Construction of a 3D Model to Computerized Training Centered in Patient: PerMed & HCI Approach

Eveling Castro-Gutierrez, Christian Suca, and Elizabeth Vidal

Universidad Nacional de San Agustín de Arequipa, Arequipa, Perú
{ecastro,csucav,evidald}@unsa.edu.pe

Abstract. As a result of the pandemic in less than two months, humanity has managed to understand the importance of using information technologies in different areas and, even more so, the importance of developing software for care, monitoring, and training in the healthcare. Personalized Medicine or Precision Medicine is gaining more and more critical, and its implementation is necessary. Different gaps cannot be covered if the software continues to be developed in isolation without considering the user as the central axis of the conception, design, and implementation of the different solutions. For this reason, in this research work proposes the construction of a 3D model of the bone structure of the pelvis based on X-ray images of a patient and a volumetric template as a model that serves for training and simulation for subsequent use in a surgical. This model based on patient-centered personalized medicine and user-centered software development. As a result, we present the creation of a model that can be adapted to each patient’s reality. Likewise, these results can be used in computerized training systems for future health professionals, either by printing the model in 3D or using the software to perform measurements on each patient.

Keywords: Human-computer interaction · Personalized medicine · Precision medicine · 3D model · Computer vision

1 Introduction

We live in times of constant changes that require us to meet specific challenges, and this offers us new opportunities in different areas. For example, in health areas, the traditional concept of medicine allows the specialist to diagnose and cure diseases; However, at present, the trend is that the medical specialist does not cure diseases but rather the patient, who is a subject with a lifestyle, genetic load, with particular characteristics that develop in an environment and is located in different cultures.

This approach is known today as personalized medicine (PerMed) or “precision medicine” it is a field that is in evolution where it is determined which medical treatments will work best for each patient [1]. At PerMed, it is moving from an emphasis on reaction to an emphasis on prevention.

There are many benefits for patients in the PerMed approach, such as a) increasing treatment efficacy, b) reducing patient side effects, c) using cell or gene therapies, d)
increasing patient adherence to treatment. Treatment, e) reducing high-risk tests, f) improving the overall cost of healthcare, and f) supporting change and commitment to patient-centered care.

Medical care in terms of human-computer interaction (HCI - Human-Computer Interaction) presents the following paradoxes: first, we observed that there is a substantial investment in innovative health technologies, in terms of the analysis of “big data”; on the other hand, there are various interactive health technologies that are implemented on a large scale that are difficult to use, and there are no proposals for innovative solutions that have achieved significant market penetration.

While [2] Blandford and [3] determine that in HCI, studies have been reported on usability, user experience, and security in novel digital technologies in healthcare areas, he points out that systems design frequently does not consider human psychology. Blandford mentions that when a health application is designed, they consider that it is relevant: a) an observational approach to understanding the realities of the system; It has been detected that the result of these applications does not align with the preferences and objectives of the users, recommending a user-centered design and the respective evaluation, b) a focus on the interoperability of the systems and c) a focus on quality data, issues that deserve greater attention in HCI and which will generate an impact on the usability and usefulness of health technology.

Blandford [2] establishes that there is a term “Design X” to refer to user-centered design for complex socio-technical systems.

The proposal that we present in this research article focuses on the construction of a 3D model of the pelvis from x-ray images and a volumetric template, focusing on obtaining an appropriate model for each patient to face the challenge of medicine personalized and following the guidelines of the construction of the user-centered model, considering that in the process of elaboration of this model we have worked with experts in the area of trauma and specialists in computer vision in the processing of images in 2D and 3D.

The paper is organized as follows. Section 2 shows the main characteristic of PerMed and HCI approaches. Section 3 describes the new proposal of the project of construction of a 3D model of the pelvis from x-ray images and a volumetric template, focusing on obtaining an appropriate model for each patient. Section 3.2 describes the initial results and discussion. Finally, we show our conclusion.

2 Background

2.1 PerMed (Personalized Medicine)

The “Personalized Medicine” (PerMed) or “Precision Medicine” [4] began in the field of oncology, but it has spread to other fields such as cardiology, where information on pharmacogenetics and pharmacogenomics have raised various and important advances in the treatments of this sickness. PerMed encompasses diagnosis and therapy, as well as supporting the prediction and prevention of diseases.

The COVID-19 pandemic has highlighted the need for healthcare systems around the world, as well as increased use of telemedicine, with a permanent focus on the way
patients are cared for. Telemedicine, in particular, maybe a critical part of personalized health care in the future. It also includes possible research topics related to artificial intelligence, data collection, data integration and interoperability, informed consent, and patient concerns regarding privacy and data access.

ERA PerMed [5] is a new ERA-Net Cofund, supported by 32 partners from 23 countries and co-funded by the European Commission. Its objectives are a) to align national research strategies, b) to strengthen the competitiveness of European actors, and to improve European collaboration with non-EU countries regarding Personalized Medicine.

The EULAC PerMed project [6] aims to integrate the Latin American and Caribbean countries (LAC) into the consortium and activities of ICPerMed (International Consortium of Personalized Medicine) and the ERANet ERAPerMed, as a means to expand the international scope of the policies of R&D related to Personalized Medicine (PM).

EULAC PerMed will also work to facilitate a PerMed that benefits patients, citizens, and society in general, with the ultimate goal of contributing to the United Nations Sustainable Development Goal No. 3 “Guarantee a healthy life and promote well-being for all in All ages.”

### 2.2 HCI (Human-Computer Interaction)

Human-computer interaction (HCI) is a discipline that deals with the design, evaluation, and implementation of interactive systems for human use [3].

Ekaterina in [7, 8] determines that poor human-computer interaction (HCI) or lack of experience with the system due to not having involved patients and/or specialists in the conception, design, and implementation of the systems could cause various errors. We assume that by improving HCI, we can, on the one hand, reduce the degree of data distortion, and on the other, improve interaction with the system and thus increase the satisfaction of specialists, patients, and other users of the systems.

Kimberly [9] presents a table of the categories found in studies about trends in healthcare systems, which is represented in Table 1.

Kimberly [9] identifies a challenge for health research; this will be HCI in training and simulation. She concludes that simulated training today focuses on the use of patient care mannequins, and there are few studies that consider smart models to simulate in this context, leaving a gap to fill. Adaptive tutoring methodologies can further streamline the learning process for clinicians and other healthcare professionals, as well as consider having more suitable models for patients’ different soft organs and bone structures.
3 Proposal

3.1 Description

Specialists require precise measurements to carry out preoperative planning in Total Hip Arthroplasty (THA), but they use complex medical images such as computer tomography (CT) or magnetic resonance imaging (MRI), which achieve a 3D model, exposing patients to certain disadvantages such as radiation to the patient, high costs in the acquisition of images, and there are not many hospitals that have the appropriate equipment for this acquisition.

Our proposal is to build a 3D model, comparing X-ray images in the lateral view and the anteroposterior view from every patient with the projections of a template volume. This comparison is applied to the registration method to align and deform the template volume according to the original X-ray images is shown in Fig. 1. The techniques for template volume (moving image) and the x-ray images (fixed images) by establishing a correct focal point describes in [11].
The pipeline of the project is represented in Fig. 2.

After applying the following process: a) Establish Region of Interest of Template Volume and b) Ray casting Simulation method (Lateral View, AnteroPosterior View), we obtained the Simulated image generated from the relocated volume with size: [333.245] mm resolution [1.1] mm. Focal Point [0, −1000.0] mm Distance from Volume to Image [−124] mm with orientation [90 0 0] degrees as we shown in Fig. 3.
In the phase of Preparation of Randomly Positioned Standard Volume to relocate the model using a scale factor, it is necessary to transform the initial template to a different position than the original one and thus get to obtain the same position that was initially set (registration method), the same similarity transformation has been used to be able to alter the volume of the template see Fig. 4.

3.2 Methodology, Results and Discussion

The methodology of the present work divided into four stages: a) data preparation, b) virtual image generation, c) Rigid Register, and d) Non-rigid Register.

In the case of the initial tests, there will be uses a computed tomography of a healthy person; in this case, a template from the “Visible Human Project” is used. This volume will be modified, applying a random transformation to become a target image, and the original volume will be used as the initial template. Then the template volume will be obtained from a simulated X-ray or DRR image [11]. These will be in AP anteroposterior views and an ML mediolateral view; with these images, the registration
process will be carried out using the ITK framework. The types of registration required they will be rigid (alignment) and not rigid (deformation). With the final transformation parameters applied to the volume, the final transformation parameters will be compared. This will tell us if the registration was successful. There must be an initial volume that is clean, that is, it does not have abnormalities in the bone structure and does not have a surgical intervention instrument so that this volume would be handy for the experimentation process. With the volume obtained from both the abdomen and the hip, these two sets of images in Dicom format were joined to obtain a volume of both the femur’s proximal part and the acetabulum of the hip. Nevertheless, this requires a previous semi-automatic segmentation when using methods of a tool like 3DSlicer.

A. Registration Tests. - Twenty synthetic data tests have been generated. With this data, we saw the errors between the values of the seven transformation parameters between the “Reference Volume” and the “Registration Volume”. Furthermore, finally, the Hausdorff distance between the final volumes and the Reference volume is observed.

B. Validation Tests. - Applying the Hausdorff distance metric, the average separation between the Reference volume and the Register volume was 0.01855 mm, which shows that for different positions of the Reference Volume, the Template Volume’s alignment is successfully achieved. The Root Mean Square Error was calculated, and a value of 0.05 mm was obtained.

4 Conclusions and Future Works

It is possible to generate a 3D model using X-rays images and an initial volume that allows adaptation to these two views. This model is oriented to cover the aspects of personalized medicine and user-centered software development.

Initial registration of X-ray images is useful; however, it would be more appropriate to establish a template model that allows instantiating the initial configuration of the X-ray images and, from this model, make the corresponding registration. Working with isolated structures allowed it to be detected that the metric we use is based on the difference in images so that with more extra or scarce information areas, the value of the metric will be lower compared to working with a template that has its entire structure.

The proposed methods were analyzed in the process of registration, from the configuration in the DRR image projection, and parameters used in the optimization process (step size, step tolerance, initial scales of transformations, and levels resolution), values that will subsequently determine the precision of the model. Likewise, in the evaluation of the model, the Hausdorff metric and its respective visualization graphs of the cost function were applied within a range of possible transformation parameters.

The present work used the focus centered-users and centered-patient, interacting with the specialist on traumatology and computer vision specialist.

It is necessary to probe this method with more clinician to improve the computational methods with a large dataset.

We could establish that this template could be used like a custom-made implant when the exist the enough clinical validations.
References

1. Personalized Medicine Coalition: Personalized Medicine Coalition - Precision Medicine Advocacy and Education. https://www.personalizedmedicinecoalition.org/. Accessed 13 Sept 2020
2. Blandford, A.: HCI for health and wellbeing: challenges and opportunities. Int. J. Hum. Comput. Stud. 131, 41–51 (2019)
3. Gulliksen, J.: Institutionalizing human-computer interaction for global health. Glob. Health Action 10(3), 1344003 (2017)
4. Medicine, A.P.: Moving beyond population averages, no. August (2020)
5. ERA PerMed: ERA PerMed. https://www.erapermed.eu/. Accessed 14 Sept 2020
6. EULAC: EULAC Permed. EULAC Permed. https://www.eulac-permed.eu/index.php/es/inicio/. Accessed 13 Sept 2020
7. Bologva, E.V., Prokusheva, D.I., Krikunov, A.V., Zvartau, N.E., Kovalchuk, S.V.: Human-computer interaction in electronic medical records: from the perspectives of physicians and data scientists. Procedia Comput. Sci. 100, 915–920 (2016)
8. Liu, P., Fels, S., West, N., Görges, M.: Human Computer Interaction Design for Mobile Devices Based on a Smart Healthcare Architecture, p. 2 (2019)
9. Stowers, K., Mouloua, M.: Human computer interaction trends in healthcare: an update. In: Proceedings of the International Symposium on Human Factors and Ergonomics in Health Care, vol. 7, no. 1, pp. 88–91 (2018)
10. Kuhllmann, J., Halvorsen, T.: Precision medicine: integrating medical images, design tools and 3D printing to create personalized medical solutions. In: 2018 IEEE International Symposium on Medical Measurements and Applications, vol. 3528725544, pp. 1–5 (2018)
11. Velando, C.A.S., Gutierrez, E.G.C.: 2D/3D Registration with Rigid Alignment of the Pelvic Bone for Assisting in Total Hip Arthroplasty Preoperative Planning, vol. 11, no. 5 (2020)