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Vision Based Voice Controlled Robotic Arm for Handling Dental Equipments

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Abstract: - This project outlines vision based, voice commanded robotic system pertaining to dental tools aiming at improving the quality and hygiene of dental services. Real time computer vision is performed using OpenCV on a Raspberry Pi with webcam and voice recognition through Google Speech API with microphone. The robot knows what kind of dental instruments are needed and picks the dental instruments on its own when the dentist says so, thus minimizing contact. The application also promotes working conditions concerning tools that involves accurate positioning and holding a tool by providing real- time visual feedback of the tools. This method enhances the instrument reachorgization, enhances the cleanness, and it enables the continuation of dental operations without frequently interruption.

Keywords: Machine vision, Voice controlled robot, Open CV, Dental equipment handling

I. INTRODUCTION

The technology in health-care has over the years advanced and created an opportunity for solutions that increase the effectiveness of patient's care. In dentistry, above all, it is essential to have high accuracy and manageability since dentists are in contact with their instruments and patients at the same time. Some of the problems that are evident in a dental clinic include: improper handling of instruments, ill-coordinated movements while adjusting the equipment or while practicing dentistry, inefficiency and physical stress.

The Vision-Based Voice-Controlled Robot for Dental Equipment recommends new solutions concerning the usage of computer vision and voice recognition in the manipulation and regulation of dental instruments. Implemented on a Raspberry Pi, it is expected that this system will offer dental workers a way to process equipment during complex operations without touch. The key goal of this project is to create an intelligent robot capable of:

- **Recognizing dental instruments** using **computer vision** techniques.
- **Receiving voice commands** to control the movement and operation of dental equipment.
- **Automating repetitive tasks**, such as tool retrieval, activation of instruments, and adjustment of dental chairs, thereby enhancing the work-flow in dental clinics.

The need for developing such system is due to the bettering the working conditions for the dentist and the general procedure through out the dental procedures. By reducing avoidable movement, the dentist can focus on time-consuming activities for example, evaluation and assessment of patients. This project's significance lies in its potential to:

- **Increase productivity** in dental clinics by automating repetitive tasks.
- **Improve the patient experience** by reducing delays and making procedures more efficient.
- **Ensure better hygiene and safety** by minimizing physical contact with dental instruments.

1.1 Motivation and Significance:

Advancements in healthcare technology have led to more diagnoses and treatments, but patients often struggle with medication adherence, especially those with chronic conditions, vitamin deficiencies, or age-related ailments. Young children may forget to take their medicine due to distractions, and parents may also forget due to busy schedules. Similarly, working adults and students may ignore phone alarms to take their medication, risking delays that worsen their health.

A smart medicine box offers a solution by setting reminders and making medication accessible on time. Unlike phone alarms, the device requires the user to press a button to turn it off, ensuring they're actively reminded. If medication is not taken promptly, the device notifies a guardian, providing an added layer of accountability. Portable and convenient, the smart med box is ideal for the elderly who may suffer from memory-related issues like Alzheimer's or Parkinson's, helping them stay on track with their medication without reliance on others. This

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device reduces stress for both patients and caregivers, promoting a safer, more reliable approach to daily medication management for all ages.

1.2 Methodology:

Outlining the necessity of accuracy and aversion to any impurities in the dental environment is the first step in the algorithm used to create the "Vision-Based Voice-Controlled Robotic Arm for Handling Dental Equipment." They are building and setting up a robotic arm with servo motors, a Raspberry Pi, a camera module, and a voice recognition module. Software development includes developing a Python-based voice control system for non-contact use and coding an object recognition system for tools using OpenCV. To avoid mistakes, the system's voice recognition, object recognition, and machine recognition capabilities are rigorously verified. Last but not least, the system is put into "live" mode, where practitioners receive training on how to utilize it safely. The given changes are the principal steps towards increasing the efficiency of work and decreasing the role of human factors in dental work.

1.3 Objective:

To design and develop a robot capable of assisting in dental procedures by controlling dental equipment through voice commands, combined with vision-based feedback, and powered by a Raspberry Pi.This project aims to combine the capabilities of computer vision, voice recognition, and robotic control to help dentists operate equipment more efficiently and ergonomically. The robot will be capable of:

- Detecting dental tools and equipment using a camera.
- Responding to voice commands to control movements, activate equipment, or perform specific tasks.
- Integrating with a Raspberry Pi to serve as the central processing unit.

1.4 Background of innovation:

In order to increase dental operations' precision, aseptic quality, and efficiency, this project introduces a voice-activated, vision-based robotic arm. There is always a chance of contamination and human mistake when using dental tools in the traditional manner, even when great care is used. Here, the robotic arm's machine vision capacity allows it to distinguish between the many components of the articulated dental instruments, and voice control helps to streamline operations and address sterility issues. From the standpoint of health care automation, this system aids practitioners by resolving issues related to tool accuracy and the physical strain that practitioners must endure. Once more, its objective is to rationalize the different dental techniques in order to enhance patient safety and quality.

II. HARDWARE REQUIREMENTS

2.1 Raspberry Pi:

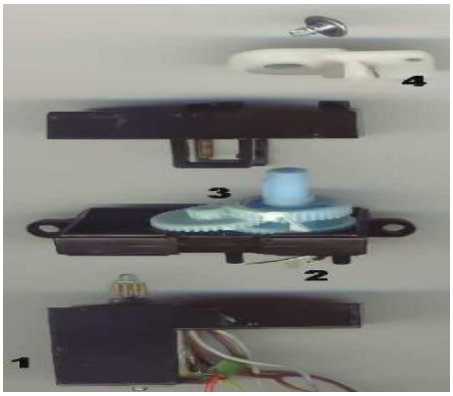
Cyber Physical Resources That Will Be Required the Raspberry Pi is a silicon circuit board which had a processor and video processing block, memory and several connectors for interfacing with other hardware and software components. From all these devices some are referred to as primary devices while others as non-primary devices. RPi is used like an ordinary PC that require respond to key presses and come with a display and power supply. It also need ‘mass-storage’ however, a hard disk drive like that used in an average PC would negate the small form factor of the RPi. We will however use an S D Flash memory card common in digital cameras I will however format it to make it look like a hard disk drive to the microprocessor of the RPi. RPi will ‘boot’ (Read the Operating System into the RAM) from this card in the similar way a computer ‘boots into’ windows from the hard disk.

2.2 Servo motor

The importance of servos is that they are automatic control systems for mechanical aspects like a position, which utilize feedback principals with predetermined error signal. An example of feedback control is auto controlling of speeds where a car's cruise control system sets a certain speed for the car. In radio-controlled (RC) appliance and equipments, hobby servos are preferred due to their low cost, robust feature and easy compatibility with microprocessor control thus appropriate for small robot systems.

RC servos work with pulse-width modulation (PWM) signals or pulses having a fixed frequency of around 50 Hz. Internally, they employ a potentiometer/motor which varies according to the pulse signals it has received. They also showed that the pulse width of the PWM signal which commands the servo determines its position and that a 1.5msec pulse positions the servo at straight and right angles while other pulses positioning it at different angles take different amounts of time. The terminology of the servo is composed of ground, power, and control cable; out of which the control cable acquires the PWM signal.

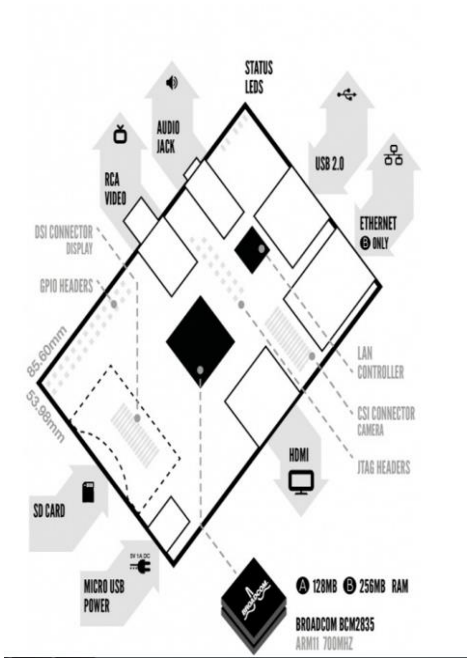
Generally, most of the RC servos uses 4.8V to 6V, although few use 12V source. A Li-Po or NiMH battery pack or ESC containing a BEC feeds in electricity. While standard pulse widths designate certain positions in angle space, servos of the same type may possess limitations and spaces distinctive from others. Most Analog hobby servos use "standard pulse servo mode" and can rotate approximately between 90-120 degrees but we get variations.



Small R/C servo mechanism

1.Electric motor
2.Angle feedback potentiometer
3.Reduction gear
4.Actuator arm

Port specification of Raspberry pi



Display

Almost all modern CRTs, all liquid crystal displays, and almost all high definition TVs can be linked with a standard, its entire size male HDMI cable and, if one has DVI, with an HDMI to DVI converter. Depending on the model of the RPi display, there are actually two main types of connections: HDMI and composite video. There are HDMI versions 1.3 and 1.4 available, and using an HDMI version 1.4 cable is recommended. Although it lacks HDMI input ports, the Raspberry Pi does include an HDMI port.

An Xbox One may be linked to an old TV by passing a SCART lead via the SCART to RCA or by utilizing an RCA cable with the yellow head. It is compatible with both PAL and NTSC TVs. Only when an A/V cable is attached in composite video and can be seen via a television, headphones, or any amplified board does the 3.5mm jack socket provide stereo output. To transmit audio to your television, you will need a cable that can convert 3.5mm to dual (red and white) RCA. It should be noted that the NIC lacks the VGA's output mode. With the exception of the most recent versions, many computer displays must have this admission. Therefore, a simple monitor that simply has a 15-pin D-shaped connection is not suitable for the task.

2.3 Energy source

The microUSB pin is where the power source is attached; it is solely used for charging and does not allow data transfer. The standard phone charger or UC can be used as long as they provide adequate power at +5Vdc for constant current of 700mA. In addition, the power supply ratings for the system that you are developing should also be never to be taken lightly. In case you are unsure of which mains adapter to use, then the replacements provided by the RPi Shop ought to be used.

Furthermore, each USB which is built-in to a PC or a powered hub could supply up to 500mA. But if you desire to use any of it as a charging source then you can only use that specific cable with plugs both to two terminals which provide a total amperage of 1000mA.

2.4 Webcam

Webcam is a video camera which is used to capture real time images of an event place and transmit them to a computer or computer network through Ethernet, USB or Wi-Fi. The most well known use of video connections is in the setup of video connections to make computers into videophones or videoconferencing stations. It will be remembered that the webcam was initially employed mainly as a video camera on the World Wide Web. Two more familiar applications are computer vision, as well as security monitoring. Webcams are the least costing classification of video telephony because they can be easily installed and their assembling cost is comparatively low. Other integrated cameras also turn to be security and privacy threat since some of those integrated cameras can also be remotely activated by spywares.

2.5 Lens

Webcams are simple contrivances, which include a lens, image sensor, support electronics and, in some, a microphone. New consumer web cams come with either a permanently attached plastic lens that can be focused manually, or with non-focusable lenses. Although, because of small formats and small apertures web cams have got large depth of field.Fixed focus lens thus work well and do not require any focusing on the part of the user.

The sensors used in webcams are generally CMOS or the more expensive CCD. Earlier models usually incorporate such sensors with CCD generally noted for better performance in low end products although CMOS is prevalent in many devices. The basic consumer Web cams record at 30 FPS with VGA quality while models like PlayStation Eye record at 120 FPS or lower VGA. While the current models are very advanced, they are capable of catering for multi-megapixel resolutions.

Support electronics process the image, which the host computer receives, normally through the USB connection. Data are transmitted in forms of images such as Jpeg, RBG or YUV image sometimes images are compressed. Such system integrated within a chip make compact webcams cheap and therefore easily accessible in the market.

Webcam

2.6 Bluetooth module

HC-05 is a Bluetooth module which is used for wireless communication. It is equally possible to use this module in either master or slave mode.

HC-05 is a Bluetooth module which it can be used in wireless communication. This module is easily programmable to be in either the master or slaveplane bluetooth serials enable bluetooth serial communication in all serial activated devices.

From those six pins is EN pin/Key which is used to put the Bluetooth module into the AT command mode. If the key EN pin is set too high of a voltage this module wil function under command mode. If not, the bot is in the data mode to begin with. By default, the HC-05 module uses a command mode of 38400bps while the data mode is 9600bps.

III. SOFTWARE REQUIREMENTS

3.1 Raspian OS:

Raspberry Pi OS (earlier referred as Raspbian) is the official OS for Raspberry Pi computers that are based on Linux. Designed for the Pi's ARM structure it was designed for efficient utilization of limited hardware resources usable for a large variety of projects including media center, IoT, and education.

Some of the noticeable preloaded software include programming languages like Python, Scratch, Java whereas programming tools include Thonny IDE and Geany. Libre Office, an office suite, Chromium for browsing, and VLC Media Player also completes packages of productivity, internet and multimedia utils. It has LXTerminal to handle command line tasks, and a simple GUI in order to minimize its impact to the system and to run with older, less powerful processors.

The Raspberry Pi OS is updated often by Raspberry Pi Foundation, for bug fixes, new features, and better hardware compatibility. This one is free, with a strong community backing it up – forums, tutorials and help sections included. The OS employs the APT package manager through which most of the programs are installed by a terminal command e.g. apt-get. Also, there is an additional program and game offering from the pi Store that gives more functionality to raspberry pi applicable on numerous fields of activities.

IV. RESULT AND DISCUSSION

Thus, the usage of Vision Based Voice Controlled Robot for dental equipment is revealed to be effective in a number of spheres of a dental practice. With Raspberry Pi, affordably priced computer vision and speech recognition system, the workplace is made more efficient for the dentist and the entire clinic.

4.1 Increased Operational Efficiency:

- Automation of Tool Retrieval: Every time the robot receives the voice command, it produces the correct label and subsequently picks up dental instruments. This has resulted into saving a lot of time that was earlier spent on bringing tools, instead of which the dentist can effectively extend his or her efforts towards patients.
- Faster Tool Adjustments: Consequently, through combining voice controls with computer vision, the robot can accurately position dental tools. Some dental instruments, including the dental drill, the suction device, and the dental chair can practically be operated with a lot of automation which saves on a lot of time that would otherwise be spent getting ready for them.

4.2 Improved Ergonomics:

- Hands-Free Operation: The system enables a dentist to work through voice control and minimize the effects of repeated movements including bending, stretching or reaching for equipment. This is particularly useful

where the patient has to be held in specific position for long periods of time and physical stress can become a problem.

- Reduced Fatigue: Using voice instructions to operate dental instruments and equipment reduces the burden on the brain and the body, which in turn relieves dental workers from fatigue during a procedure.

4.3 Enhanced Precision and Safety:

- Accurate Tool Handling: With the help of computer vision, enabled by Raspberry Pi camera, the robot is able to locate and follow the correct instruments, thus making sure that the correct tool is always to hand and correctly positioned for use. Error Minimization: Mechanized placement provides the dentist continuity of use of instruments without the need for distracting the dentist, thereby increasing the accuracy of procedures and minimizing the occurrence of accidents or introduction of contaminants.

4.4 Improved Workflow and Time Efficiency:

- Reduction in Tool Switching Time: Holding capability to obtain and deliver dental tools, the time which is utilized in a switchover of tools and devices is reduced. This is because some time during dental procedures is saved, leading to improvement and efficient use of available resources and increased patient turnover.
- Real-Time Adjustments: Voice activated commands allow the dentist to turn outputs, for example the dental chair or the suction on or off or to change its position without having to touch the controls which makes the process more efficient.

4.5 User Satisfaction:

- Positive Feedback from Dental Professionals: During initial studies, the participants, who are dental practitioners, complained that the system was easy to operate and convenient for the multitasking involved. Mobile access was especially enjoyed for its easy and effective voice command to eliminate excessive time spent on patient care.
- Patient Comfort: Some impact assumed from the investigate involves, the reduction in procedure time and the natural coordination between the dentist and the robot, have improve patient comfort during dental procedures and made the experience less traumatic.

4.6 Cost-Effectiveness and Scalability:

- Affordable Solution: Due to using the Raspberry Pi base, it can be noted that it is significantly cheaper than other existing robotic systems applied in medical and dental fields. The cost which Raspberry Pi offers makes it physically possible to implement alongside cameras and microphones which are frequently incorporated into small to medium scale dental practice**.**
- Scalability: This system is modular and can be later expanded with such modules as, for instance, multi-tool control or interfacing with other dental appliances, making the robotic system even more helpful in treating patients in small clinics or dental hospitals.

4.7 Challenges and Limitations:

- Tool Identification Accuracy: Nevertheless, the computer vision system has shown particular robustness in performing in standardized settings; however, it has not achieved high levels of accuracy in recognizing specific dental tools under different lighting circumstances or occlusion. The future work of the researchers will, therefore be directed towards enhancing the reliability of the image recognition models to use more sophisticated AI models and machine learning.
- Speech Recognition Errors: The system works best in this scenario and of course there are occasions that wide range background noise in the more clinical environment may confuse the voice commands interpretations. Some noise filtering was done before the signal passed through the speech to text system which was effective in reducing the noise levels However this was not sufficient to filter the noise totally for future updates A better method of noise elimination will be adopted alongside a better developed speech to text system.

V. CONCLUSION

This is a vision based, voice controlled robot for dental equipment, which is a fresh approach for enhancing the efficacy, accuracy, and the nonsupervisory use of Dental equipment. The combination of Raspberry Pi, speech recognition, and computer vision can make work with tools much easier for dental professionals, which directly leads to the better perceiving of patients' needs and the increased sense of the dental practice's effectiveness. Such

tasks are repetitive and involve a lot of physical stress which can be minimized from the workflow by adopting the use of the proposed system this is because, the system minimizes the amount of time, and concentration diverted from the patient during stressful operations which are repetitive in nature.

This project could pave a way for improvement in the subsequent projects including; this tool to work for multiple tools to be interacted with, a mobile application to control the performance of the particular tool, and use of the models that enhance the tool recognition system. This system is in its way raising dental practises to be even smarter, tolerable and ergonomic.

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