Human-Computer Interaction Application to Aid with the Initialization for Active Shape Modeling

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Abstract. Active Shape Modeling (ASM) has become a commonly used method to identify and compare structural image content such as organs or parts of the brain. ASM algorithms are often sensitive to image noise or can produce inaccurate results if the initial shape placement is imprecise. To overcome these limiting factors, it is important that the initial shape placement is as precise as possible. The goal of this project has been to develop an imaging application that eases and improves the initial shape placement. It aims to improve the human-computer interaction (HCI) by providing an easy to use user-interface and thus to hopefully provide the user with faster, better results. The motivation for the development of this tool has been that more precise initial shape placements may lead to improved results from ASM algorithms.

1 Introduction

In many of today's applications the interaction between the user and the application is very important such as providing adequate feedback as well as having a natural and intuitive design. This essentially determines the success of a software product. This project focuses on bringing the right amount of human-computer interaction (HCI) together with the functionality needed for the obtaining a good initialization transition matrix for active shape modeling (ASM).

This paper provides introductions to human-computer interaction, active shape modeling, and presents an application that is based on the HCI design methodologies and aims to provide better initializations for ASM algorithms.

1.1 The Problem

The problem on hand is that currently the initialization for active shape modeling is a tedious and time consuming process. It takes an experienced user multiple tools to produce a good initialization transformation. For isolated tests this might still be acceptable but for an extensive amount of test data, this manual technique soon becomes hindering and unacceptable. From this the need for an all-in-one tool emerged that can help the user perform the initialization process in a natural and intuitive way even for the most novice user.

1.1 Motivation

As stated in the above paragraph, the motivation for this project emerged from the need to have an all-in-one software application that aids the user with the initialization process for active shape modeling. Although this being the main motivation, there are other driving forces behind the project such that more precise initialization transformation information might potentially result in better results from the active shape modeling algorithm. These could theoretically be achieved because of better initialization transformations for the point distribution models and should lead to better active shape modeling results. Figure 1 shows example of a good (left image) and bad (right image) placement for the initial point distribution model.

Further there seemed to be a need for a semi-automatic solution that would allow the user to initialize a large number of data containing similar content. It would be of advantage if the user could simply apply the current transformation information to all data sets, and then would only have to do individual fine tuning. This would increase the initialization efficiency tremendously.

Last, the motivation was to develop a tool that would provide the user with real-time feedback such that all changes to the position, rotation, and size of the point distribution model would be available instantly through axial, coronal, and saggital views as well as through a 3D volume view of the MRI image and point distribution model rendered inside.
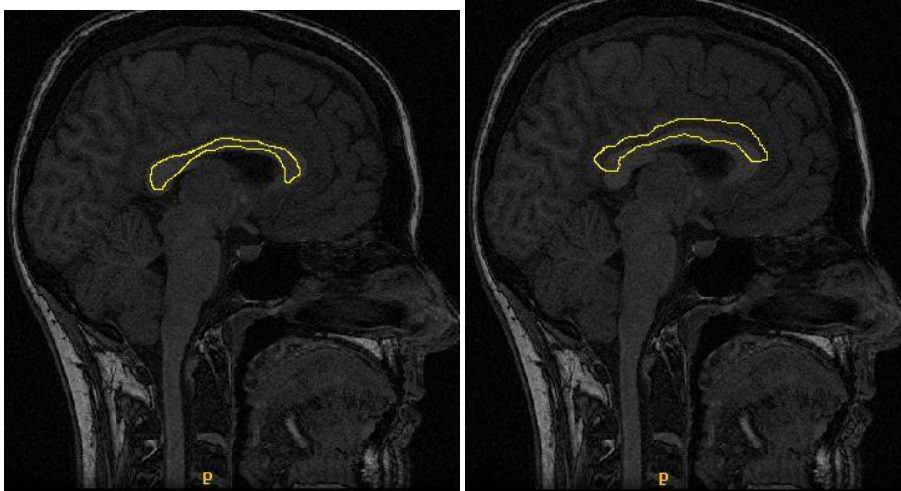

Fig. 1. The above images show the outline of a point distribution model placed on a single slice from the MRI image. The left image shows a good placement, inside the shape, which will most likely lead to good active shape modeling results. The right image shows an improper placement, some outside the shape and overlapping, which will most likely lead to results not as good as the ones from the left, good placement image.

2 Human-Computer Interaction (HCI)

Human-Computer Interaction, alternatively man-machine interaction or computer-human interaction, is the study of interaction between people (user) and computers [4]. It is a subject that is not only studied in computer science but more a multi-disciplinary subject, studied in many different fields such as for example ergonomics, social psychology or computer vision. The tool that this project aims to produce largely relies on user interaction and in specific a well designed user interface which is exactly what the study of human-computer interaction is focused on. The study pertains to software as well as hardware user interfaces. Any developer who aims to create user interfaces that are natural in feeling and intuitive in use will adhere to the key ideas of human-computer interaction. In addition to this, it has to be useful to all users, expert to novice, thus not limiting it usability to a certain clientele. The developer has to find the right mix between these four key components to achieve the best design possible.

2.1 Design Methodologies

A number of diverse methodologies outlining techniques for human–computer interaction design have emerged since the rise of the field in the 1980s [4]. Over time the methodologies have changed due to the requirements by systems and users but also by the increasing availability of computing power. Today's methodologies are mostly focused on constant feedback to the user, largely due to wide availability real-time systems, as well as focusing on the user's needs for individual aspects of a system instead of creating one complete user experience for the entire system. Two main components of today's design methodology are "User-centered design" and "Principles of User Interface Design" as described in [4]. User-centered design is mainly concerned with the part that users should be the main focus of any computer system design and collaboration between developers and users is necessary to achieve this. The principles of user interface design address topics such as simplicity, affordance and consistency during the design stage.

2.2 HCI and Automation

In the paper [1] a number of different techniques are described of how human-computer interaction can be combined with automation to meet the needs of a specific application. The level of user involvement varies for different degrees of difficulty of the problem at hand but it is always necessary to choose the level of automation based on the quality of results required by the clientele.

The method with the fewest user interaction can be applied to simple tasks for which for example reliable algorithms are available. In this case, the user simply has to confirm at the end to whether or not a result is satisfactory and if so accept, otherwise reject it.

At the next level, the user is presented the results and in the event that they are not satisfactory, the user is given the option to review the results and if necessary to make changes or to accept the initial results.

At a higher level of user interaction, the user is given the option to review and evaluate the results and if not satisfactory rerun the automation with altered parameters. This can be repeated until a sufficient solution is found.

The most advance level of user interaction which is also the least automatic one, gives the user constant feedback and allows to control the process from the beginning to end to achieve correct results every time. This approach is also called user-steered [1]. The user-steered approach was chosen for this project as it gives the user the most control over modifying the position, rotation and size of the point distribution model and immediately seeing the changes. The approaches described above will help produce products (software or hardware) that give the users a higher quality of interaction as well as better results tailored to the specific problem.

2.3 How does Automation apply to Medical Imaging

In medical imaging many tasks are redundant such that once performed for a number of instances, the computer should be able to pick up pattern and use these information to automate the process of whatever task it might be. For example in image segmentation, to repeat the segmentation of pixels on large sets of images could take numerous hours if not even days. With the resource available today and as the processing resources of computer advance, automation of digital image segmentation can be performed with higher accuracy, repeatability, and efficiency [2]. The same automation can be applied to the problem with initialization. Given a large number of image sets having all similar image content, automation should enable the user to take one manual point distribution model placement and apply this transformation to all remaining images in the set. This would increase the efficiency vastly and still preserve the accuracy required for the initialization process by quickly evaluating each placement in the remaining set without the hassle or starting over every time. Combined with the appropriate level of user interaction, automation can be efficiently implemented into medical imaging methods to bring out the full potential of human-computer interaction [1].

3 Active Shape Modeling

Active Shape Modeling is a widely used application in the area of image processing. It is used for such tasks as facial identification, computerized verification such as used at assembly lines, or medical imaging. There are also different methods available for 2D and 3D active shape modeling. In this project, the image content will be CT or MRI image series which are analyzed for the shape of certain objects.

3.1 Specifics about ASM

Active shape models are statistical models of the shape of objects which iteratively deform to fit to an example of the object in a new image [3]. The models are initially represented as point distribution models which have points that outline the shape. Usually the point distribution model is the mean shape of an object of a series of previously analyzed images with similar content or historical data from previous output from active shape model algorithms.

The goal of active shape modeling is to match the current model to a new image. The process is as described in [3]. Search for a point in the neighborhood for the current point. Determine the best match based on all points found. The strategy on which the selection of the best match is based varies with the algorithm. For example it can be based on strong edges in the image or on statistical information to what kind of point is expected.

3.2 Initialization

The main focus of the tool developed in this project, is to improve the initialization for active shape modeling. This is the main reason because by achieving a more precise transformation of the point distribution model, the active shape modeling algorithm might achieve better results. The initialization is so important because the better the initial model is placed into the new image, the easier the algorithm can deform into the proper shape for that specific image. The best possible initialization would be one that is completely inside the desired object. This way the active shape modeling algorithm only has to detect the edges of the shape correctly. In the event that the placement is partially outside, the algorithm might use a different edges for the new model boundaries.

4 Application

The focus of this project is as mentioned in the introduction to provide a tool tailored specifically to the needs of the initialization process for active shape modeling. Throughout the design progress, the methodologies presented earlier about human-computer interaction have been taking into close consideration to develop a tool not only serving its purpose for precise initialization but also to provide the user with a graphical interface that allows efficient work through simple, intuitive steps. This section gives an overview of the technologies used to build the application, the current features as well as some intended future functionality.

4.1 Technologies

From an early point, it was important to use a set of tools that are powerful, relatively easy to work with for the developer and provide a common set of features such as providing image loaders, visualization rendering, or graphical user interface compo-

nents. This was essential because this would allow more focus on the specifics needed to make this project successful. A set of software libraries was chosen to provide the foundation for the application.

Two of the software libraries are by Kitware, Inc. but are distributed as open source. One is the Insight Segmentation & Registration Toolkit (ITK) which is mainly used for some of the underlying computations. The second library is the Visualization Toolkit (VTK) which is used for rendering and loading the image as well as point distribution model files.

A third library package called the Fast Light Toolkit (FLTK) is used to provide support for the graphical user interface. It is available as open source under the GNU license agreement.

All three libraries are C++ class libraries and can be used on almost any operating platform. This is another advantage of these three libraries – cross platform compile capabilities which allows the tool to be used by a broader audience.

4.2 Intuitive Program Flow

As described earlier, the goal was to provide a tool based on the HCI methodologies and having created a user-steered semi automatic application, only a limited number of steps are required to complete the initialization process.

First the user has to load the image data and point distribution model. Next, the user will go through an iterative process of changing the model's position, orientation and size until a desired placement is found. The final step is to export the transformation matrix information. In Figure 2 this process is outlined using a program flowchart.
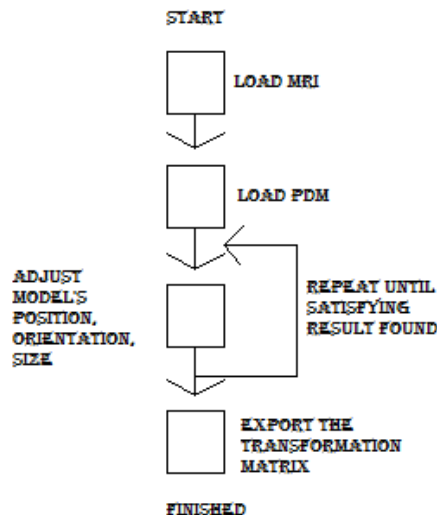

Fig. 2. The figure above shows the program workflow in a easy-to-follow step by step process. Having these simply steps should allow any user novice or expert to achieve the same results.

4.2 Application Features

In the current state of the application, several different visualization windows are provided. First it has an axial, coronal, and saggital view of the image slices with the point distribution model. In addition, the point distribution model is rendered in a separate window above the transformation sliders. Last it includes a (not fully implemented) 3D view of the image data rendered as a 3D volume together with the point distribution model. It does not work properly, because the image data is displayed as a solid object, covering the model inside. A screenshot of the current interface is shown in Figure 3 below.
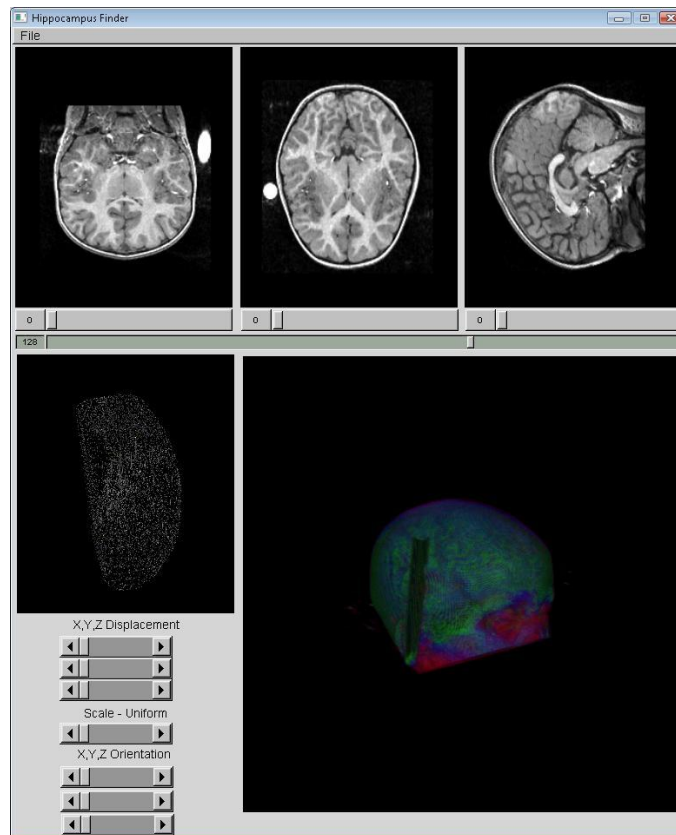

Fig. 3. The above screenshot shows the application in running state. A MRI image data set has been loaded and the point distribution model is loaded as well. On top are the axial, coronal, and saggital view. On the left bottom is the 3D view of the point distribution shape model and on the right hand side is a proposed 3D view of the MRI image data rendered as volume together with the shape.

5 Results

The preliminary results are based on the evaluation of the tool's current functionality which demonstrate the desired simplicity and ease of use. The current state looks very promising as to that all initial intended features such as the 3D view of image data and model should be implemented completely.

In comparison with the currently used tools for the initialization process, it can be said that the new tool can provide much faster and more accurate placement. The process involves three steps with Matlab, ImageToVolumeConverter and InsightSnap to verify the results. This tool offers these three steps all in one solution.

Tests comparing the actual quality improvements for the active shape modeling algorithm are not available because at the time of this being written, it is not possible to export the transformation matrix successfully in order to perform further testing.

Nevertheless, it is not expected to give results of lesser quality because of the overall faster initialization and immediate verification capabilities. In fact, the tool provides all the steps required for successful initialization process in one easy-to-use imaging tool.

6 Conclusion

This project has shown that there are problems out there that look very simple at first, seem to be able to solve with a good solution easily and successfully but then turn out to be more time consuming than anticipated. By choosing the right set of existing libraries, the project was able to evolve at a fast paste. There were some implementation hurdles along time way but those were mainly due to the not fully knowing the enormous functionality of the class libraries used. There is a little work left until the project's full completion. Overall the project was very interesting and research showed that human-computer interaction is a very important part of designing a useful tool for such tasks as the initialization for active shape modeling due the vast number of possible users from diverse background.

References

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