Aim:

1. Create a radiotherapy treatment plan using a computerised TPS (Treatment Planning System).
2. Perform treatment planning using various modes (e.g., photons, protons, etc.) of treatment and using different setups of beams to find the best treatment plan.

Apparatus Requirements:

1. A computer with MatRad software.
2. DICOM image of the Patient.

Theory:

The most common type of radiation therapy is external beam therapy, which is characterised by directing ionizing radiation from the outside into the patient's body. Treatment planning is an integral part of radiation therapy treatment, performed before the actual patient treatment using specialized software. The treatment planning process aims to simulate the dose deposition within the patient's body and to optimize the dose distribution according to clinical objectives and constraints that define a trade-off between tumour irradiation and normal tissue sparing. Treatment planning can be categorized into two parts: forward planning and inverse planning. In the case of forward planning, all the parameters like beam angle, field size, and dose per field are decided by the Medical Physicist and the best-optimized plan can be achieved by changing the above parameters manually. In the case of inverse planning, the TPS generates a best-optimized plan based on the dose and dose constraints given to it. Inverse planning is done for Intensity Modulated Radiation Therapy techniques.

We are using MatRad, an open-source dose calculation and optimization toolkit for intensity-modulated radiation therapy with photons, scanned protons, and scanned carbon ions. MatRad is entirely written in the interpreted numerical programming language MatLab and covers a wide range of functionalities from DICOM import, dose calculation, and dose optimization to plan visualization. The MatRad code base comprises the open-source CORT dataset, i.e., three-segmented patient CTs and two phantom CTs. It provides the data as MatLab files, organized in the matRad data structures ct and cst. Furthermore, own patient data may be imported via a DICOM import interface based on MatLab's image processing toolbox or via custom import interfaces for binary data formats (e.g., NRRD). MatRad's DICOM import functionality allows importing CT images, radiation therapy (RT) structure set, RT Dose, and RT Plan files. A Hounsfield unit look-up table (HLUT) is recommended and can be provided in the directory .../dicomImport/hlutLibrary. Specifically, HLUTs need to be accessible by matRad to convert Hounsfield units to electron densities relative to water in case of photon dose calculation or to relative stopping powers of water in case of protons or carbon ions. If no HLUT can be found for the corresponding CT, a generic table will be used independent of the radiation modality.

Some of the Software Parameters:

Bixel width: It is an element used for constructing the target.
Gantry and the couch angles: This sets the direction of the beam entry to the patient. In any case, the values of the couch angles are blocked intentionally in this simplified version of the software by the developers.
Radiation mode sets the type of beam (photons or charged particles: protons and carbon ions) used for the treatment planning of therapy.

Number of fractions: The number of fractions of the total dose prescribed in the objective and constraints panel is divided.
Running sequence: This is used to shape the target area with the help of a collimator.

The isocenter is the point from which the central rays of the irradiated beam pass, and it is automatically verified. In the visualization panel, we have the button for the slices illustrated in the 3D image, and by clicking on the right or left choice of the slice selection, one can slide and obtain a specific slice (the isocenter sign, complete X sign). In addition, there is a plain selection button with the choices of axial, sagittal, and coronal. Important is the visualize plan/beamlines button, which enables a deeper understanding of the different angles of the irradiation.

In the centre, we have the viewing panel where the 3D image of the irradiated region will appear. On the right-hand side, the structure visibility will provide the names of the illustrated organs. Regarding the workflow panel, there is the Load mat data button (click), which loads the data of each case (describe data cases, C-phantom-> a specified acrylic-shaped testing sample used by profs for testing the equipment) and information about the target tissue and the surrounding healthy organs. The objectives and constraints panel are enabled after inserting the data for each case, showing the organs of interest (e.g., target), as well as the organs at risk (e.g., body, core, etc.) that are about to be irradiated and we want to avoid obtaining more doses. The next button in the workflow panel calculates the matrix of influence (of radiation) button (click), with which the software algorithm analyzes the dose distribution in the shaped tissue formed by pixels in cubic size. Afterwards, the optimize button (click) finds the minimum radiation flux per pixel and illustrates an exponential graph. Our calculations must be saved in the Graphical user Interface by clicking the Save to GUI button (click and describe the saved form). The last one is the Dose Volume Histogram button, which depicts the dose deposited in the target volume and OARs.

<u>Procedure:</u>

1. Select any patient data (e.g., head and neck, prostate, liver, etc.) from the phantom directory.
2. Generate a treatment plan for 2Gy per fraction using photon beam modality. Use 3, 5, 7, and 9 beam angles and the following constraints given by QUANTEC (link below). Change the constraint values to generate an optimized treatment plan.
3. Link for dose constraints: [Radiation Oncology/Toxicity/QUANTEC - Wikibooks, open books for an open world]
4. Compare the DVH data obtained in each plan and find the best treatment plan.
5. Repeat the planning for proton beams.

Things to care about during optimization:

2. MatRad's dose influence matrix calculation algorithms are split into two parts: First, we determine the irradiation geometry by generating the steering information for the desired beam setup. In the second step, we generate dosimetric information by pre-computing dose influence matrices for inverse planning. The dose deposition of each beamlet for unit intensity is being calculated.
3. Optimizer optimizes a nonlinear optimization problem using an algorithm. The objective function and constraint functions are built from the specific objectives one can set in the table. The goal of the optimization is to find a set of bixel/spot weights that yield the best possible dose distribution according to the clinical objectives and constraints underlying the radiation treatment. The objective function converges while the number of iterations increases, showing a better approximation to our calculation.
4. Radiation zones: The red zone is highly irradiated, the blue is not much irradiated, and the gray zone is not irradiated.