A TANGIBLE PROGRAMMING SOLUTION TO DEVELOP COMPUTATIONAL THINKING: PROGRAMMING BLOCK RECOGNITION USING CONVOLUTION NEURAL NETWORK

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Dedicated to my family and friends who supported me spiritually along the way

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ABSTRACT

Computational thinking development with the word-based programming language is not efficient enough for children in early age due to the complexity in format and syntax. Tangible programming is a good approach to develop computational thinking for children at early age. In this project, an algorithm is developed to localize and classify τ-block using Convolutional Neural Network (CNN) and a program is developed to determine the arrangement of τ-block and transfer the command sequentially to the τ-bot wirelessly. In this project, an approach known as Region-with Convolutional Neural Network (R-CNN) is used to develop the detection algorithm. The developed detection model is evaluated with several cases and the result is promising. The average accuracy of the detection with the developed model is 99.59%. Besides that, a web application is developed to simulate the overall system of the tangible programming tools using HTML, CSS and JavaScript.

ABSTRAK

Pembangunan pemikiran berkomputer dengan bahasa pengaturcaraan dasaran perkataan untuk kanak-kanak pada usia awal merupakan cara yang tidak berkesan disebabkan kerumitan format dan sintaks bahasa peraturcaraan. Pengaturcaraan ketara adalah sesuata kaedah yang berkesan demi membentuk permikiran berkomputer kepada kanak-kanak pada usia awal. Dalam projek ini, satu algoritma dalam rangkaian neural konvolusi telah dibinakan demi mengesankan dan mengelaskan τ-blok dalam sesuatu imej. Selain daripada itu, satu program juga telah diaturcarakan untuk menentukan susunan τ-blok dan menghantarkan susunan tersebut kepada τ-bot secara wayarles. Dalam projek ini, kaedah yang digunakan untuk membina algoritma pengesanan adalah *Region with Convolutional Neural Network* (R-CNN). Algoritma yang telah dibina juga dianalisis dengan beberapa kes dan keputusan analisis tersebut telah memberangsang. Purata ketepatan adalah setinggi 99.59%. Selain daripada itu, satu applikasi laman sesawang juga telah dibina untuk mensimulasikan system keseluruhan alat pengaturcaraan ketara dengan bahasa pengaturcaraan HTML, CSS dan JavaScript.

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LIST OF ABRREVIATIONS AND ACRONYMS

ConvNet	Convolutional Neural Network
CNN	Convolutional Neural Network
R-CNN	Region with Convolutional Neural Network
RFID	Radio-Frequency Identification
STEM	Science, Technology, Engineering, Mathematics
RGB	Red, Green, Blue
Maxpool	Max Pooling
ReLU	Rectified Linear Unit
FC	Fully Connected
DNN	Deep Neural Network
GPU	Graphics Processing Unit
ROI	Region of Interest
JSON	JavaScript Object Notation
AJAX	Asynchronous JavaScript And XML
IoT	Internet of Things

CHAPTER I

INTRODUCTION

This chapter generally described the overview of the project 'A Tangible Programming Solution to Develop Computational Thinking: Programming Block Recognition using Convolutional Neural Network'. This section consists of 4 subsections: introduction, objectives, problem statements and scope of work.

1.1 Project Overview

Computational thinking describes a set of thinking skills, habits, and approaches that are integral to solving complex problems using a computer. Computational thinking is important and it provokes analytical ability which is important particularly in Science, Technology, Engineering and Mathematics (STEM) education for children. Although computer programming has been identified as the common method to cultivate computational thinking, but the effectiveness of word-based programming language is much lower than tangible programming due to its complexity[1]. Tangible programming is to make programming become an activity that is accessible to the hands and minds of young children by making it more direct and less abstract.

Tangible programming language is introduced by Hideyuki Suzuki and Hiroshi Kato in year 1993 [2]–[4]. Tangible programming is a form of programming that carried

out with physical contactable objects that allow young children learn in better understanding and conceptual. In contrast, tangible programming is a considerable solution that allow young age to establish computational thinking and logical thinking.

In this project, a tangible programming solution (τ) is developed to expose computation thinking to young children. The overall system consists of three major components: τ-block, τ-bot and τ-maze. However, this project is focus on the algorithm development to help the τ-bot to recognize the dedicated command and arrangement of the τ-block by the user. By just connecting the τ-block, a series of actions is formed and to be executed by the τ-bot to solve the presented τ-maze problems. Both τ-bot and τ-maze allows a real-world interaction for the children instead of sitting behind large computer monitors and correcting programming syntax error.

This project is inspired by Google Inc. which launched their open source research project, Google Project Bloks, in June of year 2016. Although, this project used a different approach which is deep learning but both projects are heading toward a mutual goal, to provide tangible programming experiences to young age.

1.2 Objective

The objectives of the project are as followed:

i. To develop an algorithm to localize and classify τ-block using Convolutional Neural Network (CNN) approach.
ii. To develop a program to determine the arrangement of τ-block and transfer the command sequentially to the τ-bot wirelessly.

1.3 Problem Statement

Nowadays, most of the programming language in the market are word-based high level languages Each of these programming languages consist of different syntax and programming architecture. As example, to execute exponential operation. In object-oriented programming language, Python, the syntax is $\mathrm{C} = \mathrm{A} ** \mathrm{B}$ where as in procedural programming language, C language, the syntax is $\mathrm{C} = \mathrm{pow}(\mathrm{A}, \mathrm{B})$. These diversity makes no sense to an entry-level programmer, especially young age. Therefore, they are

indirectly focusing on the programming syntax rather than the problem solving and analytical ability.

Besides that, from the existing tangible programming tools, [2]–[4] most of the tangible programming blocks existed are built with microcontrollers and integrated circuits (ICs). In shorts, these projects faced a difficulty in function expansion. All the existed programming blocks need to be reprogrammed in order to compatible with the newly-add blocks.

1.4 Scope of Work

In this project, the block building area is defined as the area that covered by the vision of the USB webcam. The direct distance between the building area and the USB webcam is more than 0.5 meter and less than 1 meter. The USB webcam have specification of minimum resolution 480 x 360 pixels. The block detection and recognition algorithm is developed with MATLAB program and not deployed to any standalone microcontroller. The web server is developed using Node.js framework and hosted in the same machine as MATLAB server is held.

CHAPTER II

LITERATURE REVIEW

This chapter covered the all the studies regarding the project. In this chapter, the previous work and project is studied and critically analyst the effort of the pioneer. The chapter is divided into two major section: tangible programming and convolutional neural network, the backbone of object detection and recognition. The technologies available to for tangible programming realization is studied and reviewed. The basic working principle of the artificial intelligence, specifically convolutional neural network is also covered in this chapter. This chapter is results from studies of knowledge from journals, books, internet resources etc.

2.1 Tangible Programming

Tangible programming is a type of interactive programming tools that allows users to have physical interaction and construct problem based solver [2]. Tangible programming is actually a term proposed by two Japanese researchers, Suzuki and Kato, who developed the system ‘Algoblock’ [3].

Figure 2.1: A group of kids interacting with Algoblock.

Figure 2.1: A group of kids interacting with Algoblock. Figure 2.1 displayed three primary school children building the command program using the Algoblock. Each of the block is interconnected to the previous and next building block and sent the command to the computer. The computer program respond the building block's instructions built.

2.1.1 Implementation Technologies

This subsection explained what technology can be used to implement tangible programming in life. Three different technologies are covered in the following section: RFID, computer vision and microcontroller [5]. This subsection also explained how these technologies can revolute the market of tangible programming.

2.1.1.1 Radio Frequency Identification (RFID)

RFID is a wireless technology which enable to detect the presence of the object with registered tag. RFID tag consists of two type: active or passive. An active tag has a battery to power up the device and periodically transmits the signal representing its identity. A passive tag is cheaper because it does not require a battery to operate the tag. Instead, passive RFID tag required radio energy from a RFID reader to power up the tag and transmit tag identity signal.

Typically, most of the RFID-based tangible user interface employ passive and cheap RFID tags [5]. This is because of each item or element in the entire system, from base to every single block, required a RFID tag. In other words, the RFID reader required to pick up multiple signals at the same time. It might prone to signal overlapping and tag collision. This is a drawback of RFID based user interface which is not suitable to be implement in the τ-block due to multiple blocks is required to be detect.

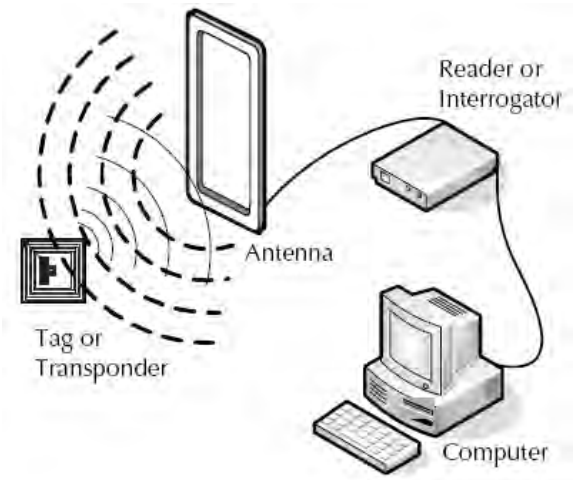

Figure 2.2: The working principle of RFID technologies.

Figure 2.2 showed the graphical working principle of RFID. As the antenna need to pick up the signal transmitted from the tag or transponder, hence multiple tag in the effective radius of the antenna can be pick up. Hence, this approach is not applicable in this project.

2.1.1.2 Computer Vision

Computer vision is a type of computer application that made computer to gain high-level understanding to images. The final aim in computer vision is to make computer can operate and complete task as human-being do [6]. Traditionally, computer vision is completed in conventional image processing method. Methods like acquisition, pre-processing, feature extraction, detection or segmentation, high-level processing etc.

The process of produce a robust algorithm using conventional image processing is time-consuming. Handcrafted features extraction filter design take very large portion of

time to fully cover and consider different lighting condition. The lighting condition can affect the robustness of the algorithm in such way. Computer represent image in digital form which transform every pixel to a range of number between 0 to 255 (3 different channel in RGB model). Different lighting condition will affect the pixel values in an image. Therefore, different condition must consider and encounter.

With the effort by Yann LeCun in convolutional neural network, [7] a huge step forward in computer vision has been made. Feature extraction can be done automatically with process such as 2-D convolution, gradient descent, backpropagation etc. The details about convolutional neural network will be discuss in Section 2.2.

2.1.1.3 Microcontrollers, Sensors and Actuators

Microcontroller-based tangible user interface is the most frequent approach that used in the previous work. For example, AlgoBlock by H. Suzuki and H. Kato and Tangible Programming Bricks by T. McNerney [2], [3]. These previous works used microcontroller and integrated circuit (IC) to communicate with the computer to display the output of the constructed bricks [8]. Signal is picked up by the sensors and processed by the microcontroller. Bricks can communicate to each other and processed by the central node.

However, in term of product sustainability, whenever a new functional brick is required to add into the system, the other existed bricks required to be reprogrammed to make the newly added functional brick compatible to the existed system. This is difficult to achieve and almost impossible to be done for a commercialized product.

2.1.1.4 Previous Work

'Algoblock', developed by the Japanese researchers, who brought the term 'tangible programming' to the community, is a pioneering work in tangible programming. This project aimed to develop collaborative problem solving skill among young age. The system consists of large computational building blocks (15 x 15 x 15 cm^3) to guide the virtual submarine to reach its goal on the computer [2].