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A NOVEL APPROACH FOR CARRYING OUT DENTAL ACTIVITIES SUCH AS DRILLING AND FILLING USING AUTOMATED ROBOTS

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Abstract- Robots aren't new to healthcare. But in the field of dentistry, robots are yet to reach their next step. It happens that most of the time; people visit dental hospitals for minor operations such as drilling and filling. For at least in our country, this case seams to appear regularly. This paper presents a new approach for carrying out the basic dental activities like drilling and filling using automated robots. In the aim of improving the quality time spent by the busy dentists and to get more accurate dental operation, this idea helps in performing the basic dental activities (drilling and filling). The prototype for this idea is carried out using Dexter ER2 Robotic Arm for performing dental activities and image processing for finding the cavities in the tooth. The image processing is carried out using the picture captured from the camera, before and after the operation. The result of the working prototype shows that, it is feasible to carry out drilling and filling using robotic arms in dentistry.

Index terms- Dental, Robotics, Image Processing And Precision.

I. INTRODUCTION

A Robot is a machine that is made to execute many automated operations with good speed and precision. There are different types of robots that are classified based on their performance and operations. The different robots are Industrial robots, Household robots, Medical robots, Service robots, Military robots, Entertainment robots, competition robots and space robots. Depending upon the location and kinematics, the robots can be classified as Stationary Robots (Commonly used in Medical field) , Wheeled robots, Legged robots, Swimming robots, Flying robots, Mobile spherical robots, Swarm robots, etc. Robots can work with or without the attention of humans. The self supported Autonomous robots relay on their own logic. These robots decide the action to be performed based on the surroundings and feedback. Generally autonomous robots learn to avoid obstacle and proceed to achieve the best result.

II. MEDICAL ROBOTS

Medical Robots are used in medical institutions and for performing major operations. These robots are often called as surgery robots. Advanced medical robots do not exist only in movies; they also came to healthcare providing lot of benefits. These medical robots can support the doctors with its high accuracy and precision and act as a good assistant. There are six types of robots. They are Surgical robots, Rehabilitation robots, Biorobots, Telepresence robots, Pharmacy automation and Disinfection robot. Surgical operations with the help of great precision are being carried out in medical field using surgical robots. Remote surgery is possible with this type of medical robot where a human surgeon is physically absent. The rehabilitation robots help the infirm, elderly people and the people with dysfunction of body parts and will be very useful for training and therapy. Biorobots uses biological characteristics in living organisms as the knowledge base for developing new medical robot designs. These robots are also used to measure the state of disease and to track the body conditions. The Telepresence robots help the medical professionals to move, look around and communicate with the patients in the remote locations. The pharmacy automation is very helpful to dispense oral solids in a retail pharmacy setting. The mechanical process of handling and distributing medications helps in tracking and updating customer information in database. The disinfection robots has the capability to disinfect the surrounding area in few minutes using ultra violet light technology.

In 1985, the PUMA 650 was the first surgical robot, that was initially used in neurosurgical biopsies and then it was used for prostate surgery. The 1990s have witnessed the so called laparoscopic revolution in which many operations were adapted from the traditional open surgery to the minimal access technique. After that, in the late 1990s saw a great deal of work in the area of Telesurgery and Telepresence surgery. The wounded soldiers were treated with the help of these robots on a battlefield. With the surgical developments, there has been tremendous progress in the area of prosthetic limbs. Prosthetic knees with the help of microprocessors began reaching the market in 1993. Then Adaptive Prosthesis combined microprocessors with hydraulic and pneumatic helps to achieve natural walking ability in accordance to the changes in walking speed. While the concept of robotics began as science fiction, today robots play important roles in day to day life. Hospitals are using robot-assisted surgery as a marketing tool to attract patients and surgeons, as well as support from the government, insurance companies, and other payers. Some of the major advances that have taken place in the surgical field

include options such as remote surgery, minimally invasive surgery and unmanned surgery. The robot assisted surgery offers many advantages. They are precision, smaller incisions, reduced blood loss, decreased pain, and faster healing time. The introduction of robots have revolutionized the medical and surgical fields wherein the doctors have the advantage of treating higher number of patients while the patients have the benefits of minimal time spent in the hospital. All in all, it results in faster treatment and better recovery rate.

III. ROBOTS IN DENTISTRY

Robots are not used widely in dentistry, when compared to the other areas in medical field. Nowadays many robotically assisted dental surgical systems are available in dental hospitals. It consists of two main parts. They are preoperative planning and surgical navigation. In the preoperative planning system, the surgeons have a different view based on CT data of the patient that are provided. The surgical navigation system uses an infrared light based navigation camera to locate the correct position of the surgical device. These types of robots help the surgeon in achieving good accuracy, designed to continuously track the movements of the patient and also have control over the drill when the dentist is advancing towards the tissue. The system will continuously monitor the patient to avoid possible mistakes by the surgeon. With the help of monitoring and the real time 3D graphics, the procedure for the dental surgery can be planned immediately and executed in the dental clinic without any delay. In Japan, dental robots that act like real patient are very useful for the dental students, during their training.
These robots react differently and create alerts, when the students are doing false operations. It is equipped with about different reactions that simulate accidents that can occur during treatment, such as reaction to pain, vomiting reflex, cough reflex and irregular pulse. The robots in dentistry have extended to perform root canal treatment, robotic implant placement to even robotic microsurgery but all of these operations are not fully automated. Some manual robots are also there in dental field, where the dentist controls the robot equipments manually by using the control interface of the equipments in the computer. The benefits of using these robots are generally a safer procedure for the dentists for more precise drilling, and faster healing times. To help the root canal surgery, a visually guided robotic system placed on the teeth within patient's mouth, while a robotic controller and a root canal image processor helps the dentist to perform the operation. These robots could the future of dentistry and this may take the place of dental assistant. Diagnoses could be performed by these robots and they can give short solution too in a short period of time.

IV. PROBLEMS IN DENTISTRY

The American Academy of Implant Dentistry estimates that 10% of American dentists perform dental implant surgery for approximately three million patients per year and this number is rapidly expanding. According to the American Dental Association, about 120 million American adults are having tooth problems and missing at least one tooth. Besides these problems, the number of patients with cavity problems is increasing day by day and is above the other problems. So, the people have to wait in queue for both normal dental surgeries like drilling, filling and major surgeries like root canals and dental implantations.
Every year more dental students are admitted to various government and private run dental institutions for graduation and post-graduation courses. Even though, large number of students are graduating every year, most dental clinic are only limited to the urban areas and they have to reach their next step in the rural areas. This is because there no provision for dental doctor in major rural areas. In these circumstances, the robots will be very useful and it will be good initiative to create awareness among the rural people.

V. PROPOSED IDEA

The proposed idea considering the above dental problems is to create an automated robot that performs basic dental activities like drilling and filling. The automated operations are carried out by image processing of the patient's teeth. The image processing helps to identify the number of cavities and the position of the each cavity. The dental activities are carried with the help of robotic arm. The drilling is carried out by using the dental driller in the end effector of the robotic arm. Likewise, the filling operation is carried out by using the dental filler in the robot. The precision of the robotic arm and image processing plays an important role for carrying out this idea in real time environment. The idea is implemented by considering various factors.

VI. IMPLEMENTATION

The implantation of the proposed idea is carried out in various steps.

A. BLOCK DIAGRAM

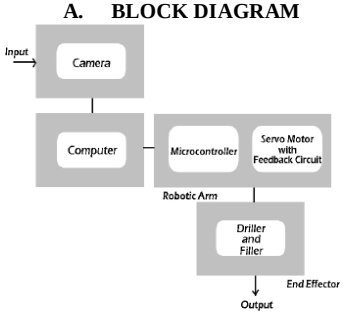

Fig.1. Block Diagram

The fig.1 represents the block diagram of the proposed idea. This shows the hardware components involved in making this automated dental robot. The hardware component consists of camera, computer, robotic arm, power supply and dental equipments like driller and filler. The camera is connected to the computer with image processing software. The image from the camera is processed by the image processing software. The robotic arm is made of microcontroller and various servo motors to move the arm to different positions. The microcontroller is used to move the robotic arm to specific positions of the tooth with cavity.

The microcontroller gets the input from the computer by the position values computed from the image processing. The end effector is present in the end point of the robotic arm. The end effector consists of two dental equipments namely the driller and filler. These two equipments are used one at a time, by the end effector.

Fig.2. Overview of proposed idea

The overview of the robotic arm is shown in the fig.2. The robotic arm is placed in the front of the person with the fixed base. To perform surgery using this technique, the patient needs to keep their mouth open in a fixed position. This can be done using the mouth holder. The camera is also kept in a fixed position in order to take the pictures of the entire teeth before and after the operation, to see the difference between the two pictures. This is performed to find out, whether the operation is performed successfully or not. There are different types of tooth found in humans.

The cavities tend to occur in different places in different tooth and this may change from person to person. So, the image processing is carried out considering the size of the cavity and the grey scale reading. Based on these criteria, the x-axis, y-axis and z-axis locations are calculated. Then the robotic arm will move to the desired locations, since all the positions are fixed. Other safety precautions are taken by using specific dental equipments connected to the microcontroller. This safety measures will be useful, when the end effector is advancing towards the tooth. The process flow starting from the image capturing to the filling operation on the tooth is shown in the flow chart.

B. FLOW CHART

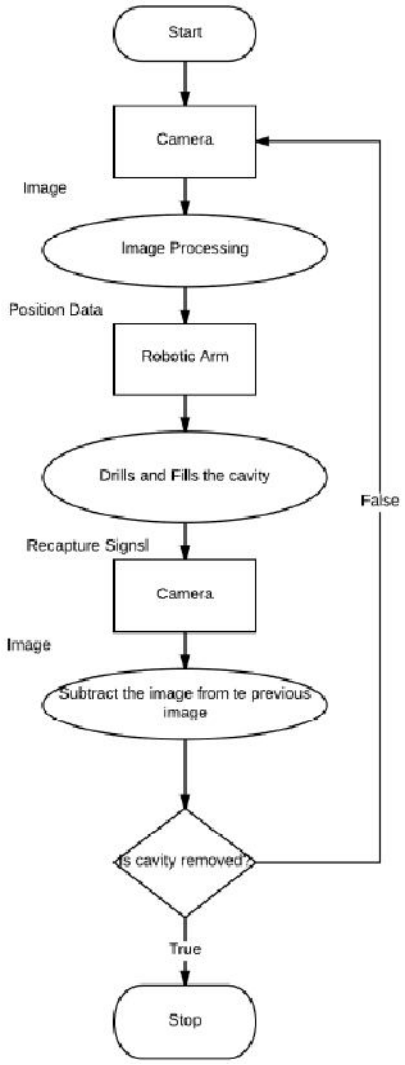

Fig.3. Flow Chart

As soon as the process is started, the camera first captures the image of the teeth. Then the image is processed by image processing software. Based on the processed image, the x-axis, y-axis and z-axis values are found and these values represent the position of the cavity tooth. Based on these values the microcontroller controls the robotic arm to reach the cavity. The microcontroller is programmed based on the required algorithm, so the robotic arm can reach the tooth with cavity for performing dental activities such as drilling and filling .Once the robotic arm reached the cavity position, the drilling and the filling operations are carried out in sequence. Then after this step, the camera once again captures an image and compare with the previous image. When the cavity is not found in the entire teeth, then the operation is stopped. The entire process is carried out repeatedly, till the teeth contain no cavity.

C. PROTOTYPE

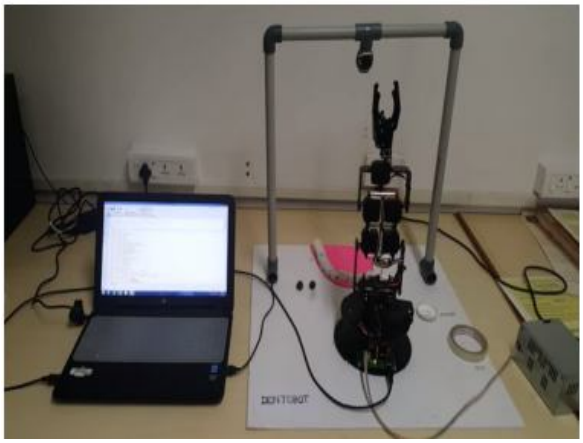

Fig.4. Prototype of the dental robot

The prototype of the proposed idea is developed using Dexter ER2 robotic arm, teeth model, camera and laptop for image processing. The End Effector of the robotic arm is assumed to have drilled and filling equipments such as driller and filling equipments. The amalgam used for filling the cavity is kept in a fixed position. The base of the robotic arm and the USB camera is also kept fixed. Image processing is taken place with the help of OpenCV software. The prototype is shown in the fig.4.

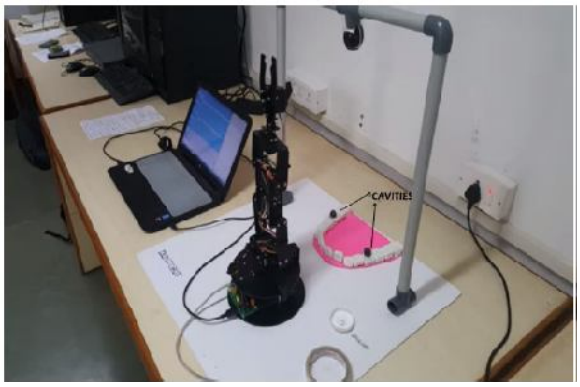

Fig.5. Tooth model with activities

The prototype also contains two black balls as shown in the fig.5 and they are assumed to be the cavities. Since, the prototype has no driller and filler, the black balls is useful to demonstrate the working idea.

D. RESULT

The result of the prototype shows the automated dental operations such as drilling and filling. At first, the process is initiated by compiling the program in the laptop. The image is captured by the USB camera and is then processed by OpenCV software. Based on the grey scale readings, the position of the cavity is found. A person's teeth can have more than one cavity. When the cavity is more, the operation is executed from the right side to the left side. The delay between every movements of the robotic arm is set carefully in order to avoid mistakes in the dental operations.

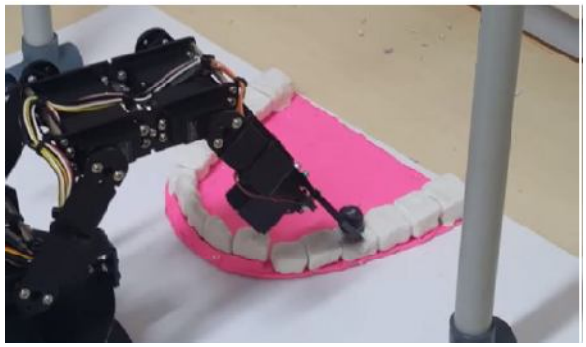

Fig.6. Removing the cavities by Drilling

The output of the image processing is the values that represent the position of the cavity. Corresponding to these values, the angle and the movement of the robotic arm is generated and is then given to the microcontroller in the arm. After this, the robotic arm moves near the cavity tooth and removes the black ball (represents the cavity) as shown in the fig.6. This operation is assumed to be the drilling operation.

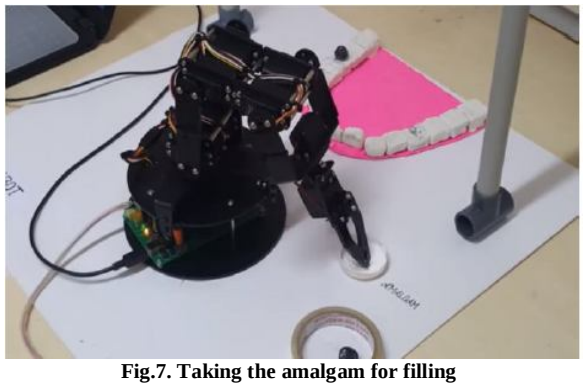

Fig.7. Taking the amalgam for filling

After this operation, the amalgam is taken as shown in the fig.7. The end effector in this operation is in closed mode. This is assumed that the robotic arm has filler as an end effector.

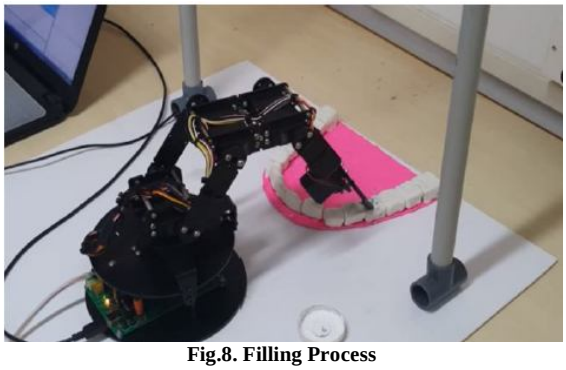

Fig.8. Filling Process

Then the robotic arm is moved near the tooth that had cavity and place the filling in the same position and it will wait for ten seconds as shown in the fig.8. This is an assumption that the robot with filler as an end effector exposes infrared light over the amalgam for few seconds. This is to make the amalgam to firmly

stick on the tooth. After this operation, the arm is returned to the initial position

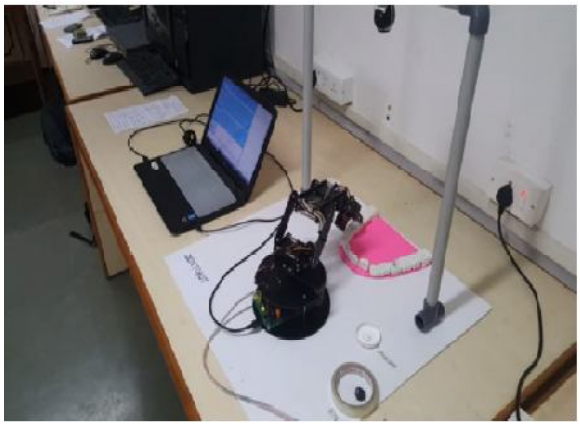

Fig.9. Repetition of the same process for another cavity

After performing the drilling and filling operation on the first cavity tooth, the robotic arm will repeat the same operation for another cavity tooth in the left side. This is shown in the fig.9. The camera will once again capture the image and compare with the previous image and again checks for cavity. If cavity is there, this sequence will be repeated once again and if there is no cavity, the operation will be terminated.

CONCLUSION

From the result it is inferred that, the prototype is working perfectly. If the assumptions are avoided and the end effector is replaced by the driller and filling equipments, the proposed idea will work in real time. Nowadays high precision robotic arms are available in the market and this will be very helpful for maintaining the precision of the drilling and filling operation. When this idea is made to work in real-time, it will be very useful. The patients can save their time by getting basic dental operations from these automated robots, instead of waiting for hours in hospital for these dental treatments. The doctors can also save their valuable time, by performing other major dental surgeries like root canal, tooth implantation, etc to the patients. These robots fulfill the requirements needed in the rural areas and it will create awareness among the people to take care of their teeth and to avoid dental problems. The cost of these dental treatments can also be brought down, by implementing this idea.

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