ELEC0145

Robotics in Medicine and Industry

Assignment 1

Year 2025/26

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Guidelines:

- **All deadlines are specified in Moodle**, under the assessment section. Penalties will be applied for late submissions in accordance with the guidelines: https://www.ucl.ac.uk/academic-manual/chapters/chapter-4-assessment-framework-taught-programmes/section-3-module-assessment#3.12

- Please also be aware of **UCL's Academic Misconduct policy**: https://www.ucl.ac.uk/academic-manual/chapters/chapter-6-student-casework-framework/section-9-student-academic-misconduct-procedure. Collaboration with other teams via exchange of ideas, sharing of codes, re-using portions of the reports etc. are not allowed and will be considered as collusion.

1 Assignment 1: Automated Bone Resection

1.1 Introduction

Bone tumour needs to be surgically removed “en-bloc” (i.e. in one piece), because disturbing the tumour (e.g. cutting into smaller pieces would risk further spreading the cancerous cells into surrounding tissue. Traditionally, this is done by either amputation or making straight cuts around the tumour (Figure 1. The part removed will then be replaced by implants where possible, to provide mechanical stability and retain limb functionalities.

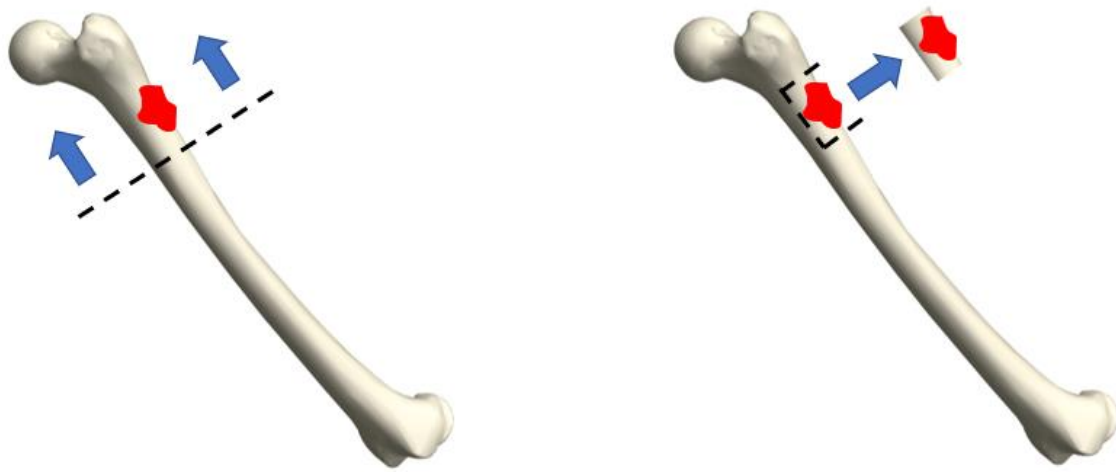

Figure 1: Removal of bone tumour - Amputation (left), straight cuts (right) [1]

Amputation is obviously a very harsh treatment, leading to severe impairment of daily lives. On the other hand, while removing a straight geometrical block around the tumour is an improvement over amputation, a considerable portion of healthy bone is still removed together with the diseased tissue, leading to a long recovery.

Straight geometrical block cuts were necessary in the past, because implants used to come in standard rectangular shapes. In recent years, technologies for additive manufacturing of metal have matured, and it has become possible to produce implants with irregular shapes. The question therefore arise: Can we cut around the bone tumour in a more conformal way (Figure 2), to reduce the removal of healthy bone? The irregular shaped void will then be replaced with a matching 3D-printed implant. This would potentially improve the patient recovery outcome.

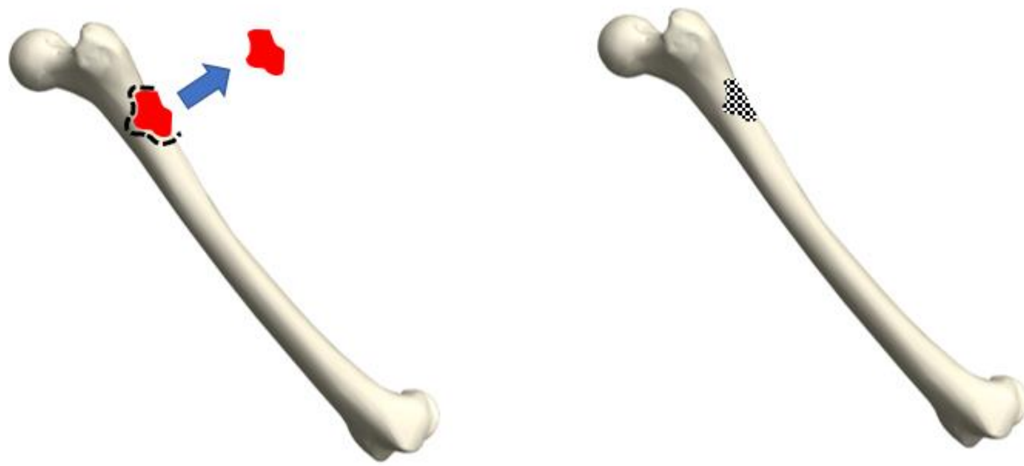

Figure 2: Conformal removal of tumour (left), replacement by conformal implant (right)

In this assignment, you are required to design an automated process to remove tumour from bone. You should first do some literature survey about current surgical tools / technologies for bone resection. Then, you will design new tool(s) incorporating one or more of the surveyed technologies, which could perform conformal bone surgery. Finally, you will also develop the computation aspect of automated surgery, i.e. given 3D image data of bone and tumour, how should the robot and your tool be positioned / moved to remove the tumour in a conformal manner.

This assignment is open-ended, in that there is no right or wrong answer. Your solution will be assessed on how comprehensive it is encompassing all areas of the surgery, and how feasible the solution is – You should "prove" the latter via extensive analysis or simulation. Also, assume that this is a new research idea where the only information you have in consultation with a surgeon is already described above in this brief, so you will need to use your own creativity and engineering judgement to complete this project.

1.2 Task 1: Literature Survey

In this task, you will write a literature survey on bone cutting tools / technologies, namely, what cutting tools / technologies are available on the market or under active research, and what the pros and cons of each are.

The page limit for this task is 3 pages including images / figures, using the font size which will be detailed later in this brief.

1.3 Task 2: Conformal Tool Design

In this task, you will present your design of a tool for conformal cutting of bone. The tool should use one of the technologies you surveyed in the earlier literature review section. Please note that "conformal" doesn't necessarily need to match 100% with the shape of the tumour – This can be approximated by ellipse, spheres, rectangular block, or multiple straight cuts (Figure 3).

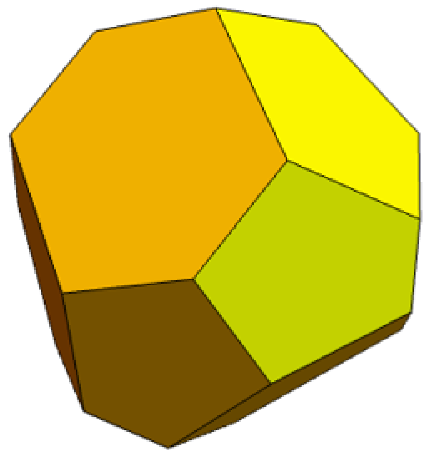

Figure 3: Irregular shapes approximated by multiple planes [2]

Please provide details of your tools e.g. CAD files, and explain how it works on the bone + tumour CAD files given to you on the Moodle page (bones_5.zip). The tumours there are of different sizes and depth, and you should show how the tool is used for each individual cases. The page limit for this task is 8 pages including images / figures, using the font size which will be detailed later in this brief.

(**Side note**: "Tool" here can be either passive or active. "Passive" means that while the tool could have some actuation e.g. to drive the blade, the tool itself does not have extra degrees-of-freedom for position or orientation, and relies fully on the robot to trace out the tumour. On the other hand, "active" means that the tool itself has some motion capability to trace the tumour, for e.g. the tool consists of a 2-DOF mechanism plus the cutting blade, and the complete tool is attached to a 6-DOF robot, therefore the whole system is of 8-DOF.)

1.4 Task 3: Surgical Planning

Now that you have designed your cutting tool, your next task is to propose a surgical plan:

- Assume you are given some imaging data, how do you parameterize the cuts using your designed tool (e.g. position and orientation of the surgical cuts)?
- For example, assume your tool is designed to cut out a rectangular block containing the tumour. How would the position, orientation, width, length and height of this rectangular block be calculated / obtained?
- Please provide the mathematical calculation or algorithm (pseudocode or flow chart) of how the parameterization is done for your tool.
- You should illustrate how your calculation / algorithm work using the Matlab data given on Moodle (TumourData.zip). After you run the code, the variable "VerticesUnique" represents the vertices of the tumour – We can assume that from some imaging data, a segmentation has already been done, and only the tumour data is given.

The page limit for this task is 5 pages including images / figures, using the font size which will be detailed later in this brief.

1.5 What to Submit

- A written report which details the literature survey, tool design and surgical planning, as described in earlier sections of this brief.
- If you have any supplemental material (e.g. Matlab code, CAD model), you should **put this into a separate zip folder**, then submit the zip folder onto the submission point on Moodle. Note: please do not submit .rar file – only .zip is allowed.

1.6 More about the Report

The report will be **marked anonymously**. Please do not include anything which could reveal your identities.

The report should have a cover page clearly indicating the following details:

- Report title.
- Submission date.

The body of the report must be organized under the following section headings:

- Executive summary
- Task 1: Literature Survey
- Task 2: Conformal Tool and/or End-Effector Design
- Task 3: Surgical Planning
- Conclusion

The list of references should appear on separate pages. References should be formatted using the IEEE Citation Style. It is extremely important that all third party sources of information are properly credited and referenced in the correct manner. The inclusion of any text or diagrams from websites or documents must be clearly indicated and referenced.

Font size should be exactly 11 points. Recommended font type is Calibri or Arial. Text should be both left and right aligned (justified text). All figures should have captions, axes labels and legends where appropriate. Curves should be distinguishable even if printed in black and white.

1.7 Marking Criteria

This assignment contributes 40% to the overall score of the module. The marking criteria are described in the following table:

	Criteria	Mark Weight
Task 1 – Literature Survey	Evidence of reading a wide range of literature, clear evidence of critical thinking, good organization.	8%
Task 2 – Tool and/or End-Effector Design	Clear details of tool and/or end-effector and how it works. Solution is feasible and can be implemented in real life.	16%
Task 3 – Surgical Planning	Clear explanation of how parameterization of cuts are done, supported by mathematics.	12%
Report (Format)	English syntax and style, general organization and formatting, figure, table and equation presentation and use, literature citations are use all appropriate.	4%

1.8 Peer Review

Your group will receive a group mark for this assignment. This will be done at the end of the term, where the peer review will cover all group elements in this module.

Individual students will then receive a different mark based on peer review. In the peer review (which will happen at the end of the term), you will be assessed by your team members on your attendance, effort, communication, contribution, respect, collaboration and standard of work.

The calculation is as follows:

- Group mark: Numerical score out of 40 (e.g. 30)
- Peer Review: Average percentage given by other students (e.g. 70%)
- Individual mark = Group mark x Peer Review (e.g. 30 x 70% = 21)

Note: Peer review submission is **compulsory**. Students who do not submit the peer review will have their individual peer review score capped at 70%.

You will be using the following peer review rubric:

Criteria	**No submission (0%)**	**Poor (40%)**	**Satisfactory (70%)**	**Good (100%)**
Attendance to meetings.	Never turns up to meetings.	Miss several meetings or late to several meetings, without notifying teammates.	Always attend meetings but late for several times. Teammates notified if cannot attend or late (with reasons provided).	Always attend meetings, always punctual. Teammates notified if cannot attend (with reasons provided).

Participation during meetings.	No participation during meetings.	Seldom actively providing suggestions, ideas, comments. Seldom participate in discussions. Seldom respectful to other students' ideas.	Actively providing suggestions, ideas, comments most of the time. Participate in discussions most of the time. Respectful to other students' ideas most of the time.	Always actively providing suggestions, ideas, comments. Always participate in discussions. Always respectful to other students' ideas.
Contribution to project and standard of work.	No contribution to the project.	Minimal contributions, frequently needs help from others.	Works independently but quality is not very high, needs some help with work.	Excellent quality of work, can work independently and able to help others if needed.
Communication	No communication at all.	Huge delay in replying messages / emails. Huge delay in seeking help, thereby delaying progress badly or create huge stress towards deadline.	Slight delay in replying messages / emails. Slight delay in seeking help, thereby delaying progress slightly or create some stress towards deadline.	Keep others up-to-date with the progress. Seek help early on (if needed) so as not to delay the project or create stress towards deadline. Fast in replying messages / emails.

1.9 Reference

[1] The original image of the bone by unknown author is licensed under CC BY-SA.

[2] The original image of the irregular 3D shape by unknown author is licensed under CC BY-SA.