimension					
	Remember	*Understand*	*Apply*	*Analyze*	*Evaluate*	*Create*
Factual Knowledge						
Conceptual Knowledge						
Procedural Knowledge						
Meta-Cognitive Knowledge						

As shown in Table 2 the Knowledge Dimension would form the vertical axis of the table consisting of four levels named as Factual, Conceptual, Procedural, and Metacognitive knowledge, whereas the Cognitive Process Dimension would form the

horizontal axis of the table consisting of six levels named as Remember, Understand, Apply, Analyze, Evaluate, and Create (Forehand 2010). All the four Knowledge Dimension levels are further subdivided into two to three subcategories.

Table 3 provides the definition of four levels of the knowledge dimension (Krathwohl 2002). It also shows the subcategories belonging to each of the four levels of the knowledge dimension of the Revised Bloom's taxonomy.

Table 3: Structure of Knowledge Dimension of Revised Taxonomy

Structure of the Knowledge Dimension Level	
Categories	**Definition and Subcategories**
Factual Knowledge	The basic elements that learners must know in order to be acquainted with a discipline or solve problems in it. *Knowledge of terminology.* *Knowledge of specific details and elements.*
Conceptual Knowledge	The interrelationships among the basic elements within a larger structure that enable them to function together. *Knowledge of classification and categories.* *Knowledge of principles and generalizations.* *Knowledge of theories, models, and structures.*
Procedural Knowledge	The interrelationships among the basic elements within a larger structure that enable them to function together. *Knowledge of subject specific skill and algorithm.* *Knowledge of subject specific techniques and methods.* *Knowledge of criteria for determining when to use appropriate procedures.*
Metacognitive Knowledge	Knowledge of cognition in general as well as awareness and knowledge of one's own cognition. *Strategic knowledge.* *Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge.* *Self-Knowledge.*

The Cognitive Process Dimension's six levels are also subdivided into two to seven subcategories which we shown in Table 1 earlier in the section concerning

terminology changes in the Revised Taxonomy. For example, Remember is subdivided into the two categories, Recognizing and Recalling (Forehand 2010).

The Taxonomy Table can be used to classify objectives, activities and assessments. This provides a clear, concise and visual representation of course material which can help teacher in deciding where and how to improve the planning of curriculum (Krathwohl 2002).

2.2.3. Emphasis Changes

The original Bloom's taxonomy was mainly designed to address the needs of smaller group of audiences like educators and psychologists. Conversely, Bloom recognized that taxonomy was "unexpectedly" used by many other audiences which were never considered while designing the original taxonomy (Forehand 2010).

The revised version of the taxonomy was meant for addressing the needs of much broader audience. Emphasis is placed upon the use of the revised taxonomy as a tool for curriculum development, instructional design and preparing assessment plans (Forehand 2010).

2.2.4. Lower Order Thinking and Higher Order Thinking

The combination of first three levels, Remember, Understand, and Apply, of the Revised Bloom's taxonomy creates the lower order thinking skills. These levels combined, describe lower order thinking skills in order to help develop students fundamental knowledge of the subject being taught. On the other hand, Analyze, Evaluate, and Create combine to form the higher order thinking skills to represent categories that go beyond recalling and understanding fundamentals. The higher order thinking skills helps learner to move toward an abstract knowledge of the subject.

This paper will emphasize the importance of the lower order thinking skills as a basis to develop tutorial materials for teaching the basic concepts of Negative Selection Algorithm.

In order to target each level in lower order thinking skills of Revised Bloom's taxonomy the paper is divided into three specific parts:

- Tutorial contains terminologies with definitions, quizzes and assessments which will help learners in remembering the basic concepts of the various topics that fall under Negative Selection Algorithm.

- Diagrams and examples will help learners in having a clear understanding of the topics.

- An application called the ColorFinder has been designed and developed. The ColorFinder application will help learners in understanding how to apply different pattern recognition techniques in Negative Selection Algorithm.

3. INCORPORATING THE REMEMBER LEVEL IN TUTORIAL

Remembering is the first level or the lowest level in the cognitive process dimension in Revised Bloom's taxonomy. The main objective of this level involves recovering important information from long term memory. Remembering knowledge is important for meaningful learning and problem solving when that knowledge is used in more complex tasks (Mayer 2002). The Remember level consists of two cognitive processes: recognizing and recalling.

The importance of this level describes how the learner should be able to connect current material to long-term memory and retrieve relevant information (Mayer 2002). Learning items like quizzes, flash cards, assignments, and memory games are widely used by teachers to assist learners in achieving the cognitive process requirements of this level. Table 4 shows the taxonomy table for the remember level.

Table 4: Taxonomy Table for Remember Level

Knowledge Dimension	Cognitive Process Dimension					
	Remember	*Understand*	*Apply*	*Analyze*	*Evaluate*	*Create*
Factual Knowledge	*X*					
Conceptual Knowledge						
Procedural Knowledge						
Meta-Cognitive Knowledge						

The Remember level emphasizes the learners' ability to first be imparted with the knowledge of terminology associated with Negative Selection Algorithm, i.e. the factual knowledge associated with Negative Selection Algorithm. The basic elements of the

Negative Selection Algorithm need to be defined for the learner to be able to make the transfer of information to long-term memory and later retrieve this information from long-term memory.

3.1. Learning Material

Since the Remember level, the first level of learning is the building block of all subsequent levels of learning, it is very important that information is provided in this part that is not overwhelming for the learners. The material provided at this level should be simple and easy to remember for the learners.

The main objective of the learning material based on Remember level is that the learner has the knowledge and understanding of terminologies related to the Negative Selection Algorithm and can retrieve it from the long-term memory.

3.1.1. Terminology and Definitions

To accomplish the objectives of Remember level, the tutorial contains terminologies and definition related to the concepts of the Negative Selection Algorithm. The aim is to introduce learners to the various elements related to the topic. It also involves memorizing and recalling of the information by the learners.

This approach will help learners in understanding and gaining information about the factual knowledge related to the topic more easily and effectively as learners tend to react well to learning material which progresses in linear steps of increasing complexity.

The tutorial encloses a navigational panel on the left side of the website that contains links to all the terminologies related to the material. Each link contains the definition and required information about the specific topic related to the material. Figure 3 provides a screenshot of the website showing the navigational panel that contains links

to all the material related terminologies and the definition of Negative Selection Algorithm.
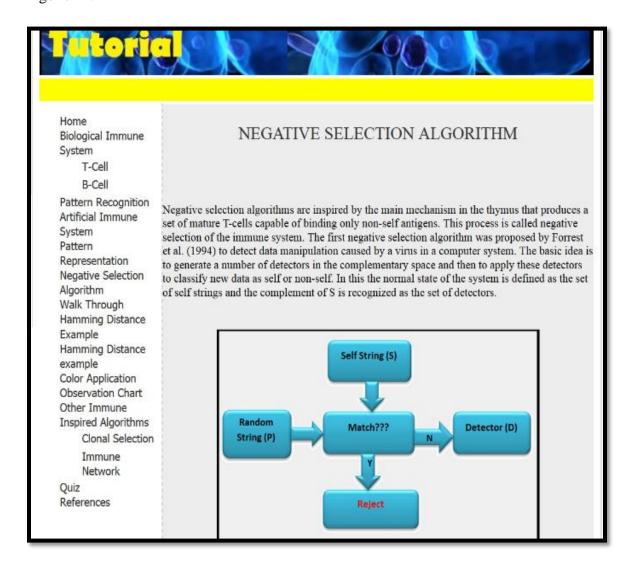
Figure 3: Screenshot Showing Algorithm Related Terminologies

3.1.2. Quizzes

Assessing learners in the Remember level can be done with the help of quizzes. Quizzes can help learners to recall the information they have learned during each level of the Revised Bloom's taxonomy.

The objective of assessing the Remember level is to find out whether learners are able to identify and retrieve information related to terminologies they have learned from the material presented on the tutorial website.

Several multiple choice quizzes have been included in the tutorial for learners to measure whether or not they have assimilated the knowledge.
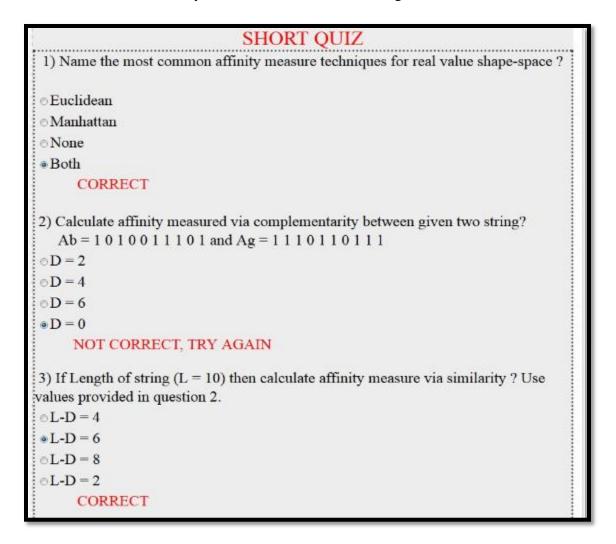
Figure 4: Screenshot of Short Quiz

These quizzes mainly focus on the activities of Remember level. Hence, by answering these quizzes learners get help in recollecting or recognizing the information.

Figure 4 provides a screenshot of short quiz presented in the tutorial, designed to focus on the activities of remembering.

The tutorial also contains a self-scored Knowledge Recap quiz. The main aim behind this quiz is to provide an assessment tool for both learners and teachers to assess how well the learners are able to retrieve or recall the information given in the tutorial.

4. INCORPORATING THE UNDERSTAND LEVEL IN TUTORIAL

Understanding is the second level in the cognitive process dimension in Revised Bloom's taxonomy. This level builds upon the Remember level. The main objective of this level is to help learners in comprehending the meaning of the material presented in Remember level. Learners understand concepts by building connections between future knowledge and their prior knowledge (Mayer 2002). To make learning efficient the emphasis is made on selecting appropriate educational activities and educational material for learners. At this stage it is assumed that the learners have the factual knowledge about the basic terms related to the Negative Selection Algorithm and are able to retrieve that knowledge from long-term memory. The Understand level involves explanation of the key concepts and theories related to the Negative Selection Algorithm using various examples, diagrams or graphics etc. Thus, on the knowledge dimension of the Taxonomy table, the Understand level falls under the category of conceptual knowledge. Table 5 shows the Taxonomy table for the Understand level.

Table 5: Taxonomy Table for Understand Level

Knowledge Dimension	Cognitive Process Dimension					
	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge						
Conceptual Knowledge		X				
Procedural Knowledge						
Meta-Cognitive Knowledge						

4.1.   Learning Material

The material provided for the Understand level should help the learners in understanding the basic concept related to the Negative Selection Algorithm. The explanation for this level should not be restricted to the definition of the terminologies; it should help learners to integrate incoming knowledge with existing schema and cognitive framework.

Learners better understand and remember information when theoretical concepts are associated with images or examples. Thus, for the Understand level the learning material includes both written and graphic explanation of concepts. The integration of the verbal and visual representation of information can help learns in better remembering and understanding of concept.

Along with theoretical and graphical representation, the learning material also contains a working example, called as Hamming Distance Example that would help in attaining a deeper understanding of the concepts of Negative Selection Algorithm.

4.1.1.   Use of Diagrams for Explaining the Concepts

The main objective here is to make learners understand the meaning of the basic elements of Negative Selection Algorithm. To make learning more efficient most of explanation is done using written material and diagrams. An effort has been made to keep the language of the written material simple so that learning is more easy and efficient.

To support theoretical explanation of the concept, material also includes pictorial representation of the concept. Picture or diagram can provide the learners with a better understanding of new concepts as majority of learners need to see information to learn it.

Figure 5 illustrates explanation of the concept of pattern recognition related to Biological Immune System using written material and a diagram. The written material will help learners to understand the conceptual knowledge related to the concept like what is pattern recognition, what are the various functions of antibody, and what is the meaning of region of complementarity whereas the diagram will be used to support the conceptual knowledge material. Hence, associating written material with pictures or diagram can help students make connections, understanding relationships and recalling related details.

PATTERN RECOGNITION

Pattern recognition in the immune system occurs at the molecular level. The cell receptor or the antibody molecule of B-cells and T-cells are of certain shape that has to be matched by the shape of the antigen. An antibody molecule has two main functions. The first function is to bind with an antigen, and the second is to perform effector function.

Figure 2: Recognition Via Region of Complementarity

As described in the Figure 2 recognition in the immune system is measured via a region of complementarity. The antigens and the cell receptors have to have complementary shapes so that they can bind together. This binding triggers the immune response which can be described as the reaction of the immune system against the pathogen that displays the antigen recognized.

Figure 5: The Concept of Pattern Recognition

4.1.2. Use of Examples for Explaining the Concepts

In addition to the diagrams, tutorial also includes multiple examples related to the material. These examples will help the learners in developing a better understanding of the information related to the concept of Negative Selection Algorithm.

The learning process becomes little easier for learners when description of a new concept or complex concept is done with use of examples as it help learners in visualizing the concept.

To support the concept of Negative Selection Algorithm the material also provides a working example on Hamming Distance, one of the pattern representation techniques of the Artificial Immune System. The working example demonstrates the logic behind the Negative Selection Algorithm by using Hamming Distance representation technique.

This type of working example allows learners to recall and reconnect to the previous knowledge gained on the subject. Thus, it helps in creating an interactive environment for learners.

The following sections will provide information on the language and on the code used in creating the Hamming Distance example.

4.1.2.1. C#

The programming language used for the scope of this assignment is C# (pronounced as "C sharp"). Specifically it is a programming language that is designed for building a variety of applications that run on the .NET framework (MSDN n.d.).

Choosing C# language as a choice for developing the working example helps in taking advantage of the .NET framework such as easy application development,

maintenance and security. Visual C# is an implementation of C# language by Microsoft (MSDN n.d.).

The trial version of Visual C# is available for free download from the Microsoft and a full version of visual C# is available for free download at Microsoft Dream Spark for Academic Institutions.

Learners do not need knowledge of Visual C# in order to work on the example of Hamming Distance.

In the tutorial, we have provided material that provides a step by step walk through for the learners to use the working example.

4.1.2.2.   Explanation of a Working Example on the Hamming Distance

The education material contains a step by step walk through, which will help learners in understanding the working of the Hamming Distance. This will help in demonstrating how the value of the affinity threshold in the Hamming Distance example can affect the recognition of string as self or non-self.

Hamming Distance is a pattern representation technique which can be used to evaluate the affinity between two attribute strings of length L.

To understand the Hamming Distance, consider two arbitrary strings Ag [1 0 1 1 0 0 0 1] and Ab [1 1 1 1 0 0 1 1]. By using the affinity value computed by comparing the two strings, will measure the affinity. If affinity is being measured via a complementarity between the two strings, then their affinity is equal to Hamming Distance (D) as illustrated in Figure 6.

On the other hand, similarity corresponds to affinity then their affinity is given by L-D (Ag, Ab).

$$Ag = [1\ 0\ 1\ 1\ 0\ 0\ 0\ 1]$$
$$Ab = [1\ 1\ 1\ 1\ 0\ 0\ 1\ 1]$$

Match (Ab, Ag):   0 1 0 0 0 0 1 0

Complementarity: $D(Ab, Ag) = \sum Match$ (Affinity = 2)

Similarity: $L - D(Ab, Ag)$ (Affinity = 6)

Where L is the string length and D is the hamming distance

Figure 6: Hamming Distance Between an Antigen and Antibody

The affinity between two molecules qualify for recognition and binding if their affinity is greater than or equal to a given threshold Ɛ, termed as affinity threshold, then the molecule is recognized otherwise not identified.

Figure 7 illustrates the use of affinity threshold. In this example the threshold value is set to 6 (Ɛ = 6). The affinity between Ab and Ag1 is Aff (Ab, Ag1) = 4 and affinity between Ab and Ag2 is Aff (Ab, Ag2) = 6. If affinity threshold Ɛ = 6 is used, then the antibody Ab recognizes Ag2, but does not recognize Ag1.

$$Ab = [1\ 1\ 1\ 1\ 0\ 0\ 1\ 1]$$
$$Ag_1 = [1\ 0\ 0\ 1\ 0\ 1\ 0\ 1]$$
$$Ag_2 = [1\ 0\ 1\ 1\ 0\ 0\ 0\ 1]$$

Match or D (Λb, Λg_1): 0 1 1 0 0 1 1 0
Match or D (Ab, Ag_2): 0 1 0 0 0 0 1 0

Affinity (L-D) (Ab, Ag_1): 8-4 = 4
Affinity (L-D) (Ab, Ag_2): 8-2 = 6

Figure 7: Use of Affinity Threshold Value ($\varepsilon = 6$)

The working example created on Hamming Distance using C# language uses the same concept described above. To use this example a user needs to set affinity threshold values by moving the slider (1 to 10) and then click on the button "FIND DETECTOR" (please see Figure 8 and Figure 9). The result shown by the example will depend on the threshold value set by the user.

Figure 9 shows the result window explaining the effect of setting affinity threshold value to 10 and Figure 9 helps a user understanding the working of the Hamming Distance technique by showing all the calculations done between the random string and set of self-strings.

Figure 8: Screenshot Showing the Result
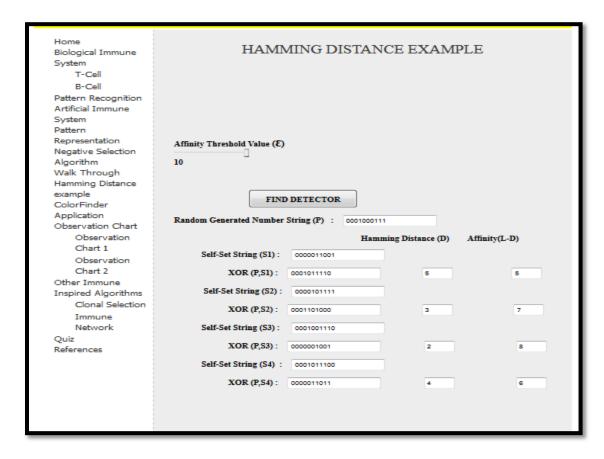
Figure 9: Calculation Between a Random String and Self-Strings

4.1.3. Assignments

To assess learners on the Understand level the tutorial contains assignments. Assignments can be used as an assessment tool by both learners and teachers to assess how well the learners are able to understand the concept explained in the tutorial.

Assignments provided at this level are specifically designed to assess the Understand level on pattern representation technique explained using a working example on Hamming Distance.

S.NO	Threshold Value ($\mathcal{E}$)	Match D(P,S1)	Affinity L-D (P,S1)	Match D(P,S2)	Affinity L-D (P,S2)	Match D(P,S3)	Affinity L-D (P,S3)	Match D(P,S4)	Affinity L-D (P,S4)	A<$\mathcal{E}$	A>=$\mathcal{E}$

OBSERVATIONS CHART

Figure 10: Screenshot of Observation Chart

An observation chart is also provided as a part of an assignment to assess learners on their understanding of the working example on Hamming Distance. The main purpose of an observation chart is that it is used to record the results of an experiment. Figure 10 show the screenshot of the observation chart used by learners to note down all the values

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and results observed in the Hamming Distance example on setting different affinity threshold value.

Having an assignment with observation chart focused on testing the learners understanding of the concepts will help find the learners completion up to the Understand level.

5. INCORPORATING THE APPLY LEVEL IN TUTORIAL

Apply is the third level in the cognitive process dimension in the Revised Bloom's taxonomy. It is closely related to procedural knowledge as it involves using procedures to perform exercises or solve problems. The Apply level consists of two cognitive processes: executing and implementing. Executing occurs when a student applies a procedure to a familiar task and implementing occurs when a student applies one or more procedures to an unfamiliar task (Mayer 2002).

The Apply level is based on the Understand level. After reaching an understanding of the different pattern representation techniques of the Artificial Immune system, learners can reinforce the knowledge learned in the Understand level by executing the provided the ColorFinder application.

Table 6 shows the Taxonomy table for Apply level.

Table 6: Taxonomy Table for Apply Level

Knowledge Dimension	Cognitive Process Dimension					
	Remember	*Understand*	*Apply*	*Analyze*	*Evaluate*	*Create*
Factual Knowledge						
Conceptual Knowledge						
Procedural Knowledge			**X**			
Meta-Cognitive Knowledge						

5.1. Learning Material

In order to achieve the learning outcomes of the Apply level, the ColorFinder application is introduced to the learners and a set of design tasks are provided for the learners to execute using the application.

5.1.1. The ColorFinder Application

In the Apply level, the ColorFinder application is used to find all the colors that are closely related to a color that is selected by the user. This application uses Euclidean Distance, one of the pattern representation techniques applied in Negative Selection Algorithm, to find all colors that are closely related to a color that is selected by the user from the color grid.

The main idea behind the application is to make learners understand how Negative Selection Algorithm can be applied to solve real world problems. The application will provide a more clear idea about self/ Non-Self discrimination concept using Euclidean distance method.

Though the learners are not required to study the implementation of the algorithm in the ColorFinder application, they need to understand the idea behind the algorithm.

An overview of the technologies used in creating the ColorFinder application is described below.

5.1.1.1. ASP.Net and Visual C#

Microsoft ASP.net is a server-side web application framework designed for web development to produce dynamic web pages (W3schools n.d.). It can be used on any Windows server to host web sites. ASP.net uses a compile language like C# to create a web application.

Asp.net with Visual C# has been used to create the complete tutorial website including the ColorFinder application. The target framework used for the application is .NET framework 4.0. There are several reasons of choosing Asp.net for developing the

tutorial website over other like it is easy to use, it provides better performance, and it creates safe and secured applications.

5.1.1.2.   SQL Server Database

The ColorFinder application uses SQL server 2008R2 database to store information related to all the colors like color name, RGB value, Hex code value etc. SQL is a standard language for accessing database. The prime function of SQL server as a database is to store and retrieve data as requested by other software applications.

SQL Database created for the ColorFinder application contains a table and couple of stored procedures. SQL Tables are used to store data records and stored procedure is a group of SQL statements compiled into a single execution plan.

In the ColorFinder application, a table has been used to store all the required information regarding colors and stored procedures that are used to retrieve required information from table regarding selected color or similar colors.

5.1.1.3.   Concept Behind the ColorFinder Application

The Euclidean Distance, the most common affinity measure technique for real-valued shape-spaces, is the main concept behind the ColorFinder application. It is one of the pattern representation technique used in Negative Selection Algorithm and it can be measured with:

$$D = \sqrt{\sum_{i=1}^{L} (\mathrm{Ab}_i - \mathrm{Ag}_i)^2}$$

All the color presented in the color grid provided by the application has a unique hexadecimal code (Hex Code) and RGB values (Red green Blue) assigned to it e.g. Black color hex code is #000000 and RGB value is 0, 0, 0.

Based on the RGB values belonging to respective colors the Euclidean Distance between two colors is calculated. In order to find all the colors that closely related to a user selected color, we will calculate the distance between the RGB values of the color selected by the user with the RGB values of the colors that are stored in the database. For example,

Selected Color (Ab): Hot Pink & RGB value: 255, 102, 153

1st Color from the table (Ag1): Mulberry Pink & RGB value: 204, 81, 122

2nd Color from the table (Ag2): Apple Blossom & RGB value: 178, 71, 71

Euclidean Distance (Ab, Ag1): Sqrt (Abs ((204 - 255) ^2 + Abs (81 - 102) ^2 + Abs (122 - 153) ^2)) = 2.64

Euclidean Distance (Ab, Ag2): Sqrt (Abs ((178 - 255) ^2 + Abs (71 - 102) ^2 + Abs (71 - 153) ^2)) = 6.16

If the calculated Euclidean distance between the user selected color and the color stored in the database is less than or equal to set affinity threshold value then the stored color is recognized as a closely related color to the color selected by the user and will be displayed as a output on the web page otherwise a message will appear on the screen stating that no similar color is found to the color selected by the user.

In the example explained above, if affinity threshold value set by user is 5 then the user selected color (Hot Pink / Ab) will recognize the 1st color from the table (Mulberry Pink / Ag1) as there calculated Euclidean Distance is less than then affinity threshold value (2.64 < 5) and not the 2nd color from the table (Apple Blossom / Ag2) as there calculated Euclidean distance is greater than then affinity threshold value (6.16>5).

The ColorFinder application uses a stored procedure to implement the same concept explained above to determine similar colors.

In the application, in order to find a closely related color to a user selected color, the user needs to pick a color from the color grid and click on the color finder button. Button will invoke an execution of the stored procedure which will calculate the Euclidean Distance between the color selected by the user and the available colors from the table and will output only those colors on the web application whose distance is less than or equal to the affinity value set by the user.

Figure 11 and Figure 12 shows screenshots of a stored procedure showing how the Euclidean distance is calculated between the picked colors and each color from table.


```
-- CURSOR ARE USED TO LOOP THROUGH THE TABLE &
-- IT ENABLES TRAVERSAL OVER THE RECORDS IN THE DATABASE.
      DECLARE db_cursor CURSOR FOR
        SELECT red,
               green,
               blue
        FROM   dbo.colornames

      OPEN db_cursor

      FETCH next FROM db_cursor INTO @Red, @Green, @Blue

      WHILE @@FETCH_STATUS = 0
        BEGIN
            SET @D = 0

 -- CALCULATING EUCLIDEAN DISTANCE BETWEEN RGB VALUE OF PICKED COLOR
(@URED,@UGREEN,@UBLUE) &
 -- RGB VALUE OF COLOR PICKED FROM COLOR TABLE (@RED,@GREEN,@BLUE).

            SET @D = Sqrt(Abs(( @Red - @URed )^2 + Abs(@Green - @UGreen)^2 +
                              Abs(@Blue - @UBlue)^2))

-- @D STORES THE CALCULATED RESULT AND COMPARE IT WITH THRESHOLD VALUE SET BY
USER
-- IF VALUE IS LESS SIMILAR COLOR IS FOUND.
            IF @D < @ThresholdValue
              BEGIN
                 SELECT @RGBHex = rgbhex,
                              @Color = ColorName
                 FROM   dbo.colornames
                 WHERE  red = @Red
                        AND green = @Green
                        AND blue = @Blue
```

Figure 11: Screenshot Showing Euclidean Calculation Part 1

```
-- SIMILAR COLOR INFORMATION IS STORED IN A TABLE
            INSERT INTO #temp_colorName
                        ([Color],
                                    [datavalue],
                        [rgbhexvalue])
            VALUES      ( @Color,
                                    @D,
                        @RGBHex);
        END

        FETCH next FROM db_cursor INTO @Red, @Green, @Blue
    END
```

Figure 12: Screenshot Showing Euclidean Calculation Part 2

5.1.1.4.   Working of the ColorFinder Application

Tutorial contains comprehensive material to guide learners in using the ColorFinder application. The material provides learners with a step by step execution guide of the application, which will help them in performing the assigned task properly and efficiently.

The ColorFinder application is divided into two parts. Figure 13 displays a screenshot showing the output screen of the first part of the application. This part of the application helps users by providing all the required information related to the color selected by the user such as color name, hex code and RGB value etc.
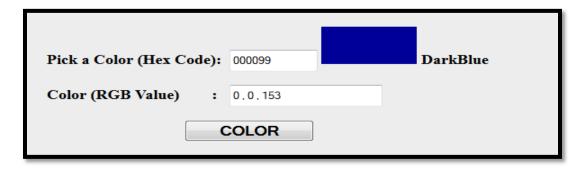

Pick a Color (Hex Code): 000099   **DarkBlue**

Color (RGB Value)   : 0.0.153

COLOR

Figure 13: The Colorfinder Application Showing Color Informations

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Figure 14 displays a screenshot showing the output screen of the second part of the ColorFinder application. This part of the application helps user in finding all the closely related colors to the color selected by the user on the basis of affinity threshold value set by the user.

Figure 14: The Colorfinder Application Displaying All Similar Colors

5.1.2. Assignments

To assess learners on the Apply level, the tutorial contains an assignment, which comprises of a set of task related to the execution of the ColorFinder application. Assignments provided at this level are specifically designed to assess learners understanding of the Apply level.

COLOR OBSERVATION CHART											
Color Picked	Threshold value (ϵ)	Similar Color 1	OB Value	Cal Value(D)	Similar Color 2	OB value	Cal Value(D)	Similar Color 3	OB Value	Cal Value(D)	D<= ϵ

Figure 15: Screenshot of Chart Use in the Colorfinder Application

For proper assessment of the learners, an observation chart is also included as a part of the assignment. The main purpose of the observation chart is to record all the observed results of the ColorFinder application. Figure 15 shows a screenshot of the observation chart used for recording all the observed result of the ColorFinder application. The purpose of having an assignment with observation chart focused on testing the learners understanding of the concepts will help the learners successfully achieve the Apply level.

6. CONCLUSION, LIMITATIONS AND FUTURE WORK

6.1. Conclusion

The primary goal of this paper was to develop a tutorial website explaining the basic concepts of Negative Selection Algorithm, to be used as a learning aid, by applying the principles of Bloom's revised taxonomy.

The educational objectives of revised Bloom's taxonomy have been successfully implemented in designing a structured learning framework for the tutorial. Structured learning, based on the level of difficulties, helps in creating educational material focused on learner's levels of understanding. This type of structured learning will help learners in achieving a more clear understanding of the concept.

Educational materials that will help learners in understanding the basic concepts of Negative Selection Algorithm has been designed and developed. The learning material developed target the lower order thinking skills of the Revised Bloom's taxonomy.

To increase the understanding of the learners, the educational material contains multiple diagrams and examples supporting the theoretical concepts related to Negative Selection Algorithm. The educational material also contains a working example and the ColorFinder application, helping learners in developing a deeper understanding of how to implement Negative Selection Algorithm concepts using different pattern representation techniques.

For the assessment of the learners at the various levels of learning, the education material contains multiple quizzes and assignments. Assessments at various stages of learning process play a very important role as they drive the way learning is processed.

6.2.   Limitation

The efficiency of the educational material provided in this paper has not been tested by actual learners in a classroom setting. The support of empirical evidence is required to evaluate the understanding of material by learners. The proper evaluation will help in understanding the benefits of developing educational material using revised Bloom's taxonomy.

The educational material has been presented as a web-based application; hence it is restricted to users who have access to internet connection.

6.3.   Future Work

This paper can be extended by incorporating higher order cognitive processes of the revised Bloom's taxonomy into existing learning material.

This paper can also include material describing detailed information about the other immune system inspired algorithms like Clonal Selection and Immune Network.

Application providing comparison between two pattern representation techniques can be developed. This type of application can help learners in understanding the importance of each pattern representation technique and there compatibility with other algorithms.

More applications can be added to describe the functionality and the use of other immune system inspired algorithms.

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