A Cloud-Based Pectus Bar Designer Software to Enhance Pectus Excavatum Surgeries

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***Abstract*—Pectus excavatum is the condition of a person's chest. This article introduces a cloud-based software-supported approach using medical images of the patient instead of a traditional approach to this anomaly. In this way, it is aimed to shorten the operation time and improve the quality of life of the patient.**

***Keywords*—cloud based software, pectus excavatum, data processing, medical imaging.**

I. Introduction

In this paper, it is aimed to design a cloud-based software that uses medical images (CT or MRI) of the pectus excavatum patients to improve the custom based shaping of the metal bars (pectus bars) used in the treatment of a rib cage anomaly while decreasing production time and overall cost and increasing flexibility and life quality of the patient.

Cloud computing is a remote service-oriented architecture in which various used defined software is involved to execute numerous computation processes and data services. In this concept, infrastructure may not be accessible physically by the end-user. Accordingly, users should be able to configure the system remotely. The cloud computing concept enhances accessibility, scalability and usability of distributed resources [1]. These systems have various advantages over local systems. However, an online structure is generally faces with serious security problems. Recently, governments have started to enact laws on the protection of personal data, but in order for them to be applicable, individuals need to be made aware of and the systems should take the necessary security measures. In order to solve hack and virus or access control problems, institutions and individuals have to establish control systems and take dynamic protection actions apart from patching system vulnerabilities [2].

Inward grows in sternum or breastbone is named as Pectus excavatum. This disorder can be detected during infancy and can significantly deteriorate during adolescence. Affected individuals may experience physical symptoms and psychological disturbances such as dyspnea and chest pain. Surgery offers a successful way to improve deformity, alleviate symptoms and improve the quality of life for those affected by moderate to severe cases [3]. Although pectus excavatum is usually evident in breast examination, various tests can be performed to determine the effect of the condition on the heart and lungs. Among these, medical imaging, such as chest X-ray and computed tomography (CT) torso scan (an example shown in "Fig. 1"), shows how much compression of the heart and lungs [3].

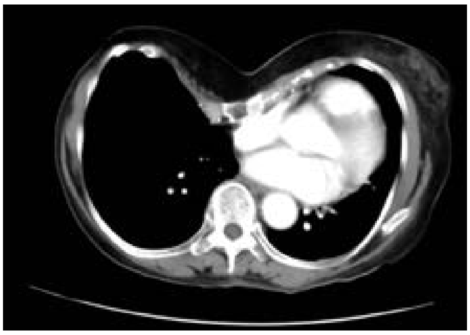

Fig. 1: A slice of CT image that shows pectus excavatum [4]

II. Literature

In literature, the standard procedure is described as elevating the sternum with a retrosternal metallic bar placed under thoracoscopic control, the procedure enables effective correction without the need for intensive costal cartilage resection or sternal osteotomy based on thorax flexibility in younger subjects. The surgical procedure of the procedure consists of identifying the most exploded area on the left and right side of the sternum, and the outward cosmic line, preforming the

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linear metallic rod using flexible stencils for modulating bar length and curve shape. A slight over-correction of the sternum is intended when the stem is modulated [5]. Today, this procedure has become the standard, but the devices and methods used as standard have lost their technological current. The surgical procedure is usually made on the basis of the principle of bending the actual bar as a result of the measurements taken with the soft metal called the template. Naoto Matsuo et. al stated that they had been observing the results of the treatment on a 3D printed model of the patients chest by reason of procedure can result in with some complications such as wound infection and recurrence [6]. Moreover, Kragten et. al reports that the physicians inability to access radiology reports such as X-Ray and CT directly and deciding only by looking at radiology reports may led the measurements to be incorrect [7]. Additionally, researchers developing custom 3D printed bars ("Fig. 2") with special coating material that equipped with pressure sensors to remove adverse effects of current procedure [8].

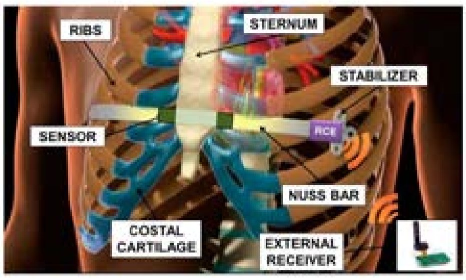

Fig. 2: Custom pectus bar equipped with sensors [8].

III. Problem Understanding

As summarized in the literature review, researchers have introduced some new methods to improve the process rather than the current procedure. In this context, this study aimed to develop a cloud-based software for physicians to improve the pectus bar placement process. By means of software, physicians can draw a required bar shape on a sagittal and transverse plane to correct the sternum and rib cage based on CT images of DICOM standard which is an international medical imaging standard. The software also will be able to load DICOM images, read metadata of patient and make various length measurements. As an output, the physician will have the position coordinate array in the X-Y plane of the bar.

IV. Method

In this paper we used quantitative methods with a group consist of an operating surgeon, an associate professor specializing in instrumentation in a biomedical engineering and two graduate students with the bachelors degree in control engineering whose professions and roles are given in Table I. We conducted a focus group study with professionals in order to understand the need more clearly.

TABLE I: Project Members

Profession	Age	Role
Assoc. Prof. Biomedical Engineering	37	Consultant
Operator Doctor	51	Consultant
Control Engineer	25	Software Design and Development
Control Engineer	26	Software Design and Development

A. *Quantitative Methods*

1) Structured Observation: Structural observation is a method based on data collection of participants and researchers [9]. Within the scope of this study, we have decided on our road map by organizing some observations and surveys on how the bar is shaped by the surgeons.
2) Interview: Interviews are crucial to reveal the implicit knowledge of field experts. Various interview methods are used in order to reveal the thoughts and experiences of the experts. These interviewing methods are divided into three main branches: Structured, semi-structured and unstructured. We mainly used semi-structured and unstructured interview data which are based on key questions and free speech respectively [10].
3) Participatory Action Research: The participatory action research methodology can be summarized in three main parts: examine, think and act [11]. This method recommends that researchers participate directly in the project environment. We not only examined the operation of the program, but also collected feedback and provided improvements on the system to ensure the continuity of the system [12].

V. Design

The design process consists of several layers. The first part of the system is the backend layer. The Backend layer is responsible for loading and processing DICOM standard images. The user first uploads the DICOM format images from the display device to the system and sends it to Python based platform. The platform reads the metadata and images in order, arranges the images in the sagittal and transverse planes of the patient and sends them to the frontend to be shown to the physician. On the frontend side (shown in "Fig. 4") the image meets the canvas structure and is written into the image canvas via the javascript language. In javascript side there is also a library formed for drawing operations. The drawing library follows the movement of each mouse on the canvas and on mouse click action user places the start and end points ("Fig. 5" and "Fig. 6") of a Bezier curve, which is a curve type commonly used in computer application consist of 4 components: start, end and two control points(M indicates start-end points, C indicates control points and numbers indicates coordinates in "Fig. 3") [13].

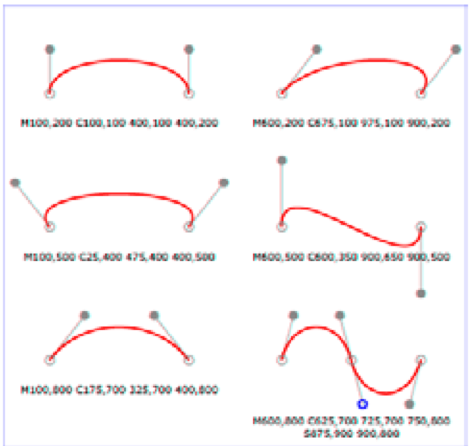

Fig. 3: Various Bezier Curves [13].

Fig. 4: Overall view of the application.

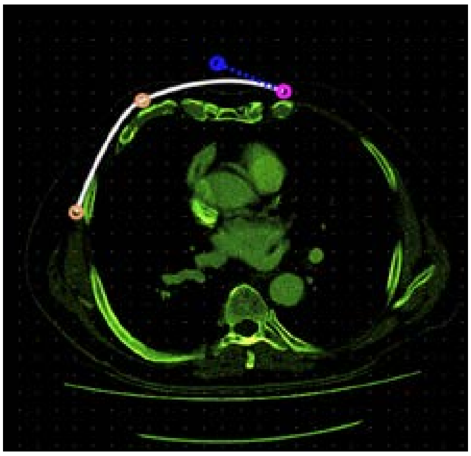

Fig. 6: Bezier Curve Creation.

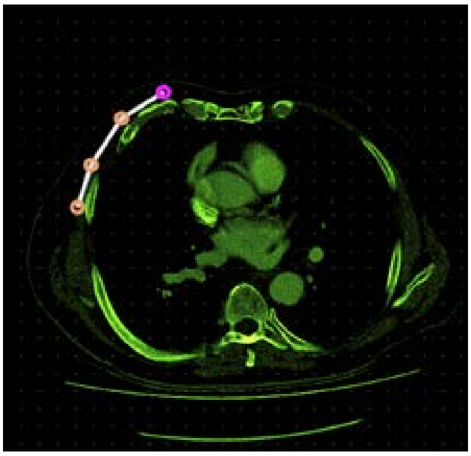

Fig. 5: Drawing Screen.

At the beginning control points are determined automatically but physicians can adjust the curvature freely. Due to the nature of the canvas structure, the entire canvas should be erased and redrawn for each change in the curve. However, this situation does not cause any operation delay thanks to todays computers high processing power. When the curve is considered suitable for the treatment by the physician, the program outputs the Cartesian coordinates of the customized curve for the pectus bar bending system. The system resolution is supported up to 1 millimeter, and the feedback from the doctors supports that this resolution is adequate. Moreover, system saves the output both locally and remotely on demand for extended flexibility. Next, the cloud system enables physicians to keep patients history and provides comparative and easy access to data on patient progress and past decisions on other cases. What is more, program can calculate the actual bar length by using pixel spacing attribute, which is the actual length between two pixels described in the DICOM standard, to calculate the bar length that fit for the patient.

VI. Findings

Within the scope of this work, we have gathered enough data to design the architecture of this work. It is a difficult process because of being a process of converting implicit knowledge of people into explicit knowledge. In this section we will cover the domain expert opinions about the system. The following paragraph includes the evaluation of the existing methodology and new the software assisted system commented by the surgeons.

The current system consists of complex operations. Firstly, the measure taken from the patient is examined by the doctors and their suitability is tested. Then, at the time of surgery, doctors try to shape the bar by means of devices with primitive technology according to today's conditions (an example of current manual bending device given in "Fig. 7"). The shaped bar is then placed under the rib cage of the patient under an operation. If there is not enough elevation, the doctor removes and reshapes the bar. This procedure is repeated until the shape of the rib cage is correct. However, this type of surgery can be painful for the patient and prolongs the healing process. The system we propose is aimed at shaping a pectus bar with pre-operative accuracy over the patient's existing medical images. In this way, the time spent for the operation will be shortened and the quality of life of the patient will increase. In addition, shortened operation planning time will allow doctors to have more time to perform surgery and eventually cause improvements in health system. Besides, surgeons will have more time to pay attention to fine adjustment of the implant before the operation.

Fig. 7: The current bending device [14].

VII. Conclusion

Cloud based pectus surgery planning software was developed that allows the surgeon to design the final geometry of the pectus bar and also determine the physical dimensions of the pectus bar to achieve desired final shape. The software we develop, provides various benefits to government organizations, citizens and doctors whose are the stakeholders. Finally, these and similar systems should be implemented by the government as a requirement of the era of digitalization.

VIII. Future Works

Cloud-based systems are becoming increasingly common today. However, data confidentiality and protection of personal data are obstacles that must be overcome. This makes data collection difficult. However, it is more accurate and safer to maintain such data by some institutions that have large data centers, such as the ministry of health, which comply with various data security protocols. It is also important to have such software improvements at this time when access to data is very easy and all systems are online.

The system is initially designed to determine the bar length and shape with machine learning. However, since the amount of data required for machine learning is not yet provided, this part is left to the following stages. In the following period multi center clinical studies will be conducted using this software. It will help to gain knowledge for implementation of various supervised machine learning algorithms. In this way, system outputs are expected to be further improved.

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