Project proposals at Altair Robotics Laboratory

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TOPIC 1 - Natural language processing and knowledge management projects

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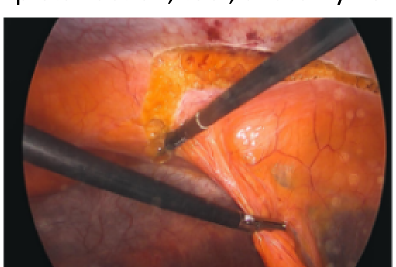
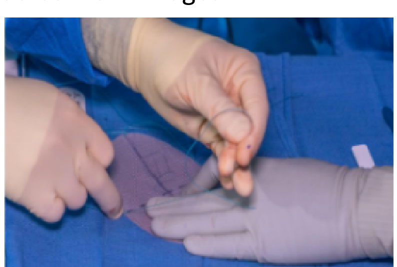
Generative language models for automatic description of surgical interventions videos.

GOAL: This project proposes the use of recently introduced generative language models (https://arxiv.org/pdf/2112.11739v2.pdf) to automatically describe surgical videos frames based on action triples (action, tool, anatomy) recognized in the image (https://github.com/CAMMA-public/cholect45). The student is expected to apply these instruments in the surgical domain and evaluate their performance according to standard protocol/metrics.

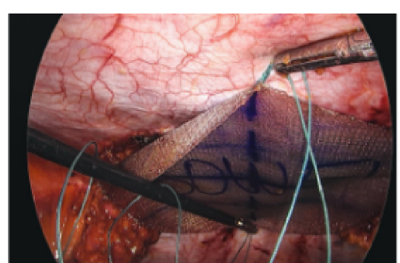
MOTIVATION: The automatic generation of textual description from operative images using deep learning techniques is a fundamental step towards the automatic documentation of surgical interventions. This application is a prerequisite for intra-operative context-aware surgical assistance. For example, the generated natural language sentence can help surgeons to decide how to perform the operation based on the current surgical view. It is an essential component towards building context aware surgical system, which aims to utilize available information inside the operation room to provide clinicians with contextual support at appropriate time. Moreover, when on-site mentoring is unavailable or a rare case is detected, providing intra-operative surgical instructions by expert surgeons is imperative.
However, generating instructions from surgical scenes is challenging, as it requires jointly understanding the surgical activity of current view and modelling relationships between visual information and textual description. Furthermore, surgical data has high heterogeneity even for the same type of surgery due to different surgical skill level, medical condition, and patient specific situation. For this reason, this thesis is of considerable clinical and methodological interest.
To better explain the task, Figure below shows examples of surgical images with below the corresponding caption automatically generated (https://arxiv.org/pdf/2107.06964.pdf) starting from triplets <action, tool, anatomy> extracted from images.



Prediction: retract peritoneum incise with scissors and electrocautery



Prediction: continue tying



Prediction: process completed at first horizontal axis position

WORK PLAN:

1. Literature survey of existing Image to text translation techniques.
2. To test existing models by varying the complexity of input features (with or without action triplets and by enriching them with more expressive information).
3. To find limitations of existing methods and to perform an error analysis.
4. To evaluate extracted sentences in terms of relevancy and their syntactical and semantic quality.

KEYWORDS: Natural Language Generation; Computer Vision; Surgical Data Science

PREREQUISITES: Background in deep learning; python programming

Automatic matching of surgical action triplets extracted from textual descriptions and operative video frames

GOAL: This project aims to find an optimal matching between images extracted from surgical videos and textual descriptions extracted from surgical manuals. The proposed approach is based on the automatic extraction of action triplets (action, tool, anatomy) both from the images (using approaches similar to this: https://arxiv.org/abs/2109.03223) and from the text (using information-extraction models: https://web.stanford.edu/~jurafsky/slp3/17.pdf), which will then be used to find the best matching according to a specific metric (to be identified).

For example, from the sentence “remove the needle cap” the information extraction method should recognize that “remove” is the action and that “needle cap” is the object of action, in this case a surgical instrument. The algorithm should then recognize that a “needle cap” is present in the Figure on the right and thus it should link the previous textual description with it. From the sentence “closing the peritoneum flap with running vlock suture”, the information extraction method should recognize that “close” is the action, that “peritoneum” is the anatomical part and “vlock suture” is the surgical instrument. These entities are recognized in the Figure on the left and the map text-image is then established.

MOTIVATION: Knowing the mapping between concepts expressed in natural language and surgical images is fundamental to improve automatic surgical report generation, clinical decision support system and for integrating multi-modal (language and video sources) knowledge into autonomous surgical robotic systems.

WORK PLAN

1. Review SOTA about information extraction
2. Review SOTA about features extraction from images
3. Implement a neural architecture that recognize action triplets labels extracted from text in images.
4. Evaluate performance

KEYWORDS: Natural Language Information Extraction; Computer Vision; Surgical Data Science

EXTENSION: To link surgical textual descriptions and corresponding operative images with kinematic data extracted using DVRK.

Linking unstructured information contained in written text to existing ontologies for the development of knowledge-based surgical robots

GOAL

The objective of this thesis is the development of an approach for the normalization of robot-assisted surgical entities written in surgical books through an ontology by using word embeddings to represent semantic spaces.

MOTIVATION

Although there is an enormous number of textual resources in the robot-assisted surgical domain, currently, manually curated resources cover only a small part of the existing knowledge. The vast majority of this information is in unstructured form which contains non standard naming conventions. The task of named entity recognition or semantic role labeling, which are the identification of entity names from text or semantic roles respectively, are not adequate without a standardization and linking step. Linking each identified entity mentioned in text to an ontology concept is an essential task to make sense of the identified entities that cannot be performed manually.

WORK PLAN

4. Revise SOTA related to ontology-linking
5. Learn to use ontology management tools
6. Search for all ontologies that contain entities and relationships of interest to the robotic-surgical domain
7. Implement an ontology linking method
8. Evaluate performance

PRE-REQUISITES: python programming. Not essential: knowledge of ontology management tools (e.g., Protegè)

KEYWORDS:
ontology, semantic-web, natural language understanding, autonomous robotics

Commonsense knowledge and commonsense reasoning in robotics: a review

GOAL
The goal of this thesis is to write a comprehensive review of the state of the art on how commonsense concepts are collected, formalized, and used in autonomous robotics.

MOTIVATION
While executing an activity, humans do not only rely on their specific knowledge, but also on a set of “obvious" skills that allow them to intuitively evaluate and react to the events' evolution. Such skills belong to what we call commonsense. It encapsulates those skills that allow human beings to understand, interpret and cope with everyday situations. While general commonsense skills are acquired by experiencing life situations, field-specific commonsense is acquired during apprenticeship and training. Field-specific commonsense is the “glue" knowledge that is not explicitly described in surgical manuals, but it is acquired during the long and articulated training and is essential to carry out complex interventions.
Understanding how to describe, represent and learn this knowledge represents an aspect of paramount importance to develop robust, reliable, high-specialized and autonomous robotic agents.

WORK PLAN
1. Comprehensive review of the literature on commonsense in robotics
2. Experiment with different commonsense management techniques on real scenarios

Interruzione pagina

TOPIC 2 - Computer vision related thesis proposals

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Endoscopic image translation for sim-to-real navigation in Colonoscopy procedure

GOAL: Current state-of-the-art progress in colonoscopy navigation has been achieved using Deep Reinforcement Learning (DRL) in a virtual environment due to its ability to show robust goal-directed behaviours [1]. This project targets to translate the learnt behaviour from the virtual environment to a real clinical setup also called sim-to-real translation. The main challenge in sim-to-real translation is that the DRL trained in a virtual domain has significant shortcomings before its use as an actual robot due to the discrepancies between reality and virtual environments such as image textures, lighting conditions and modeling errors [2]. Hence, this project will develop an Image-to-image translator to convert a real endoscopic image into a simulated image. This will enable the DRL agent to employ the behavior learned in the virtual environment to act in the real clinical setup.

MOTIVATION: Future generations of surgical robotic systems will provide an increased level of autonomy. In the field of intraluminal procedures, such as colonoscopy, the tools used for the intervention have non-ergonomic designs, and it isn't easy to control these instruments precisely as a complex mapping between input and output motion is needed. This drastically increases the cognitive and physical workload of the clinician. Hence, automation in endoscopic navigation will place surgeons in a supervisory position and allow them to focus on critical aspects of medical decisions rather than control of the interventional tool. Data-driven approaches such as DRL have emerged as a viable option to learn robust goal-directed behavior. Current ongoing studies compare the navigation performance of the surgeon with a DRL agent. However, a major drawback of DRL is that they require millions of trial-and-error attempts to discover goal-directed behaviors. Such behaviors are impractical to train in the realistic domain due to safety, ethical and economic constraints. To tackle this issue, some works have proposed to use a sim-to-real approach, where autonomous agents can be trained in a simulated environment, and the learned policies can be transferred when deploying the robotic system in a real environment. These sim-to-real techniques work well when the state space consists of a low-dimensional vector such as kinematic values of the robot and environment [5]. When dealing with high-dimensional state input such as images, the DRL algorithm fails to generalize to a real scenario and, in most cases, shows unanticipated behavior. This is because simulation images have different lighting conditions, textures, and details than real-world images. Deep Neural networks used in DRL learn features specific to the simulated domain and perform poorly when shown real images. An image translator that can convert a real image to a simulated image can enable the agent to act effectively as the agent has been trained on simulated images. During the execution time in the real environment, the raw camera image will be translated to a simulated image, which will act as an input to the DRL agent. The action output by the agent will be applied to the real robotic system.

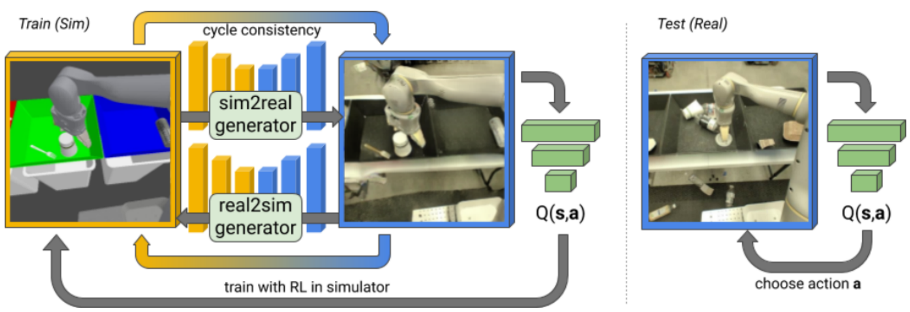

Fig 1: A CycleGAN maps an image from the simulator (left) to a realistic image (middle); a jointly trained

RL task ensures that these images are useful for that specific task. At test time, the RL model may be transferred to real robot (right). Adapted from [3].

Existing works have used CycleGAN loss with an RL loss to train an end-to-end architecture. The project will divide the task into two parts: First, the RL part learns an RL policy in the simulator (this part has already been established) and second, an image to image translation part to map images from simulated domain to realistic (the objective of this project).

Image-to-image translation (I2I) aims to transfer images from a source domain to a target domain while preserving the content representations. Recently, contrastive learning has shown success in unpaired I2I. This project aims to provide a theoretical contribution towards contrastive learning and demonstrate its application on the endoscopic image dataset. The I2I will enable training motion planning methods in simulation and deploying them in real environments. Recent works in I2I for endoscopic videos have promising outputs for fold detection and segmentation in Colonoscopy.

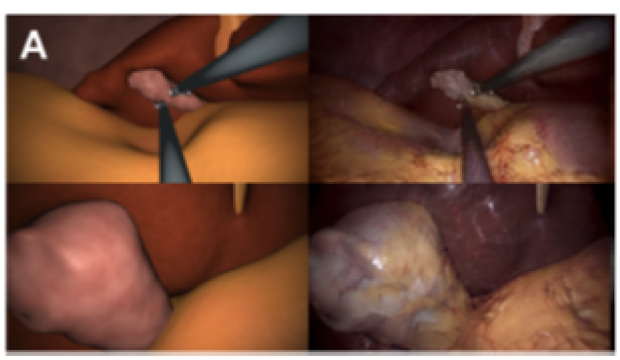

Fig 2: Endoscopic image translation from simulated domain to real images for laparoscopic images. Adapted from [4].

WORK PLAN: Expected project duration 6 months

1. Literature survey of existing Image to image translation techniques:
   https://arxiv.org/pdf/2101.08629.pdf
   This objective involves studying State-of-the-art methods for Image-to-image translation and

identifying their limitations. An in-depth analysis could lead to a theoretical contribution towards a training loss function with better convergence. This step will also provide an overview of the evaluation techniques.

2. Implementing the code for Cycle-GANs and Contrastive learning on standard benchmark dataset: code available on GitHub repository. https://github.com/taesungp/contrastive-unpaired-translation. This step will provide a template code to modify the loss function. Recent advances in representation learning methods could inspire the loss modification step.
3. A dataset of real endoscopic images has been gathered (Some open-source dataset available): https://www.nature.com/articles/s41597-020-00622-y These images would be identified as real-domain images
4. Recording images from Unity scene of Colonoscopy: These images would be identified as simulated domain images
5. Implementing Cycle gans, contrastive learning for a surgical dataset: The code of this project is available https://gitlab.com/nct_tso_public/laparoscopic-image-2-image-translation
6. Combining with RL and performing real robot experiments.

PRE-REQUISITES

- Background in Machine learning and Statistics
- Python programming

KEYWORDS: Sim-to-real, robotic learning, image-to-image translation, reinforcement learning, colonoscopy navigation

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2. Rusu, Andrei A., et al. "Sim-to-real robot learning from pixels with progressive nets." *Conference on Robot Learning*. PMLR, 2017.
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4. Pfeiffer, Micha, et al. "Generating large labeled data sets for laparoscopic image processing tasks using unpaired image-to-image translation." *International Conference on Medical Image Computing and Computer-Assisted Intervention*. Springer, Cham, 2019.
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Human vs machine attention during colonoscopy navigation

MOTIVATION: Navigation using virtually simulated endoscopic image inputs has been used both for clinical training but also for DRL training [1] (please check previous project proposal for more details). However, the application of DRL in the real clinical procedure is hindered by the poor interpretability of end-to-end neural networks (black-box models). Since autonomous surgical systems are high-risk systems, this reduced interpretability places severe limitations on their certification and clinical use. The objective of this project is to shed light on the inner working principles of DRL models by analyzing the image attention areas that are used by the DRL agent during navigation. Furthermore, an additional goal is comparing these attention areas with the pixels attended to by humans while executing the same tasks. This project will investigate two questions:

1. How similar are the visual representations learned by RL agents and humans when performing the same colon navigation task?
2. How do similarities and differences in these learned representations explain RL agents' performance on these tasks?

GOAL: Specifically, we will compare the saliency maps of RL agents against the visual attention models of expert surgeons when navigating the same colon models (with increasingly complexity) in simulated virtual environment. For this, the navigation data of 30 gastrointestinal surgeons with different level of expertise has been collected. This data includes pupil tracking to estimate visual attention. Moreover, current progress in this project has implemented the code for extracting saliency maps of the RL agent.

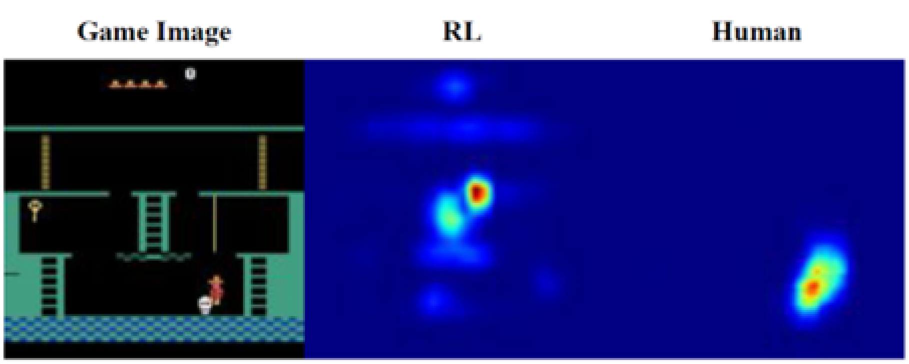

Fig 2: DRL vs. human attention for video games [2]

WORK PLAN: Expected project duration 6 months

1. Use the surgeon pupil data to get the heatmap of visual attention for each frame (Software: Pupilcapture).
2. Compare the statistics of the surgeon heatmap with DRL heatmap, eventually evaluating different methods for extracting the attention map from DRL agents
3. Experiments with different RL setting (to be defined based on the preliminary results obtained in the previous points):
   a. Different RL algorithms
   b. Different hyperparameters

c. Different textures and lightings

PRE-REQUISITES

- Background in Machine learning and image processing
- Python programming

KEYWORDS: robotic learning, reinforcement learning, autonomous colonoscopy navigation, attention models.

REFERENCES

1. Pore, Ameya, et al. "Colonoscopy Navigation using End-to-End Deep Visuomotor Control: A User Study." *arXiv preprint arXiv:2206.15086* (2022).
2. Guo, Suna Sihang, et al. "Machine versus human attention in deep reinforcement learning tasks." *Advances in Neural Information Processing Systems* 34 (2021): 25370-25385.

TOPIC 3 - Image guided percutaneous interventions with medical robotics and AI (soft tissues)

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MOTIVATION: Modern artificial intelligence (AI) have paved the way for powerful computer-aided detection and diagnosis (CAD) systems that rival human performance in medical image analysis and robotics. By combining AI image processing techniques and robotics, we are interested in improving the outcome of the biopsy procedure.

Prostate cancer and breast cancer are the most prevalent cancers in men and women. In 2020, there were 2.3 million women diagnosed with breast cancer and 685 000 deaths globally. As of the end of 2020, there were 7.8 million women alive who were diagnosed with breast cancer in the past 5 years, making it the world's most prevalent cancer. More than 1 million men received a diagnosis of which one third are found to have clinically significant prostate cancer each year worldwide.

Multi-parametric magnetic resonance imaging (mpMRI) is playing an increasingly important role in the early diagnosis of both prostate and breast cancer. mpMRI combined with ultrasound (US) scanning and biopsy for histopathological evaluation are the best method for early diagnosis of breast and prostate cancer. The combination of mpMRI and US during the biopsy is cumbersome and dependent on the operator skills that performs a so-called cognitive biopsy. This procedure could benefit from the integration with a robotic system. By using the robotic system, all the information (tumour location from mpMRI, delicate structures to be avoided from real-time US, the position of the needle by using the robotic tracking and US imaging) may be integrated into the same reference system of the robot, without

the need for the cognitive and subjective assessment. A lot of research was carried out to realize such systems but there is no widely spread robotic system to assist such procedure. The Altair laboratory implemented and tested prostate and breast biopsy systems and is working on a robotic setup to be tested on humans. This setup is divided in the software part mostly intended to assist the vision of the robot through AI solutions applied to medical imaging (mpMRI and US mostly) and to manage the interaction with the user, which is the doctor, while the hardware part handle the medical instrumentation (biopsy probe and US sensor).
The following proposals are referred to the software part of the system but with a close connection with the hardware part.

Tumor extraction and diagnosis from multi-parametric MRI (mpMRI) dataset of the prostate

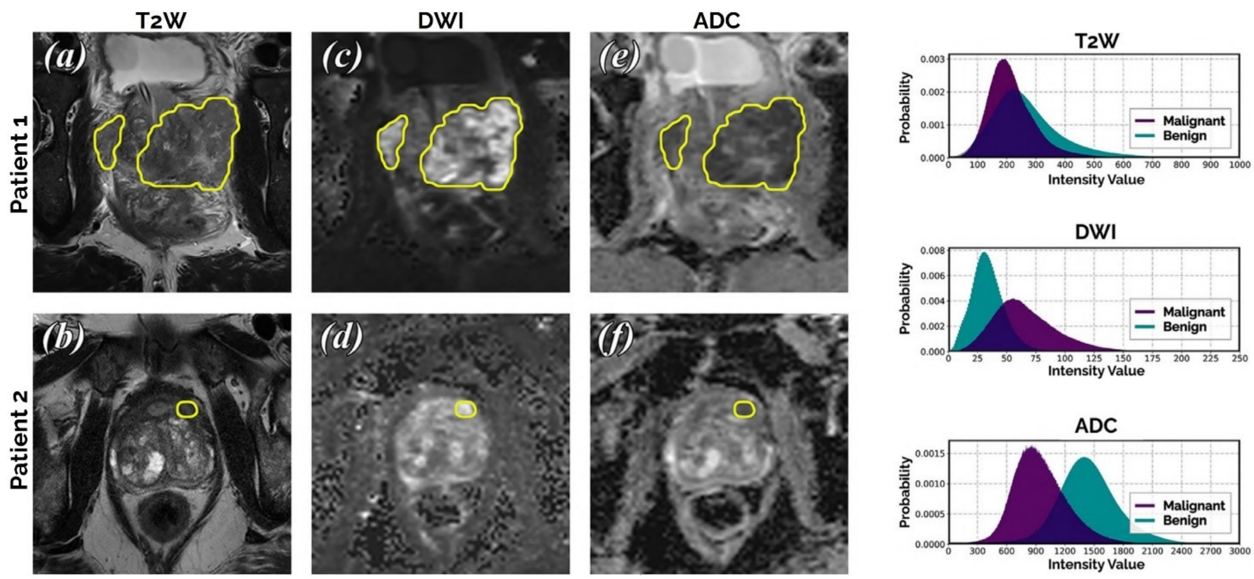

Figure: example of tumors in the same section as seen in MRI with different parameters (mpMRI): a) T2 Anatomic MRI, b) DWI diffusion weighted MRI, c) ADC apparent diffusion map MRI.

GOAL: The student should investigate AI methods (deep learning techniques) and build prototypes for the contouring (segmentation) of the tumour in mpMRI. A database of images with the ground-truth will be available. The ground-truth will contain not only the geometry of the tumour(s) inside the 3D mpMRI but also information about the malignancy expressed as PIRADS score (1 to 5).

WORK PLAN: Expected project duration 6 months. Possibility for a funded scholarship after the fulfilment of the stage/thesis (6 months).

1. Review of literature and testing of the solutions already in use in Altair laboratory
2. Extension of the actual solution with new dataset
3. Implementation of new algorithms to improve the results
4. Integration of the solution in the GUI if the robot

5. Testing of the overall system

PRE-REQUISITES

- Background in Machine learning and image processing
- Python, C, C++ programming
- Computer vision and robotic courses are a plus

Creation of a local map of the prostate for robotic navigation using medical imaging and AI

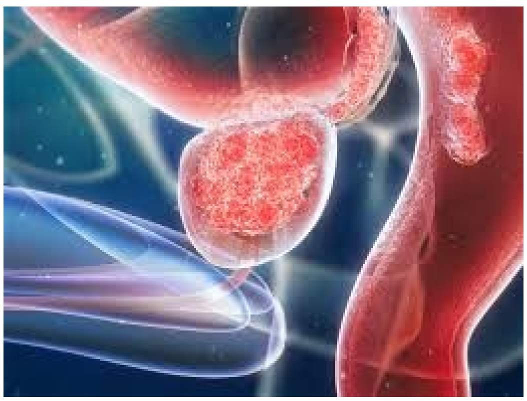

Figure: an artistic rendering of the prostate and the surrounding anatomy

GOAL: The student will work on the generation of 3D models from medical images, especially MRI and US. The models will be generated from the segmentation of the prostate and surrounding structures in MRI in the pre-operative phase (offline) and from the segmentation of the prostate in the US images in the intra-operative phase (online).

WORK PLAN: Expected project duration 6 months. Possibility for a funded scholarship after the fulfilment of the stage/thesis (6 months)

1. Review of the literature and existing methods (supervised and unsupervised)
2. Identify the prerequisites (e.g. ground-truth, type of imaging to be used (e.g. T2 MRI) etc.)
3. Test of the algorithms for the segmentation and generation of 3D models (meshes)
4. Integrate the solution in the robotic pipeline and GUI

PRE-REQUISITES

- Background in Machine learning and image processing
- Medical imaging knowledge
- 3D modelling, computer vision

Project proposals at Altair Robotics Laboratory

Integration of AI algorithms with a GUI software for real-time medical image processing in a robotic biopsy procedure

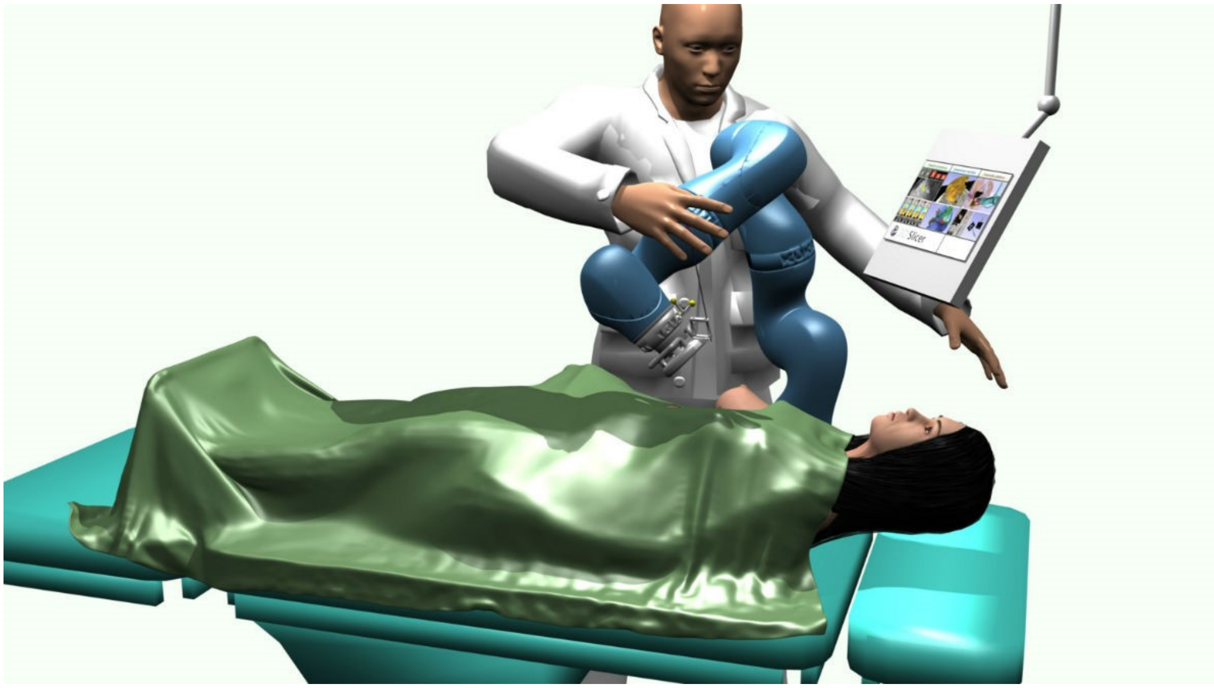

Figure: an artistic rendering of the MURAB robotic system for breast biopsy. The doctor moves a compliant robot manually or through a dedicated interface (right)

GOAL: The student will integrate the AI algorithms developed by the team into the robotic interface with a regard to the real-time constraints. The focus will be on the communication between libraries implemented in different programming languages (e.g. python and C) and on the transmission of large amount of data (i.e. medical images) in a client-server architecture.

WORK PLAN: Expected project duration 6 months. Possibility for a funded scholarship after the fulfilment of the stage/thesis (6 months)

1. Familiarize with the existing solution and interview the people involved about the problems encountered so far
2. Identify different solutions that can bridge between the neural-network (AI) and the robotic platform GUI
3. Implement and test the solution
4. Demonstrate real-time functioning

PRE-REQUISITES

- Strong Python, C, C++ programming skills

- Machine learning and robotic courses are a plus

Medical image registration through deformable models for robotic biopsy of the prostate

GOAL: The student will work on the implementation of algorithms for the simulation of deformation of anatomy (e.g. breast, prostate) under the action of external forces exerted by a robot holding a probe or a needle.

WORK PLAN: Expected project duration 6 months. Possibility for a funded scholarship after the fulfilment of the stage/thesis (6 months)

1. Review of the theory and software implementations (e.g. SOFA) of deformable models
2. Identification of the model and the parameters that best suits our problem
3. Testing in simulation
4. Testing in a physical setup
5. Integration in the robotic platform.

PRE-REQUISITES

- Python, C, C++ programming skills
- Computer vision, image processing at advanced level
- Robotics and AI courses are a plus

Ultrasound image processing for real-time robotic biopsy of the prostate

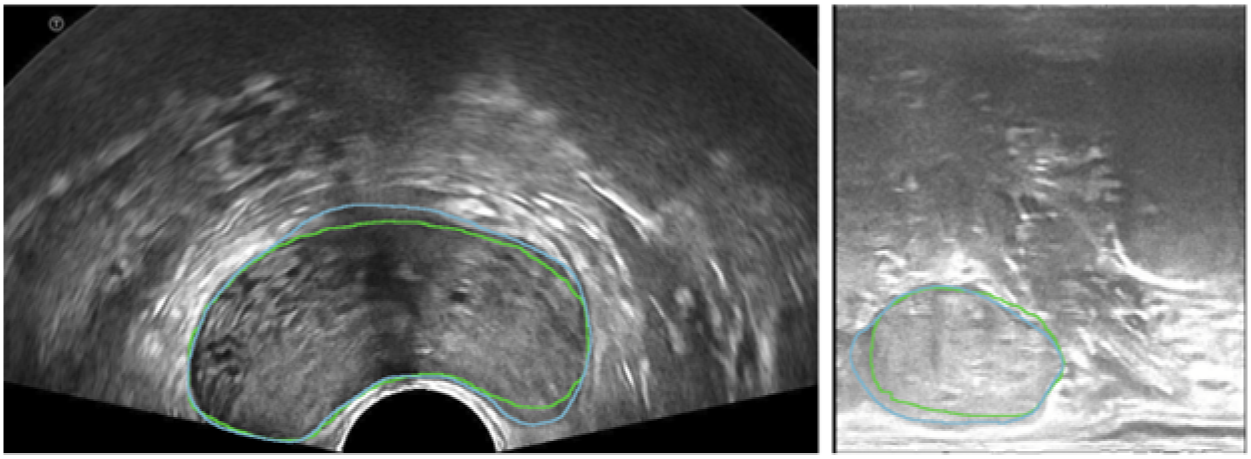

Figure: Prostate as seen in US image with manual (green) and AI segmentation (blue)

GOAL: The student will implement AI techniques at the state of the art to achieve real-time prostate segmentation during an ultrasound guided robotic biopsy of the prostate. The student will work in a team that is developing the hardware part and the user interface software.

WORK PLAN: Expected project duration 6 months. Possibility for a funded scholarship after the fulfilment of the stage/thesis (6 months).

1. Review of the previous work and of literature
2. Define the architecture and the input-output structure
3. Implement and test AI algorithms with high accuracy and real-time performance
4. Integrate the solution in the robotic platform.

PRE-REQUISITES

- Python, C, C++ programming skills
- Machine learning and robotic courses are a plus

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TOPIC 4 - Image guided percutaneous interventions with medical robotics (orthopedy)

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MOTIVATION: In vertebroplasty the precise insertion of a probe is of paramount importance for the success of the intervention and to mitigate the risks. Therefore, the procedure can be managed only by expert neuroradiologists. The use of a robot may overcome this limitation as well as improving accuracy of the needle insertion. The benefits of such a system are based not only on the hardware structure but also on the integration between image analysis software and user interface software. The image analysis software handles the registration between images acquired with different sensors and at different moments of the intervention (i.e. computed tomography before the intervention and C-arm scans during the procedure), while the UI allows for robot planning and the control of the doctor during the robotic procedure.

Registration of C-arm images of the vertebrae with computed tomography (CT) images during vertebroplasty with the robot

GOAL:

Realization of an interface for the management of a robot for vertebroplasty

GOAL:

Interruzione pagina

TOPIC 5 - Micro-Robotics, Micro-Mechanisms, and Robotic Surgery: Perception, Haptics, and Force-Feedback VS Force/Torque Sensors, Actuators, and Cable-Driven Systems

Giovanni Gerardo Muscolo - giovannigerardo.muscolo@univr.it

MOTIVATION: Exteroceptive sensors can increase the physical perception of the robot. Thanks to the implemented sensors, the robot is more able to recognize obstacles and to interact with the environment.
If the user controls the robot, the force-feedback that the robot gives to the user can increase the user's perception of the environment. This is true in robotics, micro-robotics, and in any system in which the robot works controlled by an external user.
In the robotic surgery research field, force-feedback, haptic feedback, and tactile feedback of surgical instruments could be used to increase the surgeons' perception of the patient's body.

Project proposals at Altair Robotics Laboratory

The multidisciplinary use of F/T sensors and actuators, and the complexity to define human-machine interaction, open new challenges to design F/T sensors and actuators for micro-robotics and robotic assisted surgery. In following, some works are proposed:

THESIS_1: Sensors and Actuators for Applications in Micro-Robotics and Robotic Surgery

GOAL: The objective of this thesis is to study some used sensing elements in micro-robotics and robotic surgery (such as Fiber Bragg Gratings (FBG), Strain-Gauges (SG), Capacitive Transductions (C), etc.) in order to propose novel design architectures and models to control F/T sensors and actuators in micro-robotics and robotic surgery.

WORK PLAN: Expected project duration 6 months

- Analysis on the state of the art of sensors and actuators in micro-robotics and robotic surgery.
- Modelling and control of sensors and actuators (using MATLAB®).
- Simulation of the proposed system (using MATLAB®).
- Experimentation with realized prototypes (using ICE lab and Altair Robotics Lab).
- Comparison between simulation and experimentation.
- Discussion and Conclusion

PRE-REQUISITES

- Basic concepts on Control Theory
- Basic concepts on MATLAB®
- Basic concepts on Simulink®
- A Good knowledge on Mathematics and Physics is appreciated.

KEYWORDS: Micro-Robotics, Robotic Surgery, Force-Torque Sensors, Micro-Actuators, Microfluidic Actuator, Micro-Mechanisms, Sensing Elements, Stewart Platform, Surgical Instruments, Parallel Manipulators.

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2. M. Sorli and S. Pastorelli, “Six-axis reticulated structure force/torque sensor with adaptable performances,” Mechatronics, vol. 5, no. 6, pp. 585–601, 1995.
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Project proposals at Altair Robotics Laboratory

THESIS_2: Force Feedback and Haptics in the Da Vinci Robot: study, analysis, and future perspectives

GOAL: The objective of this thesis is to study the force feedback, the haptic feedback, and the tactile feedback as basis to increase the surgeons' perception. The Da Vinci Robot of the Altair Robotic Lab will be used for study, analysis, and experimentation.

WORK PLAN: Expected project duration 6 months

- Analysis on the state of the art on perception, tactile feedback, haptic feedback, and force feedback.
- Design of control architectures for haptic and force feedback (using MATLAB®).
- Simulation of the control system (using MATLAB®).
- Implementation using the Da Vinci Robot (available at the Altair Robotics Lab).
- Comparison between simulation and experimentation.
- Discussion and Conclusion

PRE-REQUISITES

- Basic concepts on Control Theory
- Basic concepts on MATLAB®
- Basic concepts on Simulink®
- A Good knowledge on Mathematics and Physics is appreciated.

KEYWORDS: Haptic Feedback, Teleoperation, Force Feedback, Tactile Feedback, Surgeons Perception, Da Vinci Robot.

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THESIS_3: Cable-Driven Systems in the Da Vinci Robotic Tools: study, analysis and optimization

GOAL: The objective of this thesis is to study the cable-driven systems in the tools of the Da Vinci Robot, available in the Altair Robotic Lab. Simulation and experimentation can give us more info on novel design architectures and controllers for the surgical instruments of the next future.

WORK PLAN: Expected project duration 6 months

- Analysis on the state of the art on cable-driven systems and the used one in the Da Vinci Robotic tools.
- Study, analysis, and design of control architectures in the Da Vinci Robot (using MATLAB®).
- Simulation of the control system (using MATLAB®).
- Implementation using the Da Vinci Robot (available at Altair Robotics Lab).
- Comparison between simulation and experimentation.
- Discussion and Conclusion

PRE-REQUISITES

- Basic concepts on Control Theory
- Basic concepts on MATLAB®
- Basic concepts on Simulink®
- A Good knowledge on Mathematics and Physics is appreciated.

KEYWORDS: Da Vinci Robot, Da Vinci Robot Kit, Cable-Driven Systems, Parallel Manipulators, Mechanics, Control, Applied Mechanics, Micro-Mechanisms.

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