Unified Modelling Language Application for Laparoscopic Instrument Design

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Abstract: *Laparoscopic surgery is a very popular medical intervention for the diagnosis and treatment of some abdominal problems and diseases. Compared with open surgery, laparoscopic procedures reduce patient trauma and recovery time. Still, at the same time, the surgeon's dexterity is reduced as a result of the operation specificity and instrument construction. Correct behaviour of every device and instrument during its activities is an important condition for the proper operation of the whole system. The main purpose of this work is to model the operating behaviour of an instrument-organ interaction in an environment which is similar to the real one. The ultimate target of this study is focused on the development of a functionally operating model of a laparoscopic executive instrument for robots with improved engineering characteristics. To achieve the goals, the following main tasks are decided: i) Unified Modelling Language is applied to demonstrate the operating behaviour of a device in real-time. UseCase diagram and 3 Activity diagrams have been developed; ii) an original model of an instrument with 4 degrees of freedom for robot-assisted surgery is designed. In contrast to EndoWrist technology created by Intuitive Surgical Incorporation, USA for DaVinci instruments (with 3 orthogonal rotations), we offered other construction decisions. The designed instrument provides a kinematic structure with a combination of perpendicular and parallel rotations (R⊥R‖R) which avoids additional rolls and allows obtaining the optimal working area of this instrument. This study is a continuation of previous work in the surgical robotics area.*

Keywords: *Laparoscopic surgery, Modelling, Robotics, Surgical robot, Software, UML diagrams.*

Introduction

Trends in advanced medical technologies are designed and introduced novel devices and tools for better patient outcomes. Scientists are working both on upgrading existing devices and on developing new ones. Social and economic effects are interrelated. Correct behaviour of every device and instrument during its activities is an important condition for the proper operation of the whole system. The main purpose of this work is to model the operating behaviour of an instrument-organ interaction in an environment close to the real one. The ultimate target of this work is focused on the development of a functionally operating model of a laparoscopic executive instrument for robots with improved engineering characteristics. To achieve the goals, the following main tasks are decided: 1) Unified Modelling Language (UML) is applied to demonstrate the operating behaviour of the device in real time. UseCase diagram and 3 Activity diagrams have been developed; 2) an original model of an instrument with 4 degrees of freedom (DOF) for robot-assisted surgery is designed.

The most appropriate way to describe Object-oriented models is to use Object-oriented description tools, such as the Object-oriented UML language.

UML provides standard notation for the analysis, design and implementation of systems; and the transition from Concepts to Objects. Fig. 1 shows that the Concepts can be considered on two levels: the level of generalized concepts and the level of elementary concepts. The latter mainly reflect non-composite simple Objects [8, 19]. First-level, Concepts, contains an idea which is the result of a generalization of a certain degree. Such ideas are usually associated with the understanding of category. In some cases, this is a reflective category – a generalized idea of type Class. The Class includes such unrelated Objects. The Component category is something complete that is part of something bigger, for example, a system. The Component consists of interconnected Objects. It is seen that the Concept can be directly related to 1) an Object of the Object-oriented paradigm or 2) a group of such Concepts that have similar qualities but are not related to each other or 3) any different Objects (Fig. 1).

The project model consists of two parts: an architectural and functional model which show its architecture and mode of operation [7].

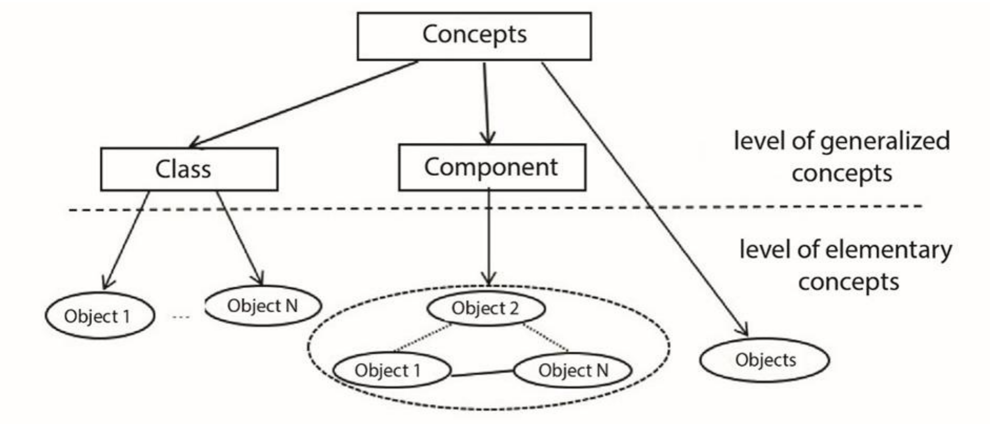


Fig. 1 An architecture of interconnected objects [7]

Application of Unified Modelling Language

UML is a language for modelling the dynamic behaviour of a system in real-time [1, 2, 5, 15]. In practice, UML represents Object-oriented software which allows any system modelling from a different point of view. Some of the tasks of the UML application include visualization of system activities and description of the activities sequence, including parallel, branched and simultaneous flow which show the dynamic behaviour of the system using forward and backward movement techniques.

UML diagrams are suitable for analysis, design and development of systems [18]. UML possibilities for the creation of a model can be used, and after that, the model can be reused in simulation environment software. Automatic generation of simulation models and algorithms for automatically transforming UML models into simulation models which can then run on simulation software are part of the capabilities of the software (e.g., activity diagrams) [20].

The dynamic system behaviour describes the system's demeanour during its operation [9]. There are several types of diagrams in UML which can provide different aspects of the system model [11, 16]. Fig. 2 shows UML diagrams and their architectures [7].

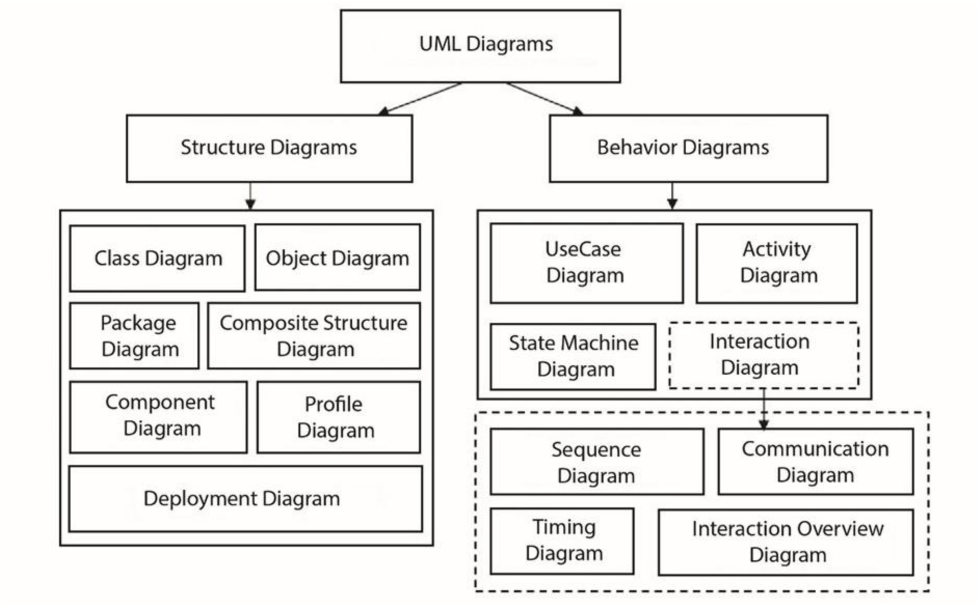


Fig. 2 UML diagrams and their architectures [7]

Behaviour diagrams

Behaviour diagrams present the interaction and current states of the Components in the model and show how they change over time. These diagrams can observe how the system works in a real environment and the effect of data operations or events. This type of chart includes a UseCase diagram, Activity diagram, State diagram and Interaction diagram. This type of diagram (Behaviour diagram) reflects to requirements for the functionality of the system. It is a means of describing communication with consumers and other stakeholder countries regarding the objectives of the system. The UseCase diagram shows the interaction between the system and various entities, such as users, and describes how the system interacts with them. This type of diagram describes scenarios for using the system and the interaction with different subjects or objects (e.g., users, software, hardware or subsystems).

UseCase diagrams

The behaviour diagram uses several basic primitives: Consumer Cases, Actors and Interactions. One of the Behaviour diagrams is the UseCase diagram which includes characterization of the system by internal and external factors. In turn, internal and external factors are known as Actors. UseCase diagram is characterized by Actors, the use case and their relationships. UseCase diagram is used to model the application system and/or subsystem. Single-UseCase diagram describes the functionality of a system. Some UseCase diagrams make it possible to model the dynamic state of a system. Also, the UseCase diagram is used: to add together system requirements; for system appearance; to identify external and internal factors influencing; and allows visibility of requirements-actors interactions.

In general, the UseCase diagram is suitable for collecting system design requirements: internal and external influences. When analysing a system, use cases and participants are determined. UseCase diagrams are then modelled to represent the appearance.

In UML there are five diagrams for modelling the dynamic system nature [6]. Each model poses some fundamental objectives. Diagrams demonstrate a running system from different aspects. To see the system dynamics, it is necessary to use different types of diagrams. The scheme of UseCases diagram is one of them and its specific purpose is to gather system requirements and participants. UseCase diagrams can indicate system events and their flows without their applications. These diagrams can be presented as a black box where only input, output and the function it performs are known. These diagrams are used at a very high level of design which is refined over and over again to get a complete and practical picture of the system. Also, a well-structured UseCase diagram describes pre-condition, post-publication conditions and exceptions. These additional elements are used for test cases when performing testing. An example of a UseCase diagram is shown in Fig. 3.

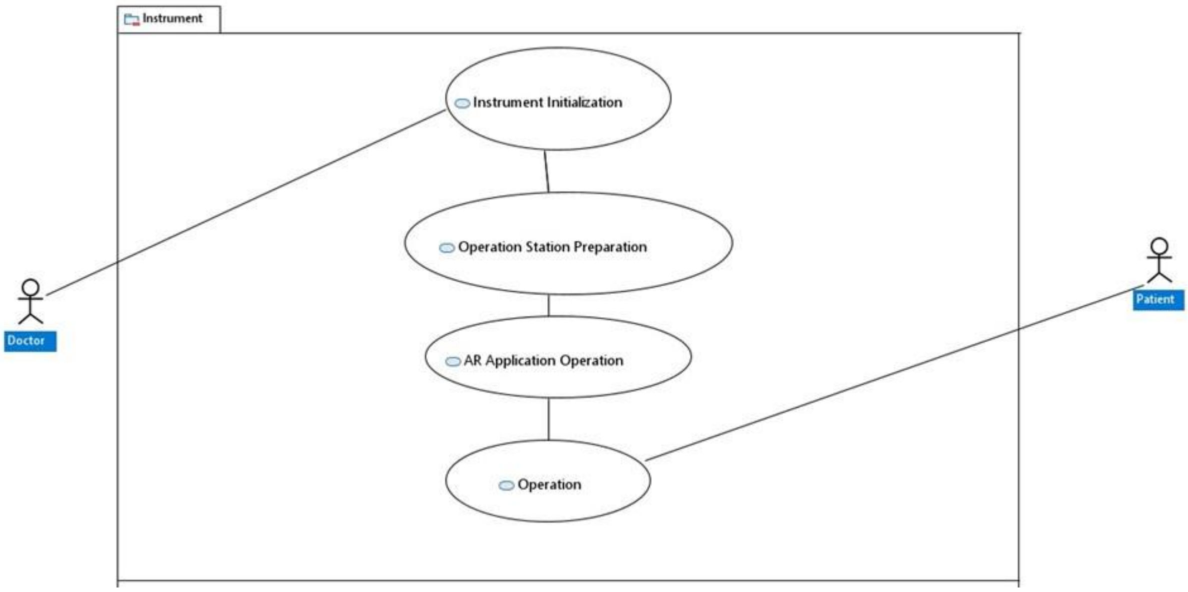


Fig. 3 An example of UseCase diagram

Although the cases of use are not the best solution of direct and inverse kinematics problems in engineering, they are still used in a slightly different way which makes them convenient to use. In straightforward engineering tasks, UseCase diagrams are used to make Test Cases, and in reverse tasks, they are used to prepare the details of requirements of an existing application. UseCase diagrams can be used for requirements analysis and high-level design.

Activity diagrams

One of the diagrams in UML for dynamic system behaviour is the Activity diagram. It visualizes the flow of system activities, describes the sequence of activities and includes parallel, branched and simultaneous flow of the system. This diagram looks like a flowchart with a flow of activities performed by the system. The activity itself is visualized as the operation of the system. Control flow is directed from one operation to another. This flow can be sequential, branched or simultaneous. Activity diagrams include all types of flow control using branches and joining. The activity diagram aims to express the flow of messages from one activity to another. Activity is the specific operation of the system. Activity diagrams are used to show the dynamic behaviour of a system and to build a system using forward and backward movement techniques. Diagrams of activities have their characteristic possibilities such as branching, parallel flow and sailing. The main element is the Activity itself, performed by the system. At the beginning, we mark the individual activities and the way they are with each other, with restrictions and conditions. To build an Activity diagram, we need to be familiar with Activities, Associations, Conditions and Constraints.

An activity diagram is suitable for modelling the control flow from one system activity to another. This type of diagram can have multiple systems that describe the flow from one to the other. This feature is not applicable in other diagrams. The systems can be databases, external queues or any other system. An activity diagram is useful for modelling of work process using activities, business requirements and system functionalities for studying the important requirements.

Interaction diagrams
Interaction diagrams are a subclass of Behaviour diagrams and are used for the description of interactions between different elements in a model. This interaction is part of the dynamic behaviour of the system. The interaction diagram defines Objects involved in the interaction, the message that flows among Objects, and the sequence in which messages and Objects organization runs. Interaction diagrams include Sequence diagrams, Communication (also known as collaborative) diagrams, Timing diagrams and Interaction overview diagrams.

Different elements' interactions in the model as a part of the dynamic behaviour of the system are described by Interaction diagrams. The following two Interaction diagrams are modelling the order management system. The first diagram is a Sequence diagram and the second is a Communication diagram. The sequence diagram and Communication diagram covered the interactive nature of UML. The sequence diagram includes the time sequence of the messages, and the Communication diagram is related to the structural organization of the Objects that send and receive messages. The main target of Interaction diagrams is focused on a system's interactive behaviour visualization which is a difficult task. Therefore, the solution uses different types of models to capture different aspects of the interaction. Sequence and Communication diagrams are used to capture dynamic nature but from different sides. The flow of messages in the system, the structural organization of Objects and the interaction between the Objects are described. Dynamic behaviour is a momentary picture of a working system at a certain point in time.

The sequence diagram captures the time sequence of a message flow from one Object to another, and the Communication diagram describes the Objects organization in the system involved in the message flow. The sequence diagram has 4 Objects (Customer, Order, Special Order, and Normal Order). It is important to understand the timing of message flows. The message flow is nothing more than calling an Object method.

The communication diagram is related to the organization of the site. The sequence of method calls is indicated by some numbering technique. The number shows how the methods are called one after the other. Unlike the Sequence diagram which does not describe Object organization, the Communication diagram shows Object organization. The choice between the two diagrams depends on the requirement type. The sequence diagram is selected as a priority in the time sequence. A communication diagram is important if the organization is required.

The main purpose of the two diagrams (Sequence and Communication diagrams) is similar as they are used for capturing the dynamic behaviour of the system. Sequence diagrams are used to capture the order of messages passing from one Object to another. Communication diagrams are used to describe the structural organization of the sites involved in the interaction. A set of diagrams is used to capture the dynamic behaviour of the system as a whole. Interaction diagrams are used when we want to understand the message flow and the structural organization. Message flow means the sequence of control flow from one Object to another. Structural organization means the visual organization of the elements in the system. Interaction diagrams can be used to model the control flow over time and to model the control flow by structural organizations.

Structure diagrams

Class diagrams

The class diagram is a static diagram or static view of an application. The class diagram is used only to visualize, describe and document various aspects of the system and to build executable code for the software application [2, 6]. The class diagram describes the attributes and operations of the Class and the Constraints imposed on the system. These diagrams are widely used in the modelling of Object-oriented systems as they are the only UML diagrams which can be mapped directly with Object-oriented languages. The class diagram shows a collection of Classes, Interfaces, Associations, Collaborations and Constraints.

The purpose of the Class diagram is to show the static structure of classifiers in the system. This diagram provides a basic notation that can be used by other UML diagrams. Class diagrams consist of a set of Classes and relationships between Classes. The class diagram includes analysis and modelling of a static view of a system. Class diagrams are the only diagrams in which direct mapping with Object-oriented languages is possible. This is the most popular UML diagram.

Class diagrams are the most popular UML diagrams used to build software applications. They have many properties that are taken into account when drawing. The class diagram is a basic graphical representation of the static view of the system and represents various aspects of the application. The whole system is represented by a set of Class diagrams. Each element of the system and the individual relationships must be identified in advance. The responsibilities (attributes and methods) of each Class must be identified. A minimum number of properties must be specified for each Class (unnecessary properties will complicate the diagram). The diagram must be reworked as many times as possible to be correct.

Software tools such as Enterprise Architect, Eclipse, Microsoft Visio and others can be used to create UML diagrams. These diagrams serve for Object-oriented modelling of the system and describe the Objects through classification and behaviour of the system in different situations. Depending on the detail with which a system can be described, diagrams can have different degrees of abstraction.

This paper describes UML application, UML application for laparoscopic instrument design (1 UseCase diagram and 3 Activity diagrams), a laparoscopic executive instrument design with 4 independent movements, and conclusions and intentions for future work.

UML application for laparoscopic instrument design

Software tools such as Enterprise Architect, Eclipse, Microsoft Visio and others can be used to create UML diagrams. These diagrams are used for Object-oriented modelling of a system and they describe Objects through the classification and behaviour of a system in different cases [17].

The Eclipse software product is free. It is an environment for developing programs for different programming languages (IDE for C/C++). The Papyrus plugin is added to Eclipse to create UML charts. Depending on the detail with which a system can be described, diagrams can have different degrees of abstraction. The Avicenae project has been created and the listed diagrams have been added to it. After installation of the listed products, you can open the project and look at the objects and relations between them so that you know which one is used.

In the present study, the description of the instrument begins by developing diagrams in the following order: UseCase diagram next Activity diagram next Class diagram next Interaction diagram (Fig. 4). They were done using case and three Activity diagrams. Class and Interaction diagrams will be a topic of future work.

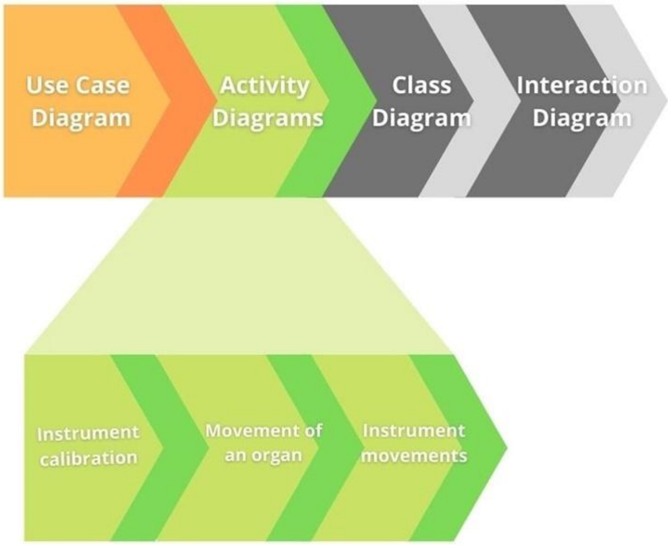


Fig. 4 Order of developing UML diagrams

UseCase diagrams and Activity diagrams for laparoscopic instrument design

Traditional laparoscopic instruments can perform 4 free movements: 4 regional movements are possible, down-up movement and rotation on the 3 axes. The surgeon's task is homeostasis (stopping the bleeding), grasping, cutting hollow abdominal organs (stomach, small and large intestines, bile, etc.), and moving tissues in one or another direction. Movements during the repair of the gallbladder from the bed of the liver are cutting-gripping and/or twisting, stretching simultaneously. Movements down and up, left and right are limited to between 10 and 50 degrees. The forward and reverse movement cannot be more than 100 mm. These laparoscopic instruments have 4 degrees of freedom. Regional movements are possible: down and up and rotation on the 3 axes.

Activities of the laparoscopic instrument / movements of the surgeon

1) Free movement: translation when the instrument makes contact with the tissue. Movements during the repair of the gallbladder from the bed of the liver are cutting-gripping and/or twisting, stretching simultaneously. Movements down and up, left and right are limited to between 10 and 50 degrees. The forward and reverse movement cannot be more than 100 mm.
2) Orientation to properly grip the tissue and to allow the blade to penetrate the tissue.
3) Displacement and/or palpation of tissues.
4) Rapid rotation and translation backwards to release or repair the organ.

5) When cutting, the plane of the blade is held against the skin, with approximately constant contact and force.
6) Free movement: with instrument translation when removing the tool from the body patient.

As a result of this work and having regard to the above information, the following UseCase diagram and 3 Activity diagrams have been developed.

The UseCase diagram gives the idea of the full range of possible cases in which the tool will be used, linking boredom with the specific actors (Actors) involved in the situation. In this case, Actors are the surgeon and the patient, both involved in a situation where the surgeon can perform the following interventions through the instrument (Fig. 5): homeostasis, gripping and incision, movement of organ, movement that does not affect the patient and twisting or stretching captured tissue.

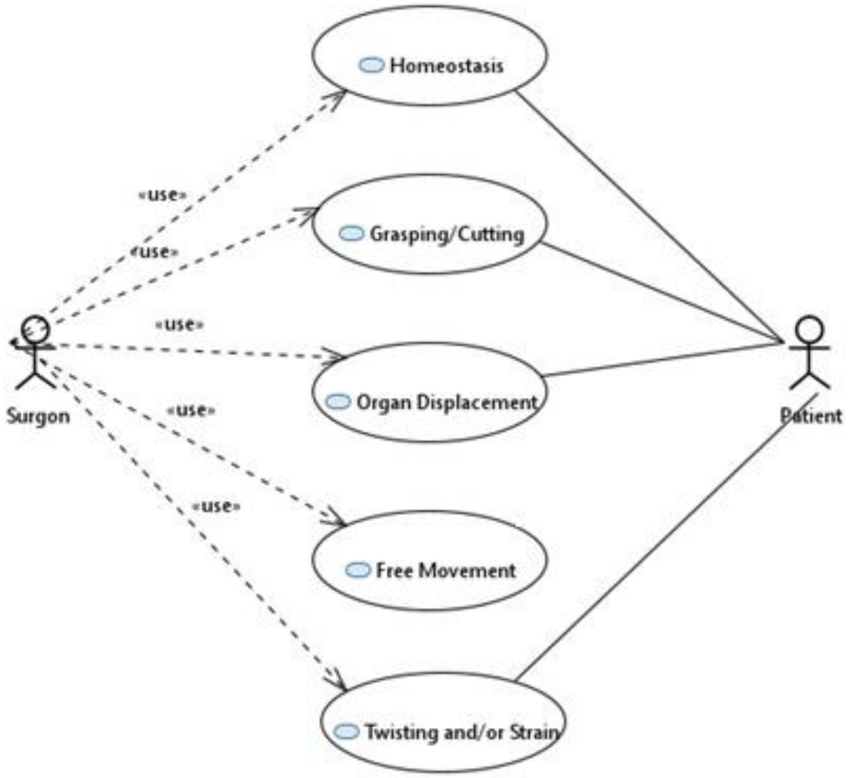


Fig. 5 A UseCase diagram of possible cases in which the tool will be used

To be used, the instrument must be calibrated for each subsequent operation. If the calibration has been done successfully, the instrument can be used to perform homeostasis (Fig. 6). Its activities are as follows: free movement until reaching the contact surface (organ tissue), gripping, electrocoagulation by electric current or stretching/twisting of the tissue, moving when succeeding homeostasis.

The device should be again calibrated before the next use, and only then can proceed with the following steps: free movement to contact with the tissue of the target organ; tissue contact and organ grasping; removal of grasping organ from the current position. After these procedures, the tool can be returned to its initial position. Fig. 7 presents a diagram of the activity “Movement of an organ”.

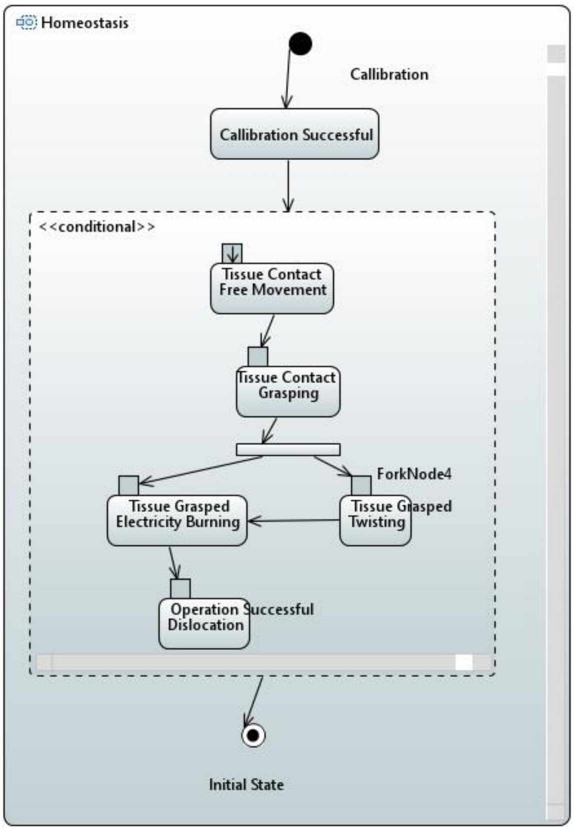


Fig. 6 An activity diagram after instrument calibration

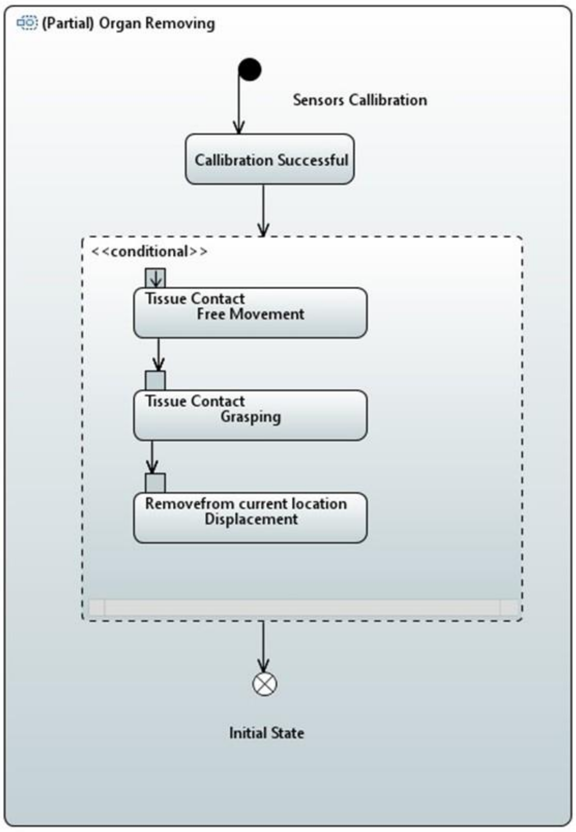


Fig. 7 A diagram of the “Movement of an organ” activity

Movements of the tool can be continuous, with a constant speed or step movements with a certain size of the step. Depending on the specific situation and case of use, after calibration one of the following can be started: constant/stepwise movement on the 3 axes, constant/stepwise rotation on 1 of the axes. By combining these capabilities, the tool receives the necessary degrees of freedom so that it moves from its initial position to the set one (Fig. 8).

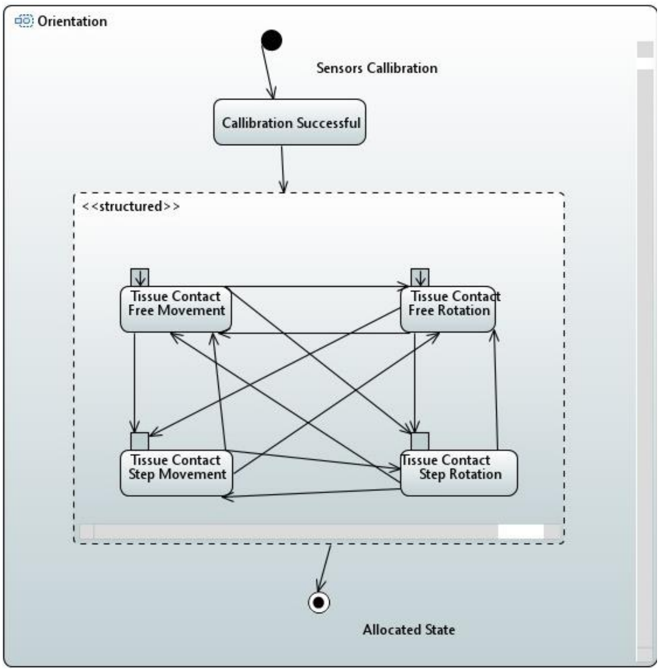


Fig. 8 An activity diagram for instrument movements

A laparoscopic executive instrument with 4 independent movements

There are two fundamentally different ways to implement minimally invasive surgery: 1) Instruments are moved manually by the surgical team; 2) Instruments are moved by specialized multi-handed robot/s. The control is remote (the operating surgeon monitors the movements of the robot's executive instruments and directly with a keyboard or joystick makes the necessary adjustment). In laparoscopic surgery, the instrument can be held by a robot but control and moving are big challenges.

The problem of object manipulation with irregular geometric shapes is a specific task for the synthesis and design of special and specialized devices. Its exact definition is related to the location (environment) and functional application of the devices [12]. Although irregular shapes should be grouped according to selected characteristics, dimensions should also be grouped. The requirements regarding the accuracy of gripping and possibilities for relative movement to the contact parts during movement, gripping forces, and the presence of residual deformations, etc. must be determined [3, 4]. Many factors require different approaches to irregular object manipulation compared to those with regular. One of them is the need for higher adaptability of the executive links to the form which with appropriately selected contact parts will be appropriate for even distribution of the load between them. This, under the same other conditions, is a prerequisite for greater reliability in gripping (low probability of dropping the object). As is well known, adaptability can be achieved through active and passive means. Controlled impact on contact forces is related to the precise modelling of contact with the object and its reduction to the possibilities of the active drive. When it comes to irregularly shaped objects, modelling is complicated. It could be achieved with universal instruments with actively controlled degrees of freedom (on the order of capabilities of the human hand).

If the tool has 2 links, the driving force F_d before object contact is determined [4]. Also, R_n is the normal component of reaction in the contact point, α is the current opening angle of the instrument link, μ is the coefficient of the friction.

$$F_d = 2R_n(sin\alpha + \mu cos\alpha). \quad (1)$$

When the Object is gripped reliably, the following Eq. (2) is considered [4]:

$$F_\alpha = 2\mu F\chi v^n, \quad (2)$$

where F_α is an action force on the object (gravitational and inertial force F_α # $m(g + \alpha)$).

The expression assumes that the instrument has 2 executive links and the forces (normal and friction) are equal. $F\chi v^n$ is the normal component of the gripping force.

From the Eq. (2) driving force in 2 executive links is calculated [4] in Eq. (3):

$$F_d = 2[R_n(sin\alpha + \mu cos\alpha)] + F\chi v^n(sin(\alpha + \Delta\alpha) + \mu cos(\alpha + \Delta\alpha))]. \quad (3)$$

A laparoscopic executive instrument with 4 independent movements (degrees of freedom) has been designed. Each of its joints is driven independently by a separate motor. As a consequence of the limitations imposed by the operating environment (the manipulation is performed in a narrow working space in the patient's body), motors are situated at the base of the instrument which is situated outside the trocar, respectively, outside the human body. This provides free working space for the instrument. The diameter of the hollow tubular body is 8 mm since the diameter of the trocar where the instrument is inserted is a standard size of 10-12 mm. The length inserted is also standard: 68 mm. Due to the limitations imposed by the environment and the human body, according to the specificity of the intervention, the instrument movements in the direction forward and back are limited to 100 mm.

The following Eq. (4) shows the linear relationship between the external force of the joint and its motor drive current:

$$R_n = \frac{nkI}{L}, \quad (4)$$

where R_n is the estimated reaction force; n is the reduction ratio of the gearhead; k is the torque constant of the drive motor; I is motor current (stepper motor); L is the distance between forces applied by location and joint axis.

Prototypes of surgical instruments could be made by 3D printing. Its structure makes position control and force reflection easy. Motors are situated on the base and the inertia of moving components remains low. All motors work in torque control mode to reflect forces at each joint.

Working space depends on linear links' dimension *ln* and joint restrictions: permissible angles of rotation of links ($q_1min \leq q_1 \leq q_1max$, $q_2min \leq q_2 \leq q_2max$, $q_3min \leq q_3 \leq q_3max$, $q_4min \leq q_4 \leq q_4max$). The value of permissible angles of rotation at the jaws is determined by the type of activity (grasping, moving, cutting, clamping, etc.). It is most often symmetrical for both jaws and therefore, the kinematic chains are the same but with autonomous drive. This provides a differential approach to the Objects which means that the Action is performed by controllable movement of one jaw relative to the other during the manipulation without moving the Object. An uncontrollable move occurs when the jaws are driven (opened, closed) by one engine and the Object of manipulation is not symmetrically located to the two jaws.

We used the known direct kinematic problem from mechanics that could be the solution for remote control of the operations (by the leading doctor of the operation). Moreover, to refine the action, a systematic position error in the working position can be entered in the control block. The direct kinematic problem is solved as a standard procedure [4]. It is possible to develop a simulation program to outline the workspace and possible operations there. Movement in this space is obtained from 4 actively controlled motors and the corresponding transmission mechanisms, corresponding between motors and executive links. In its most general form, this connection can be recorded.

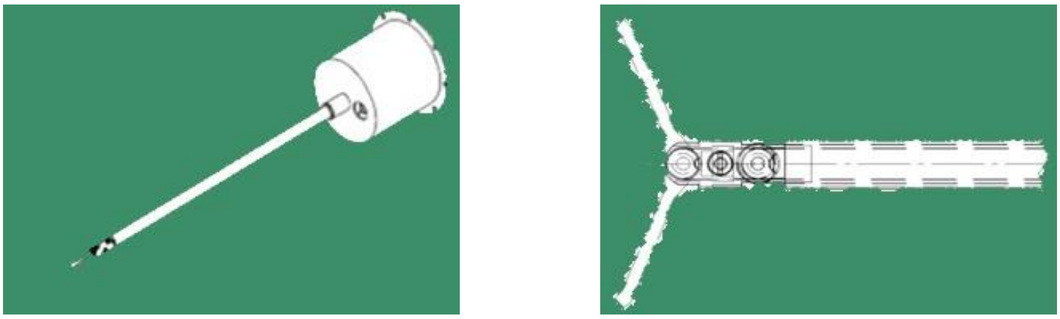
$$\varphi = Jq, \tag{5}$$

where $\varphi = [\varphi_1, \varphi_2, \varphi_3]^T$ is a vector of angular velocities and executive link; J is the Jacobian matrix that shows the values of transfer functions including depend movements; and $q = [q_1, q_2, q_3]^T$ is the vector of angular velocities in the robot's joints [4].

The expression (5) can be described in more detail in the form of Eq. (6) [4]:

$$\begin{vmatrix}\varphi_1\\\varphi_2\\\varphi_3\\\varphi_4\end{vmatrix} = \begin{bmatrix}\frac{\partial\varphi_1}{\partial q_1} & 0 & 0 & 0\\ 0 & \frac{\partial\varphi_2}{\partial q_2} & \frac{\partial\varphi_2}{\partial q_3} & \frac{\partial\varphi_2}{\partial q_4}\\ 0 & 0 & \frac{\partial\varphi_3}{\partial q_3} & 0\\ 0 & 0 & 0 & \frac{\partial\varphi_4}{\partial q_4}\end{bmatrix}\begin{bmatrix}q_1\\q_2\\q_3\\q_4\end{bmatrix}. \tag{6}$$

There is a need to determine the optimal area for the movement of the tool using quality indicators. These indicators are based on a Jacobian matrix. As a result, the geometry of the instrument could be optimized, so that in a certain area the configurations will provide optimal movement from the kinematics point of view. This is important when scaling movements, with a larger "size" of movement by the operator (master) providing minimal movement of the robotic tool. With optimal configuration (good quality indicator) control system is facilitated. Fig. 9A and 9B show the designed laparoscopic instrument and end-effector to it.



A) B)

Fig. 9 Designed laparoscopic executive instrument

The instrument is suitable for grasping, holding and moving irregular objects in minimally-invasive surgery where the executive links are fully open at the rotation angle of 120 degrees depending on the position and allows to movement of only one of the jaws.

For sensor data gathering relying and motion simulation, some interesting approaches can be taken to build a common simulation software platform [10, 13, 14]. Fig. 10 is an example of the control panel with possible software functions.

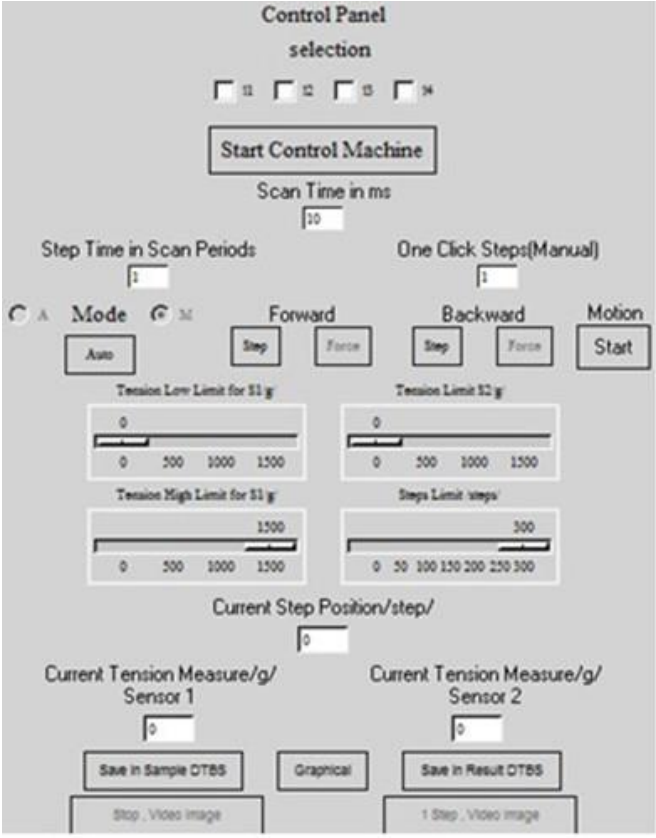


Fig. 10 Control panel of possible software functions

The options and sequence of actions in the control panel of software functions are listed below and will be described in detail in future work: 1) Doctor; 2) Motor Selection 1, 2, 3, 4; 3.1) Start Control Machine; 3.2) Stop Control Machine; 4) One-Click Steps; 5) Step Time in Scan Periods; 6.1) Tension Low Limits for S1; 6.2) Tension High Limits for S1; 6.3) Step Limits 0; 6.4) Step Limit 1 “Remote TCP Access Enable”; 7) Fast Positioning; 8) Motion; 9) Mode; 10) Current Step Positions of Motors; 10.1) Step position in the work area; 10.2) Step position from the beginning to the work area; 11) Sensor 1 and Sensor 2; 12) History, Save; 13) Automatic Control; 14) Dynamic Measurement Graph; 15) Stop. Video Image, 1 Step Video Image и Video Control; 16) Save in Sample DTBS or Save in Result DTBS; 17) Base date in simple-DTBS SAMPLES and Base date in results-DTBS RESULTS; 18) Graphical.

Conclusions and intentions for future work

Correct behaviour of every device during its activities is an important condition for the proper operation of the whole system. The main purpose of the work is to model the operating behaviour of an instrument-organ interaction in an environment close to the real one. The ultimate target of this work is focused on the development of a functionally operating model of a laparoscopic executive instrument for robots with improved engineering characteristics. To achieve the goals, the following main tasks were decided: i) Unified Modelling Language was applied to demonstrate the operating behaviour of a device in real time. As a result of this work some diagrams that describe the activity of the designed instrument with 4 degrees of freedom were developed. After that, the model will be reused in a simulation environment software to demonstrate its operating behaviour in real-time. ii) An original model of the instrument with 4 degrees of freedom for robot-assisted surgery was designed.

In future work, we will develop Class and Interaction diagrams. The models of the operating behaviour of an instrument-organ interaction in an environment close to the real one can be used in virtual reality training simulators for surgery that allow 3D anatomic model exanimation and better surgical skills.

It will be created as an application using augmented reality which will consist of adding the behaviour of the virtual environment (added Objects) in the interaction of the instrument with the real world. Format conversion of a human liver model will be used to visualize augmented images and video streams, based on work with the designed instrument.

Acknowledgements

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