BOOK CHAPTER | RE for Robotic Systems in Dentistry
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Requirement Engineering For Robotic System: The Next Generation In Dentistry

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ABSTRACT

Robotics has been successfully applied in engineering, commerce and now in medical field; and has opened a new frontier with numerous areas for expansion and exploration. Robotics with dental application is a relatively untraveled area to pursue. The virgin areas in dental research is an opportunity for new and better products and has been important development direction of medical robot. More 'intelligent' products is the next big step. Robotics offer improved predictability, speed, increased precision, quality and safety of various procedure; ranging from patient robots to robots used in endodontics, oral surgery, implantology, prosthodontics and orthodontics. An architecture of robotics, artificial intelligence (AI) and machining learning (ML) to analyse large amount of data with the help of data-driven analysis algorithms based in ML drives the next generation dentistry. The main aim of this paper was to review current research in the field of dental robotics. A review of literature was performed using electronic searching methods of Pub Med database and Google for the applications of robots in Dentistry. Extracted data from selected papers were synthesized.

Keywords: Robotics, AI, Machine Learning, Dentistry, Orthodontics, Prosthodontics, Data.

Introduction

Robotics is the branch of technology that deals with the design, construction, operation and application of robots as well as computer systems for their control, sensory feedback, and information processing.

Robotic systems are expected to assist or replace their human counterparts for efficient and effective performance of various tasks such as industrial operations or surgical procedures. (Buzurovic, Podder, Fu, & Modular, 2010). According to the Robot Institute of America, a robot is defined as "are programmable, multifunctional manipulator designed to move material, parts, tools or specialized devices through various programmed motions for the performance of a variety of tasks (http//www.robots.com/education).

A robot can mimic a wide range of human characteristics and perform accurate, complex, repetitive and rigorous tasks and is useful in all aspects of our life. Robotics is not yet used in dentistry even though all the necessary technologies have already been developed and could easily be adapted (Maass, Chantier & Cakmak, 2003).

The first step towards development of a robotic system is to determine the necessary requirements of how the system should function optimally and the available constraints associated with its operation. (Kotonya & Sommerville, 2018). The requirement definition of a system is described through a process known as Requirement Engineering (RE). This process refers to the routines to defining, documenting and maintaining the system requirement. (Kotonya & Sommerville, 2018).

According to Kotonya and Sommerville. The RE process must include the following phases: elicitation, analysis and negotiation, specification, validation and managements. Since robotic systems often rely on special-purpose hardware and operating software, the requirement engineering for these systems usually involve s both hardware and software requirement.

History of Robotics.

The pioneering work conducted at the National Aeronautics and Space Administration (NASA) marks the origin of robot-assisted surgery. In the mid-1980s, a remotely controlled robotic system was developed by NASA for surgically operating soldiers on the battlefield as well as astronauts in space. In 2000, the USA Food and Drug Administration (FDA) approved the first robotic system for performing laparoscopic surgery in a doctor-robot set up.

In 2001, the validation of the doctor-robot concept was performed via a transcontinental live robotic cholecystectomy. It was the first instance that a team of surgeons operated on a patient elsewhere (telepresence) (Haddadin, Suppa, Fuchs, Bodenmüller, Albu-Schäffer, & Hirzinger, 2011).

Since then, robots have been employed in surgical specialties such as general surgery, gynecology, and urology. Robot-assisted surgery has also prompted progress in minimally invasive surgery by providing equipment with high accuracy and freedom of movement, elimination of the negative effect of instrumental and hand tremors, and real-time stereoscopic vision of the surgical area. Robots offer surgeons easier operational access and flexible working settings **(**Wu, Wang, Fan, & Chow, 2019).

Application of Dental Robotics

1. Dental patient robot.

Dental therapy skills often depend on the competence and ability of clinicians to develop extensive experience using methods that accurately reflect actual treatment procedures and conditions. Fresh graduates lack clinical skills and experience in treating patients, which necessitated clinical training on consenting volunteer patients.

Ethical issues related to environmental studies, medicine and dentistry have made such clinical training difficult. Hence, 'Phantoms' consist of simple functional cephalic region and arrangement of teeth which is different from actual patients. As a result concept of dental patient robot was initiated in Japan.

These robots include:

- **Showa Hanako** was created in Tokyo, Japan by Showa University with assistance from the robotics company Tmsuk. It is a realistic robot that has features and perform a variety of patient gestures and reactions such as coughing, shaking its head, moving its tongue, blinking, sneezing, rolling of eyes, and even get fatigue for mouth opening for too long. It can simulate gag reflex, making it no different from an actual patient.

- **Geminoid DK** was invented in Japan at Advanced Telecommunications Research Institute. It is a remotely controlled robot with advanced motion-capture technology that can do human facial expressions and different head motions.

- **Simroid** is a next generation dental training robot manufactured at The Nippon Dental University Kokoro aimed to access the student's attitude towards the patients while doing a procedure rather than the technique. The robot can perceive pain and express discomfort based on the sensors in the mouth implicating negativity and making the students conscious.

  It has an artificial skin that can even tear easily if the mouth is kept wide open. It also reacts and responds to questions or commands because of speech recognition abilities that allow the students to develop communication skills as well. The robot finally evaluates and rate the treatment based on the reading of its sensors and the two cameras that record the entire procedure (Bansal, Popli, Keshri, Khare, & Goel, 2016).

2. **Dental Nanorobots**

Nanorobotics is the technology of creating machines or robots at or close to the microscopic scale of 2 nanometers. Nanorobots represent microscopical objects artificially capable of free diffusion inside the human body and which can interact with human body cells or can manipulate them, with a nanometric resolution (10^{-9}m) in order to fulfill their tasks.

As a regular robot, a nanorobot can be manufactured out of thousands of mechanical parts, made out of nanomaterials such as carbon nanotubes, metallic nanoconductors and diamondoid materials (Freitas, 2000). Multiple Nanorobots working on the teeth in unison, invisible to the naked eye, may be used for cavity preparation and restoration of teeth. The cavity preparation is very precisely restricted to the demineralized enamel and dentin, thus providing maximum conservation of sound tooth structure (Mjor, & Nordahl, 2006).

3. **Surgical Robots**

In the last decade, surgery and robotics have reached a maturity that has allowed them to be safely assimilated to create a new kind of operating room in medical field. This new environment includes robots for local surgery and telesurgery, audiovisual telecommunication for telemedicine and teleconsultation, robotic systems with integrated imaging for computer-enhanced surgery and virtual reality (VR) simulators enhanced with haptic feedback, for surgical training (DiGioia, Colgan, & Koerbel, 2018).

Application of robotics in oral and maxillofacial surgery where the surgeon interactively programs the robot at the time of the surgery following which the robot does the preprogrammed task in the operation theatre such as milling and drilling of bones, osteotomy cuts, selecting and positioning of plates, surgical planning, etc (Lueth, Hein, Albrecht, Demirtas, Zachow, Heissler, Klein, Menneking, Hommel, & Bier, 1998)

4. Tooth-Arrangement Robot

Commonly used in the field of prosthetic dentistry, a single manipulator robotic system is used for the fabrication of complete denture prosthesis using DOF (degree of freedom) CRS robot manufactured in Canada. Three-dimensional virtual tooth arrangement programming software undertakes the entire procedure (Zhang, Ma, Zhao, Peijun &Wang, 2008).

5. Orthodontic Archwire Bending Robot

Robotic technology is used for automatically bending orthodontic archwires to a specific shape. The bending equipment known as Sure Smile archwire bending robot, where there are gripping tools and resistive heating system combined with the application of CAD/CAM, 3D imaging and computers for the fabrication of orthodontic appliances(RigerIsford,2004) The rapid adoption of dental lasers makes for substantial evidence. The technology has proven its worth in periodontics, endodontic and prosthodontics treatments. Similarly, intraoral and CAD/CAM imaging have made the production of crowns, faster, more predictable and accurate.

6. Robot-Assisted Dental Implant Surgery.

The robotic arm helps the surgeon achieve the correct location, angulation and depth when placing dental implants through its sensors, producing true and unique guidance. Yomi provides dental surgeons with robotic guidance during surgery (Xiaojun &Yanping, 2005).

Conclusion

Robotics could offer in dentistry practice, improved accuracy, predictability and safety, quality of care to the professionals and quality training of dental students. It has the potential to alter people's quality of dental health in just few years. Improvement in Artificial Intelligence 9AI), Machine Learning (ML) and robotics will, certainly, birth sophisticated technologies. Embracing it will only mean more profits, better performance and easier operation for dentists across globe. Robots will change the future of dentistry forever to an extraordinary level and should be embraced by dentists and dental students for their clinical practice.

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