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THE DEVELOPMENT OF OBJECT DETECTION SYSTEM FOR INDUSTRIAL LINAC PROJECT AT SLRI

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Abstract

The prototype of linear accelerator for industrial applications has been under development at Synchrotron Light Research Institute (SLRI). The primary purpose of this new project is for food irradiation application using x-ray. For efficient beam scanning purpose, a real-time object detection system has been developed by using a machine vision USB camera. The software has been developed by using OpenCV which is run on an embedded system platform. The result of the image analysis algorithm is used to control a beam scanning magnet system of the linac in real-time. The embedded system, both hardware selection and software design, running the object detection task will be described in this paper.

INTRODUCTION

Food irradiation is the process of exposing food and food packaging to ionizing radiation, such as from gamma rays, x-rays, or electron beams, without direct contact to the source of the energy (radiation) capable of freeing electrons from their atomic bonds (ionization) in the targeted food [1, 2]. Accelerator-based system is one of the platforms that can provide a good facility for food irradiation. There are three key elements of the accelerator-based system to be considered, an accelerator system to deliver the energetic beam, a scanning system to provide uniform beam coverage of the product, and a material handling system that moves the product through the beam in a precisely controlled manner [3].

Synchrotron Light Research Institute (SLRI) has been developing the prototype of linear accelerator for industrial applications. One of the main purposes of this new project is for food irradiation application, which is globally utilized during recent years. This proposed project is targeted to increase the availability of the low-cost machines for domestic uses since agricultural products are Thailand's primary economy.

In the prototype of this irradiation facility there are several main components for each key element. The accelerator system consists of an electron linear accelerating structure of the S-band standing wave type, a 3.1 MW magnetron driven by a solid-state modulator, and a hot-cathode electron gun. The scanning system comprises a beam scanning magnet and a scanning horn. The material handling system is composed of conveyor system, motor drive system, and electronic control system. The diagram of this accelerator-based irradiation facility prototype can be shown in Fig. 1.

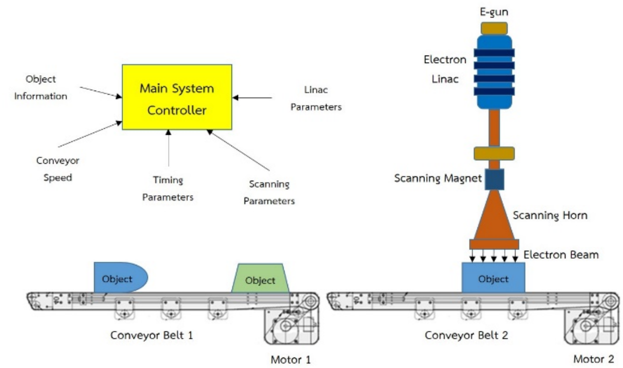

Figure 1: A prototype of accelerator-based irradiation facility.

The primary goal of irradiation facility is to deliver the specified amount of the required radiation to the products without unnecessary, wasteful, and excessive dose. Thus, monitoring and control of the process parameters and the information of objects to be scanned are important. Applying machine vision system to the irradiation facility is one way to detect object information on the conveyor belt. This system can support the material handling system in order to improve the efficiency of the facility.

This paper describes a real-time object detection system developed for this irradiation facility. The system design with selected hardware and image analysis algorithm software is described in the next section. Result and discussion, together with the relationship to the beam scanning magnet control system, are presented in the following section. Concluding remark is discussed in the final section.

SYSTEM DESIGN

This section describes the brief description of system design, both hardware and software, for object detection system developed in this project. In order to complete the object detection purpose, we apply machine vision to the material handling system. Figure 2 shows a diagram of the designed irradiation facility with the object detection system. It also shows scanning magnet controller and motion controllers necessary to be implemented in the system in order to complete all tasks to operate the facility.

Hardware

Typical machine vision system consists of lighting, lenses, vision processing unit, image sensor, and communication between sensor and processing unit. For this prototype, we consider choosing vision camera as an image sensor and lenses, with appropriate resolution and interface, for test and installation. Lighting is left for consideration once the system is installed. For processing unit, a

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single board computer is selected for embedded hardware running image analysis algorithm. A brief technical specification of the vision camera is listed in Table 1.

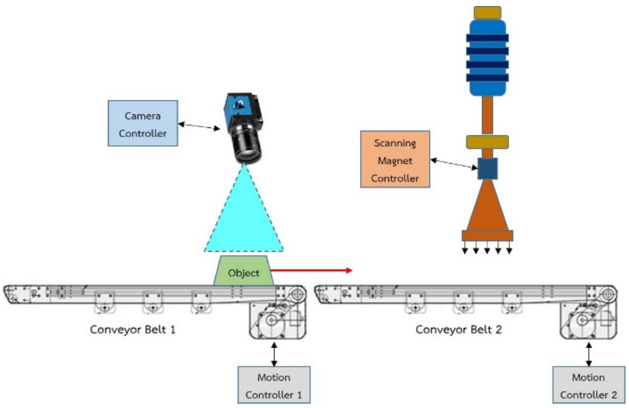

Figure 2: Irradiation facility with object detection system and controllers.

Table 1: Vision Camera Specifications

Definition	Value/Type
Resolution [pixels]	720 x 540
Frame Rate [fps]	70
Acquisition Mode	Continuous
Interface	USB 3.1

Figure 3: Vision camera, single board computer, and conveyor belt of the prototype.

Software

Object detection software is implemented using Visual C# running OpenCV algorithms with some digital image processing techniques, which is typical for image analysis and processing software. The main concepts of the software design are:

- Detecting boundaries of an object moving on the conveyor belt
- Drawing appropriate contour around an object
- Splitting image of an object into vertical slices (perpendicular to moving direction of the conveyor belt)
- Finding the top and bottom parts of the object in each slice of the image in order to find the object size

An example of the output obtained from running the soft-ware is shown in Fig. 4.

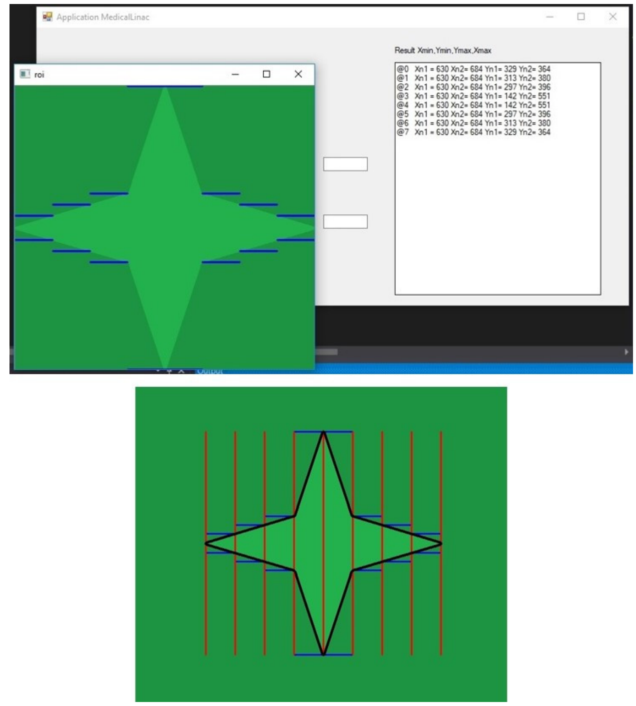

Figure 4: Output of the software with sample object.

RESULT AND DISCUSSION

The hardware and software of the system are tested with the conveyor belt used in this prototype. The chosen object is placed in the middle of the conveyor and the image is captured. The top left picture shown in Fig. 5 shows the original image of the star-shaped object. The algorithm converts the original image into grayscale and binary im-ages illustrated in the top right and the bottom left pictures, respectively. The bottom right picture shows how the con-tour detection, image splitting, and object size detection are performed. Figure 6 shows the GUI for software settings and reporting the results of the object size detection. Since the color of a transporting belt of the conveyor is uniformly distributed with a green color, the result of this software design is very satisfactory.

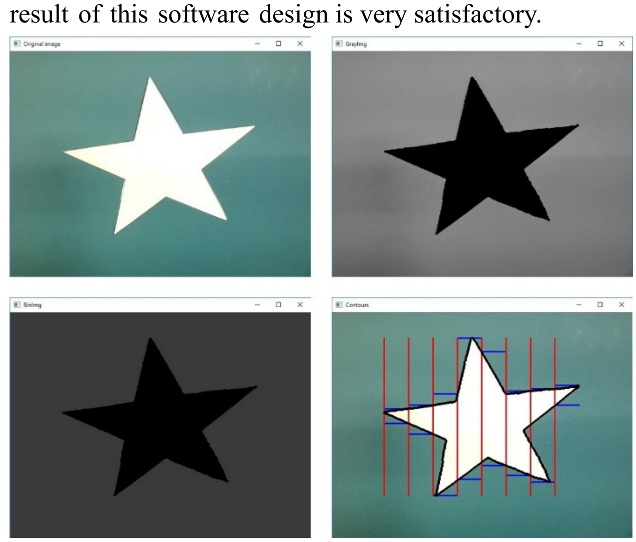

Figure 5: Hardware and software test.

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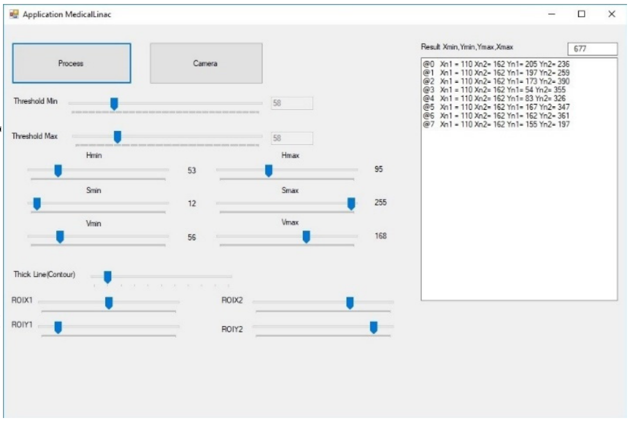

Figure 6: GUI for software settings and reporting results.

Consider the beam scanning magnet of the scanning system. The beam with uniformly distributed output at the output of the scanning horn is desired in scanning the product or object to be irradiated. The time-dependent magnetic field deflection of the beam is very important characteristics that is required to control the scanning magnet. As a result, if the object has rectangular shape, the time varying magnetic field strength shown in Fig. 7 is typically de-sired to give the scanning action that can be used to effec-tively spread the beam across the object [3]. The detail of how to control the magnetic field using current control is not discussed in this paper.

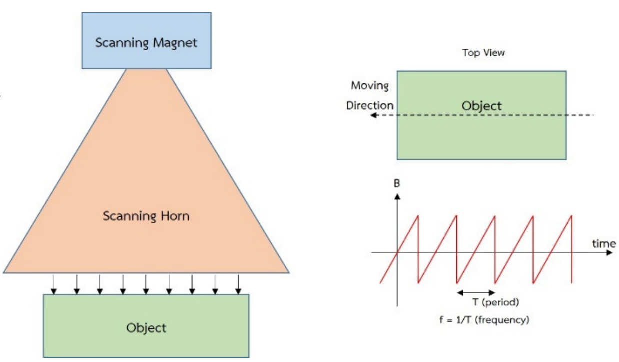

Figure 7: Beam scanning magnet system and time-dependent variation of the magnetic field.

To control the irradiation to the product with accurate amount of dose without wasteful, excessive dose and without excessive energy, the resulting time-dependent magnetic field for each scanned object is expected to be controlled effectively. Applying this currently developed object detection system to the prototype is prospectively proposed. Appropriate time-dependent magnetic field output that should be generated for the tested object is shown in Fig. 8. The object size for each splitted image (top and bottom parts in vertical axis), the number of splitted images (scanning magnet frequency-dependent), and boundary of the object (along moving direction) are outputs of the ob-ject detection system. This magnetic field variation is ex-pected to provide full coverage for irradiation. Neverthe-less, other process parameters and control systems are fur-ther needed for real-time operation of the prototype such as scanning magnet control and conveyor belt velocity control. Motion control system of the prototype is discussed in [4].

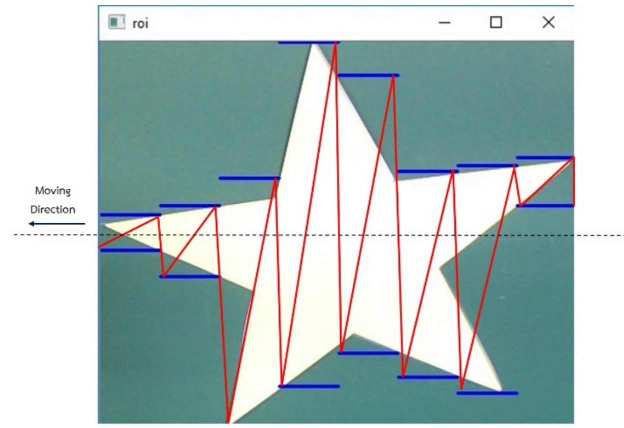

Figure 8: Expected time-dependent magnetic field for the tested object.

CONCLUSION

The proposed real-time object detection system is developed for the prototype of linear accelerator for industrial applications, specifically for food irradiation application using x-ray. The primary purpose of the system is to provide detailed information of the object or product to be scanned in order to generate a precise time-dependent magnetic field shape out of the scanning magnet. The system design, both hardware and software, is described in detail. The output of the image analysis algorithm is achieved as desired. This result will be further applied as the input to the beam scanning magnet system in order to control magnetic field efficiently. Moreover, the system is expected to be used for real-time motion control of the material handling system of the project.

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