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Software for the Use of Multi-Modality images in External Radiotherapy

SEVENTH FRAMEWORK PROGRAMME

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1. Preface

This report takes the technical annex (annex I) of the Contract as background. The document is meant to provide some initial guidance for platform choices, interfaces, abstraction layers, software modules, communication and collaboration.

2. Introduction

This section provides an overview of a high-level system architecture which accommodates RT planning preparation by determining precisely the biological target volume and a short introduction to the various components involved in such a system.

2.1. Overall system architecture

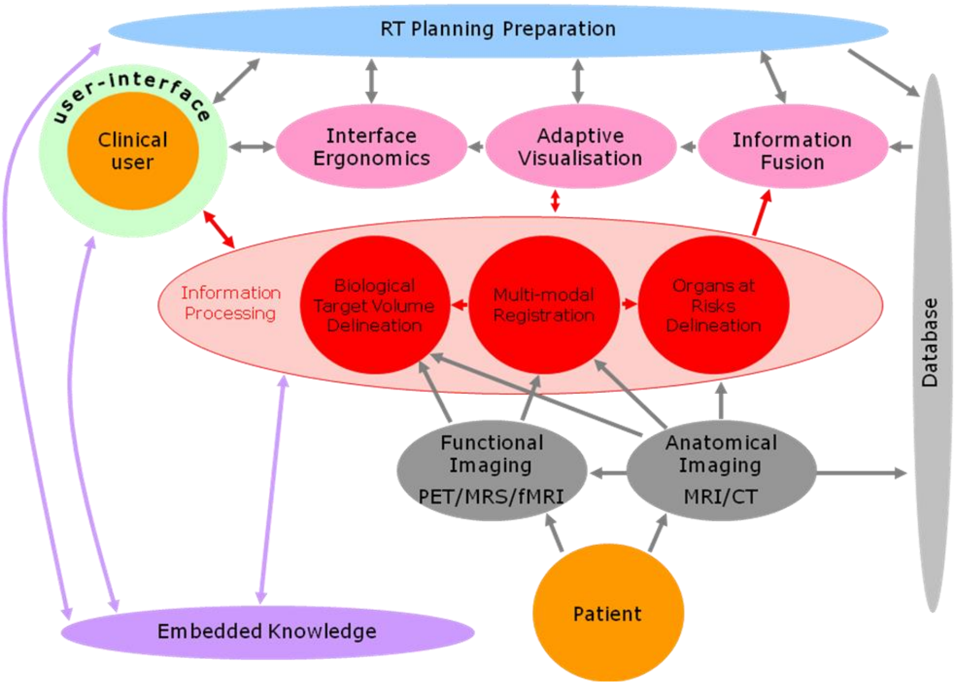

Figure 1: Overall system architecture

Figure 1 demonstrates the overall architecture of a general system for radiation therapy planning preparation using multi-modal images. The next few sections give brief descriptions of the specific components involved in such a system.

2.2. The patient

The patient is the primary source of information in the total system. Since the challenge for radiation therapy is to reach the highest probability of cure with the least morbidity, the patient is the centre of attention in such a system design.

2.3. Database

A large database will be generated by the different clinical-focused teams of the consortium, again of complementary type (physical or numerical phantoms, patient data, with or without respiratory gating). This reference database is essential to test and validate the developed methods and the platform at each step of the development.
For each patient dataset of the database, a case description document will be made available, including information regarding 1) the patient demographics and clinical details, 2) its medical condition, 3) the series of image and contours available (details on acquisition protocol, details on imaging purpose and

clinical findings), 4) the treatment, 5) the use of the dataset within the scope of the SUMMER project, and 6) the tumor location (few screenshots). The case report does not exceed 2 pages.

2.4. Anatomical Imaging

In radiation therapy, treatment planning is traditionally based on computed tomography (CT) and magnetic resonance imaging (MRI). These radiological investigations have the significant advantage to show the anatomy with a high resolution.
These structural imaging are typically used, registered to other modalities, to precisely locate the tumor. And, due to their high definition of anatomical parts, they are also used for the delineation of the organs at risks.

2.5. Functional imaging

Anatomical imaging has its limitations in tumor affected structures of normal or equivocal morphology like lymph nodes for instance. In order to complete information given by CT and MRI, functional images will be used to visualize metabolic pathways and information on tumor biology.
Positron-Emission Tomography (PET) used with a FDG tracer shows the glucose metabolism that is increased in most solid and lymphatic malignancies, such a metabolism is not visible on a CT. Magnetic Resonance Spectroscopy (MRS) can provide metabolic map of a lesion and is able to distinguish recurrent tumor from radiation necrosis or radiation injury. Finally, fMRI (functional MRI) is mainly used in brain affection, to monitor growth and function of any remaining brain tumor following the treatment.

2.6. Multimodal Registration

Non-rigid image registration is a fundamental task in medical image processing. Among its most important applications, one may cite multi-modality fusion, where information acquired by imaging devices or protocols is fused to facilitate diagnosis and treatment planning or to align temporal sequences of images to compensate for motion of the subject between scans; pre and post treatment (potentially with large deformations) image fusion, in order to see the treatment progress.

2.7. Biological Target Volume Delineation

The challenge is RT treatment is to have the most precise contour of the lesion, in order to optimize dose distribution. This component incorporates methods for automatic and semi-automatic segmentation of the biological target volume, based on functional and structural images.

2.8. Organs at risks Delineation

In the same way, a precise knowledge of the organs at risks' position will ensure a minimal dose delivery and consequently minimal side effects due to the radiation. This component consists of the development of automatic methods for the segmentation of organs at risk delineation.

2.9. Information fusion

All the previously defined segmentation methods will produce different delineation results. Information fusion consists here to find an intelligent method producing a kind of consensus between all the generated contours identified in different modalities, in order to present a final result to the user.

2.10. Adaptive visualization

Adaptive visualization involves tasks such as providing a re-usable, extendable and scalable rendering framework implementing the different concepts, but also investigating a data specific (CT, MRI, MRS...) and task specific (BTV, OAR delineations...) visualization for multi-modal images.

2.11. Interface ergonomics

This task consists of improving human computer interfaces through ergonomic researches. By establishing user requirements, gathering focus group to extract expert knowledge and collecting needs of clinical users, intuitive presentations and mechanisms can be designed to test the integrated demonstrators.

2.12. RT planning preparation

This component refers to the final objective of the project, i.e. the planning of the radiotherapy treatment. Once the biological target volume is well delineated and the organs at risks are well-localized, the dose to be delivered can be planned by the specialist.

2.13. Clinical user

Second to the patient, the most important element of the system is the clinical user. The user interface and workflow design will be user centered as described in Annex I of the Contract.

2.14. Embedded knowledge

This system component refers to any information encoded into the system to provide embedded knowledge skills. The embedded knowledge will be distributed in various components.

3. Platforms, modules and interfaces

The most important is to create a working environment which is comfortable and easy-to-use for the researchers. All the following tools have been chosen in order to facilitate the work and the cohesion between the partners.

3.1. Team collaboration software: Confluence

The Confluence team collaboration software has been chosen to create a common exchange platform for the SUMMER researchers to create, share and discuss content. The platform contains information about:

- The SUMMER project
    - detailed information concerning each of the 9 working packages
    - an overview of the project progress, in terms of deliverables and milestones
    - planned secondments and partner visits
    - important conferences in the field, planned attendance, brief summary of interesting lectures/abstract/posters potentially
- Each individual researcher
  Weekly or monthly, each researcher indicates the status of his/her research, as well as the expected work to be done in the coming weeks and possible deadlines. This way, other users have the possibility to follow each researcher working progress, and it contributes to a better collaboration and planning.

3.2. Operating system and programming language

During the development phase, each researcher is free to choose its operating system (Windows or Linux), development platform and programming language. However, it is highly recommended to start developing software following final prototype requirements. To be integrated, the software must be implemented in C++ and run under Windows 7 64-bits operating system, for memory management reasons. Compatibility is the responsibility of each researcher.
Please refer to Section 4 for additional details about machine specification.

3.3 Platform: MITK

One of the challenges of the project was to find a common development platform in order to standardize the work of each partner. The choice of this platform is important and the platform should be easy-to-use in order to provide a unique prototype combining all the developments at the end of the project.
The Medical Imaging Interaction Toolkit (MITK) has been selected. It is a free open-source software system for the development of interactive medical image processing tools. MITK combines the Insight

Toolkit (ITK) and the Visualization Toolkit (VTK) with an application framework. As a toolkit, MITK offers features that are relevant for the development of interactive medical imaging software such as segmentation and registration tools.

3.4. Software modules

This list comprises some of the software modules which are needed in the final system. It is by no means an extensive list since all of the requirements of the final system are not known at the time of writing.

Toolkit / Library Name	Purpose
ITK Insight Segmentation and Registration Toolkit	a toolkit that provides developers with an extensive suite of software tools for **image analysis**.
VTK Visualization ToolKit	a toolkit that provides developers with an extensive suite of software tools for **image visualization**.
Boost	a collection of class libraries for C++ (from math to threading, built on Standard C++ and highly portable)
Qt	a development framework with tools designed to streamline the creation of applications and user interfaces for desktop, embedded and mobile platforms.
CTK Common ToolKit	a toolkit combining VTK and Qt to propose DICOM, DICOM application hosting, widgets, and plugin framework.
GDCM Grassroots DICOM	a C++ library dedicated to reading/parsing and writing DICOM medical files
DCMTK DICOM Toolkit	a collection of libraries and applications implementing large parts the DICOM standard for examining, constructing and converting DICOM image files
OpenCV Open Source Computer Vision	a library of programming functions for real time computer vision
OpenCL Open Computing Language	a framework for writing programs that execute across heterogeneous platforms consisting of central processing units (CPUs), graphics processing units (GPUs), digital signal processors (DSPs) and other processors

3.5. Sharing source code and documentation

A subversion server (SVN) has been set up to manage the consortium code base and documentation. The repository can be checked out from [**PRIVATE**].
A user with read-only access to the repository has been added to the system so that all SUMMER members can browse the repository. The username and password are:

username: [**PRIVATE**]
password: [**PRIVATE**]

All members of SUMMER who are involved in the development of software will get a user with read-write access to the repository.
An MITK project has been created for SUMMER, where modules and plug-ins developed by the researchers can be shared. To prevent the project from being corrupted, MITK module or plug-in are added to the SVN only once their stability has been tested by the researcher.

3.6. Data Structure

A data structure has been created in order to standardize the different developments. This structure shall be the reference for all the developed functions. That means inputs and outputs of functions shall be in this format for images.
The structure is divided into three parts:

- A first class Volume3D defines how the 3D volume is stored in the memory (a tridimensional array of float stored in z, y, x). It gives access to a pointer on the volume (VoxelArrayConstRef dataArray()), the size of the voxels (in mm), the dimensions of the volume (in voxels) and the registration matrix if needed.

- A structure FrameInfo stores information about each frame to load in volume3D.
- An additional function (LoadVolumeFromDicomFiles) has been created in order to load a volume from a list of DICOM files. It first reads each DICOM files and stores each FrameInfo in a list in order to create the Volume3D. Finally, the function LoadVolumeInVTK converts the Volume3D in VTK type vtkSmartPointer<vtkImageImport>.

3.7. Data format

The DICOM format is the standard format for most medical images.
CT, PET and MRI (T1, T2, FLAIR, perfusion, EPI, DTI) are using this format to encode the images.
New imaging techniques, such as MRSI, have a DICOM format described in their standard. However, this DICOM format is not always applied by the manufacturers. Consequently, MRSI data are saved in vendor specific format: .RDA for data acquired with a Siemens machine, .SPAR/.SDAT for data acquired with Philips machine.

3.8. Data exchange

AQUILAB Share Place will be used to centralize the data from the different partners, constituting the database for the project. The project members will use this secured solution to share and exchange any data.
Share Place includes an exclusive technology that ensures state-of-the-art encryption and security, automatic DICOM/DICOM-RT anonymization and robust capabilities to save, retrieve, and trace any data in a secured environment.

4. Machine specifications

4.1. Hardware

In order to successfully install the SUMMER prototype on a machine, the machine must have the following configuration:

- GeForce Nvidia graphic card with min. 2GB GPU memory and supporting CUDA 3.0
- Quad-core processor
- Min. 16 GB CPU memory
- Mouse, keyboard

Extra peripherals remain to be selected, depending on feedback from user-study. Those may include: graphic tablet, touch screen, leap motion, tablet.

4.2. Software

Beside the software / toolbox / library presented in **3.4**, the following software may be required.

Software	Motivation
C/C++ Minpack	To solve NLLS optimization problem related to MRSI spectra quantification
Peripheral specific software	To make different peripherals usable