Voice Control for Flexible Medicine Robot

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Abstract — *The use of robots in medicine is a promising direction of research. The possibility of controlling a medical robot with the help of a voice is considered. We use a logical model to form voice commands. A set of commands for carrying out intracranial operations is presented. The results obtained can be used to create a subsystem for entering the voice information of a medical robot.*

Keywords — *voice control, medicine robot, logic model, command phrase.*

I. Introduction

Robotic system is a set of different units that automatically operate and perform specific actions according to specific functions except control functions [1-5]. Recently, these systems have been widely used in all areas of life and human activities especially in medicine. Among the different approaches of using robotic systems in medicine, we can distinguish the following:

– Robots that are used to provide diagnostic and counselling functions that allow not only to diagnose a possible disease [6] but also to correct procedures performed by physicians in complex medical cases [7-9].

– Robotic manipulators that are used in complex operations in order to achieve the most accurate effect of surgical intervention [10, 11] where human functional features are limited. This can be both passive holders for microsurgeons [12] and complex robotic systems with special functions [7].

– Robots that are used as assistants for elderly or sick people and robotic prostheses [13-15].

Using robots allows the use of microscopic scalpels to compensate for the trembling of the surgeon's hand, providing a 3-dimensional stereoscopic video with greater rotation and high accuracy.

Nevertheless, the greatest interest, in our opinion, is represented by robotic medical systems that are able to react to the actions of doctors on the basis of natural language communication, which will allow to control robot more quickly and increase accuracy.

II. Materials and Methods

Robotic systems can be successfully used in medicine as medical robots allow surgeons to reach the most difficult surgical areas using more accurate and less invasive methods. Now the most famous is robot-assistant da Vinci. Its producer is Intuitive Surgical, USA. The robot da Vinci is designed as an auxiliary tool for surgeons. The robot is not programmed for independent surgery because the procedure and the process path are remotely controlled by human. The robot uses special tools, including miniature imaging cameras and standard instruments (i.e. scissors, scalpels and tweezers), designed for precise dissection in cavitary surgery [16, 17].

Let us consider robotic application in epilepsy surgery. In [18] authors say epilepsy is one of the world's oldest recognized diseases. It affects more than 50 million patients globally. So there is a compelling case to develop a minimally invasive alternative to surgery. There are several motivations for a procedure of this kind to use real-time MRI guidance. This technology can provide high-quality images to locate the tip of a needle in soft tissue, and MRI can be used to monitor the delivery of thermal therapy through MR thermometry. But the closed bore of the MRI scanner limits the access to the patient which makes the surgical robot a prerequisite for such surgery [18]. Epilepsy surgery is cost-effective and depends on patient selection, localization and meticulous technique [18, 19].

M. S. Eljamel [19] reports the use of a new robotic system in this surgery. Here the brain is imaged for both image guidance and robotic application. The robot uses CT-visible reflective fiducials. Registration is performed by image-guided surgery (IGS) system and the robot. The robot is used to insert depth electrodes for intra-operative epileptic focus localization and to localize the temporal horn. There is a conclusion that it is feasible to use the robot to localize the temporal horn and place depth electrodes during epilepsy surgery with greater precision and consistency and potential time savings.

In [20] authors propose to use robotic assistance to place stereotactic laser ablation catheter into a brain lesion via a safe, accurate, efficient, and minimally invasive manner. This technique uses a combination of Visualase laser ablation, ROSA robot, and intraoperative MRI, which can facilitate a safe, efficacious, efficient, and minimally invasive approach that could be used for placement of 1 or multiple electrodes in the future.

Authors [21] also affirm that using robots for depth electrodes implantation for stereotactic electroencephalography is a less invasive technique. It allows accurate implantation of multiple deep brain electrodes along predefined trajectories and has not been associated with any major surgical complications in their initial experience. It is better than conventional electrocorticography that involves a craniotomy and implantation of grids of electrodes directly onto the brain surface. It is invasive and carries a high risk of major complications such as acute subdural haematoma and infection.

In all these articles there is general disadvantage: The authors did not use the voice control of the robots, while its use would allow to free eyes and hands of the surgeon, making it more convenient and accurate to focus on the process rather than dispersing to the control panel. The surgery process is greatly simplified and accelerated, accuracy and productivity are increased, excess steps number is reduced to a minimum.

Let us consider robot voice control using in surgery. First of all, we must note that surgery robot works with small commands vocabulary. It has to understand moving commands in 3 dimensions. So, voice control must take into account angles, moving to specified point and rotation about an axis. Moving steps dimension corresponds to application area for example SYMBIS Surgical System has 50 nanometers step [22].

In response to voice command, the robot control system must ensure adequate execution of real manipulation commands for manipulator junctions. However, the commands may contain inaccuracies, errors and commands may be entered in the wrong order which will result in being unable to be handled by the robot control system. Thus, input information by voice must not only be accepted and recognized, but also checked for compliance with a certain logical structure.

Let us construct the logical model for medical robot control voice commands. We propose to use standard tools for voice commands input: standard sound card and microphone. After receiving audio information, the voice commands model can be divided into the following stages.

1. Voice commands (command phrase) sequence is divided into individual words based on the signs of speech energy changes.
2. Recognition of separate command words. At this stage, separate words are mapped to an existing command library
3. Determining the affiliation of recognized words to classes (library sections).
4. Command phrase and its parts verification of compliance with the command format to determine whether the order of phrase-words matches any provided command.
5. Phrase meaning verification. At this stage, the meaning of the phrase is determined, for example, it is checked whether the medical robot has the required (specified in the command phrase) degree of mobility (column, shoulder, elbow, etc.) and the specified tools to perform the specified command.
6. Verification the possibility of command executing by checking the robot's ability to perform the required command at the current moment from the current position with the current tool in the current workplace.
7. Verification the possibility for simplifying the command by searching for any other possible option to execute the command.
8. Control command forming, which includes the direct compilation of the robot control command.

Working language library may contain such subsections (concepts):

- Command: a sample of commands list that robot is able to perform.
- Link: a sample of robot links list.
- Tool: a sample of tools list that robot can use.
- Hand: a sample of robot hands list.
- Angle: rotation angle degree.
- Distance: values of possible movement distance.
- Coordinates: coordinates of movement in the world coordinate system.
- Axis: one of the coordinate axes in the world coordinate system.
- Preposition: prepositions list.

III. Results and Discussions

In this work we suggest using voice control in the medical robot for surgery and to make the idea clearer, let us consider its using in complex intracranial surgery (Fig. 1).

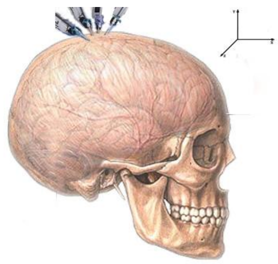

Fig. 1 Intracranial Surgery Using Medical Robot

For such type of surgery, first of all we have to select coordinate system, then we must specify necessary commands. For example, let us consider skull drilling, this means that we have to have commands such as: drill moving, drilling, rotation, points fixing … etc. where each definition must be considered and defined in details:

- Command may come in the form: "*turn*", "*move*", "*fix*", "*open*", "*close*", "*take*"
- Library subsection joint consists of the following: "*base*", "*shoulder*", "*elbow*", "*wrist*", "*gripper*".
- Angle, distance and coordinates correspond to the numbers that measure the rotation, distance or specify point.
- Class Axis represents movement axes: "*x*", "*y*", "*z*".
- Class Preposition contains the following words: "*on*", "*in*", "*to*", "*from*".

Using the words contained in the library, we can create following command, in which the right-hand side represents directly control commands in the robot-oriented language:

- ***turn <joint> <to> <angle>***

$$\exists a(\exists b \exists c \exists d(a \in NC \wedge b \in B \wedge c \in C \wedge d \in D)) \rightarrow$$
$$\rightarrow \exists s(s \in S)(s \equiv MOVE\_JOINT(b, d))$$

where
NC - voice control subsystem commands set.
B - robot joints set.
C - prepositions set.
D - rotation angles set.
S - robot control commands set.

Thus, this command means that there exists *a* belonging to the voice commands set NC such that for it there exists *b* from robot joints set B and *c* from prepositions set C, and also *d* from the angles set D that the MOVE_JOINT command will be executed, which belongs to robot control commands set S, with robot joint name (*b*) and degree angle (*d*):

- ***move <to> <distance> <axis>***

$$\exists a(\exists b \exists c \exists d(a \in NC \wedge b \in B \wedge c \in C \wedge d \in D)) \rightarrow$$
$$\rightarrow \exists s(s \in S)(s \equiv GOS(x, y, z))$$

where
NC - voice control subsystem commands set.
B - prepositions set.
C - distances for moving set.
D - axis set.
S - robot control commands set.

This command consists of the following: there exists *a* belonging to voice commands set NC such that for it there exists *b* from prepositions set B and *c* from distances for moving set C, also *d* from coordinate axis set D, that the GOS command which belongs to robot control commands set S, whose arguments are the distances for moving along each axis (x, y, z).

- ***move <to> <x, y, z>***

$$\exists a(\exists b \exists c(a \in NC \wedge b \in B \wedge c \in C)) \rightarrow$$
$$\rightarrow \exists s(s \in S)(s \equiv GOS(x, y, z))$$

where
NC - voice control subsystem commands set.
B - prepositions set.
C - coordinates set.
S - robot control commands set.

This command means: there exists *a* belonging to voice commands set NC such that for it there exists *b* from prepositions set B and *c* from coordinates set C that the GOS command that belongs to robot control commands set S, whose arguments will be distances for moving along each axis (x, y, z).

- ***move <to> <point c>***

$$\exists a(\exists b \exists c(a \in NC \wedge b \in B \wedge c \in C)) \rightarrow$$
$$\rightarrow \exists s(s \in S)(s \equiv GOS(c))$$

where
NC - voice control subsystem commands set.
B - prepositions set.
C - points names set.
S - robot control commands set.

This command can be described as follows: there exists *a* belonging to the voice commands set NC such that for it there exists *b* from prepositions set B and *c* from points names set C that a GOS command that belongs to robot control commands set S, with the argument – the point name (*c*).

- ***fix <point b>***

$$\exists a(\exists b(a \in NC \wedge b \in B)) \rightarrow \exists s(s \in S)$$
$$(s \equiv LTEACH(b)),$$

where
NC - voice control subsystem commands set.
B - points names set.
S - robot control commands set.

The command can be explained as follows: there exists *a* belonging to voice commands set NC such that for it there exists *b* from points names set B that the LTEACH command which will belong to robot control commands set S whose argument will be the point name (*b*).

- ***move <to> <object>***

$$\exists a(\exists b \exists c(a \in NC \wedge b \in B \wedge c \in C)) \rightarrow$$
$$\rightarrow \exists s(s \in S)(s \equiv GOS(c)),$$

where
NC - voice control subsystem commands set.
B - prepositions set.
C - objects names set.
S - robot control commands set.

This command means that there exists *a* belonging to voice commands set NC such that for it there exists *b* from prepositions set B and *c* from objects set C that the GOS command which belongs to robot control commands set S whose argument will be object name (*s*).

– ***fix <objects>***

$$\exists a(\exists b(a \in NC \wedge b \in B)) \rightarrow \exists s(s \in S)$$
$$(s \equiv STORE(b))$$

where
NC - voice control subsystem commands set.
B - objects names set.
S - robot control commands set.

The command is explained as follows: there exists *a* belonging to voice commands set NC such that there exists *b* from a set of objects B that a command STORE belongs to robot control commands set S with argument (object name (*b*) will be executed).

– ***open <gripper>***

$$\exists a(\exists b(a \in NC \wedge b \in B)) \rightarrow \exists s(s \in S)$$
$$(s \equiv OPEN \ / \ CLOSE)$$

where
NC - voice control subsystem commands set.
B - joints set.
S - robot control commands set.

The command means that there exists *a* belonging to voice commands set NC such that there exists *b* from robot joints set B that command OPEN/CLOSE belongs to robot control commands set S which will be executed. The "close" command is described similarly.

– ***take <object> <in> <point d>***

$$\exists a(\exists b \exists c \exists d(a \in NC \wedge b \in B \wedge$$
$$\wedge c \in C \wedge d \in D)) \rightarrow$$
$$\rightarrow (\exists cs(cs \in CS) \rightarrow can\_be\_executed(cs))$$

where
NC - voice control subsystem commands set.
B - objects set.
C - prepositions set.
D - points names set.
CS - robot control commands sequences set.

This command is described as follows: there exists *a* belonging to voice commands set NC such that there exists *b* from objects set B and *c* from prepositions set C, and also *d* from points names set D, that commands sequence *cs* belongs to robot control commands set CS, provided that this command can be executed.

– ***take <object> <in> <x,y,z>***

$$\exists a(\exists b \exists c \exists d(a \in NC \wedge b \in B \wedge$$
$$\wedge c \in C \wedge d \in D)) \rightarrow$$
$$\rightarrow (\exists cs(cs \in CS) \rightarrow can\_be\_executed(cs)),$$

where
NC - voice control subsystem commands set.
B - objects set.
C - prepositions set.
D - coordinates set.
CS - robot control commands sequences set.

This command can be represented in the following form: there exists *a* belonging to voice control commands set NC such that there exists *b* from objects set B and *c* from prepositions set C and also d from coordinates set D that commands sequence *cs*, which belongs to robot control commands set CS, provided that this command can be executed.

– ***move <object> <from> <point d> <to> <point f>***

$$\exists a(\exists b \exists c \exists d \exists e \exists f(a \in NC \wedge b \in B \wedge$$
$$\wedge c \in C \wedge d \in D \wedge e \in C \wedge f \in D)) \rightarrow$$
$$\rightarrow (\exists cs(cs \in CS) \rightarrow can\_be\_executed(cs))$$

where
NC - voice control subsystem commands set.
B - objects set.
C - prepositions set.
D - points names set.
F - points names set.
CS - robot control commands sequences set.

The command is described as follows: there exists *a* belonging to voice commands set NC such that there exists *b* from objects set B and *c* and *e* from prepositions set C and also *d* and *f* from points names set D that a commands sequence *cs* which belongs to robot control commands set CS, provided that the command can be executed.

To implement the previous discussed commands, it is very important to coordinate the drill holder. First of all, we must choose the coordinate system either world coordinate system or spherical coordinate system, then we have to specify the starting point and direction, in addition to determine and control the drilling depth which can be achieved by additional of artificial intelligence elements or advisory unit.

IV. CONCLUSIONS

The presented commands set descriptions, in fact, constitutes a logical model that characterizes the basic rules of robot control commands voice formation, on which it will be possible to develop specific software capable for controlling medical robot.

Thus, in this article, the logical model for the formation of voice commands for robot control has been developed. The initial information for it are the commands spoken by surgeon during the surgery. The entered command phrase is subjected to a series of checks on the correspondence of its components (separate words) to classes of working words and expressions, the order of phrases application and the possibility of working words combinations in a command phrase. The practical value of this work lies in the ability to control medical robot via interpreted voice commands.

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