IMPLEMENTATION OF A MICROSOFT HOLOLENS 2 FOR SUPPORTING DIAGNOSIS AND MONITORING TREATMENT OF SCOLIOSIS

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Keywords: Scoliosis, Augmented Reality, Microsoft HoloLens 2, Diagnosis, Treatment Monitoring.

Abstract: *Scoliosis is a condition in which the spine deforms to the left or right, as judged by a lateral curvature of more than 10 degrees. In the frontal view, the scoliotic spine may appear S- or C-shaped. Idiopathic scoliosis is a 3D deformity of the spine that develops for unknown reasons and can seriously affect patients' health, appearance, and quality of life. Due to the progressive deterioration of the spine, untreated scoliosis can lead to back pain and further complications in adulthood. When an abnormality is detected, various diagnostic methods are used, such as X-ray examination. Since adolescent tissues can be damaged by X-rays, they should be kept to a minimum. Based on previous experimental results, a hardware upgrade was made to develop an application to help medical professionals detect, record, and track the development of adolescent idiopathic scoliosis. The application, which runs on Microsoft HoloLens 2, was developed using the Framework Unity3D, which was primarily used to assess and document the scoliosis condition. The basic function of the developed application is to identify the spinal curvature using the HoloLens 2 tracking system on the patient's back surface to create a 3D digital representation that allows calculation of the deformation curvature. The next step is to apply markers to prominent anatomical points on the 3D surface using specially developed algorithms. A generic 3D model of a physiologically normal spine is then registered with the patient-specific 3D surface. The application can display radiographs taken for the same patients in accordance with standard medical practice. Other features include a data management system that allows archiving, searching, and retrieval of patient records, including 3D visualizations of the patient-specific spine, and another feature that allows statistical analysis of diagnostic parameters from follow-up exams. As a result, a 3D model of the back of a patient is successfully created. However, the quality of the model could be improved in future work. Future application development will include clinical evaluation by medical professionals. This may include more sophisticated hardware, such as high-end 3D scanners, to enhance the scanning process, create the 3D model, and enable dynamic spine analysis.*

1 INTRODUCTION

Scoliosis is a spinal disease in which the spinal deforms during the growth period or even at later age. A lateral displacement from the normal axis and a malrotation of one or more vertebrae might result from this deformation (see Figure 1). This curvature of the spine, which typically occurs in one direction, can inflict cosmetic and functional harm, as well as a significant decline in the quality of life, especially for young patients. Therefore, it's even more essential to detect the disease's progression early on and to keep track of it on a regular basis. Depending on the degree of the deformity, a clinical check-up is performed every 3-6 months as usual. During growth spurts, projection radiological examinations are essential in addition to clinical screenings for early diagnosis of degeneration [1][4].

Figure 1: Frontal and sagittal x-ray images of the patient with adolescent idiopathic scoliosis.

Although projection radiological examinations pose low risk of radiation dose, higher frequent examinations may result in increased overall radiation exposure. The patient may suffer negative consequences because of higher radiation protection risk. Adolescent tissue is acutely susceptible, which is why, according to the Radiation Ordinance, X-rays are used with caution. Consequently, in the event of stable scoliosis, an X-ray screening should be performed only every 3-6 months. Increased radiation exposure can cause irreversible tissue damage and, in the worst-case case, cancer [6][7][8]. A state-of-the-art non-invasive method was sought to keep radiation exposure to a minimal level while still providing excellent patient care. The aim is to create an innovative and novel application to help medical professionals detect, document, and monitor the progression of idiopathic scoliosis in children and adolescents, and to accompany the examination.

2   MATERIALS AND METHODS

Based on initial results [12] the hardware chosen for developing an application which can increase patient safety and accomplish the stated aims is the Microsoft HoloLens 2. This equipment is basically a pair of mixed reality glasses that scan the surfaces of a room and generate a three-dimensional interpretation based on triangles that use the integrated Time-Of-Flight sensor. The back and spine of a patient are observed and captured using this technology to calculate the curvature of the spine using the Cobb angle.

2.1 Hardware and Software

The individual cameras and sensors of the Microsoft HoloLens 2 allow users to interact with digital objects in a real space. The central development platform for this Augmented Reality (AR) application is Unity. A *Scene* is the view in Unity that contains the world and its associated information. *GameObjects* ('Selection Area' in our game) is the most essential entity of the *Scene*, as they serve as the foundation for all other objects inside the *Scene*. We used an already existing package "mrtkvolumeselector" for mesh cutting [11]. The code was taken as the basis and adapted and extended to suit the purpose of this project. A *GameObject* is simply a container for components which are created by writing scripts and then are linked to the *GameObject*. The following are some components: *Camera*, *Light*, *Transform*, *Scripts* in general. Because it provides the position, scale, and rotation of the *GameObject* in the game environment and permits the concept of parenting, the *Transform* component must be present in a *GameObject*. *SetParent* on the child's *Transform* component is used to set it. When the offspring's parent is changed, the offspring's transformation becomes relevant to the parent while the global position, rotation, and scale remain constant. Relocating the parent has an impact on the children, whereas moving the child has no impact on the parent.

2.2 Physical landmarks detection

One of the Unity application's main foundations is landmark detection. In theory, several landmarks are placed in notable places on the 3D model of the patient's back after it has been constructed. The inner line which lines the vertebra and the outer line which lines the patients back, as well as the Cobb Angle, are then calculated to establish the exact curvature of the spine. The proposed idea to achieve this was to create a Convolutional Neural Network (CNN), that can recognize each landmark independently. An algorithm will be used to generate training data that will create this model. In a test data set, the algorithm should then put the landmarks on 3D models with the best accuracy. Following the successful tests, the algorithm should be able to recognize landmarks in a real session and appropriately put them on the patient's back [2] (see Figure 2).
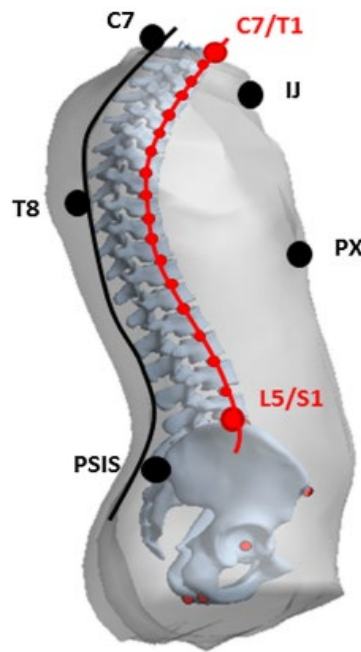
Figure 2: Landmarks on 3D Model [3].

2.3 Prediction of Internal spinal alignment and 3D patient-specific model

After landmarks are placed on the back of the patient they are linked to the spine. A line must be connected from one shoulder landmark to the next, as well as from one hip landmark to the next. The outer line, i.e., the shape of the spine, is defined by using multiple landmark points, which can be seen as a sketch. The outer line is formed by the connecting landmarks and runs directly over the patient's back. The calculation, as well as the representation of the inner line, are essential for inferring the real curvature. The anatomical landmarks on this inner line are situated in the center of the vertebral body [4]. See Figure 3 to get a raster stereography example for measuring a spine.
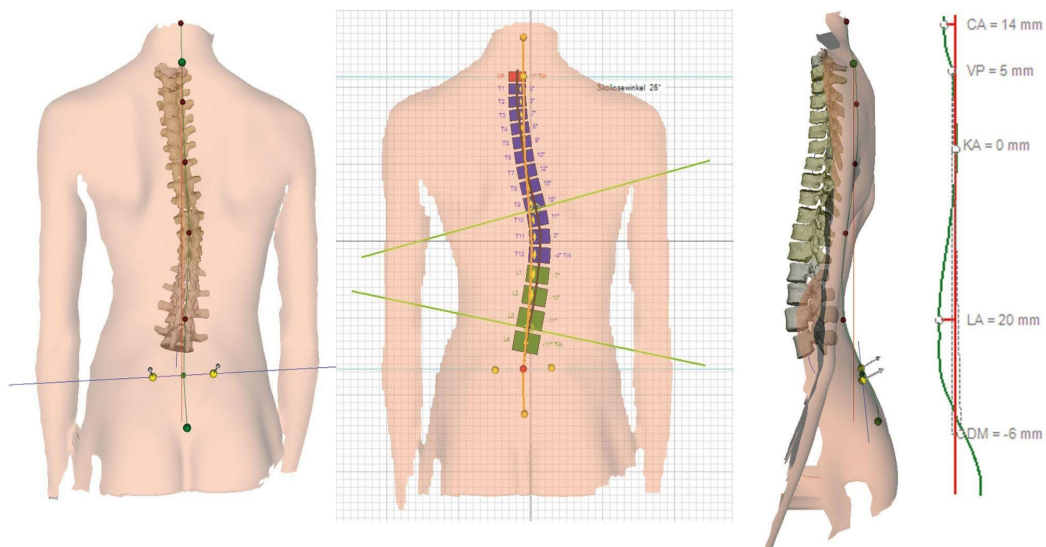

Figure 3: Raster stereography example for measuring the spine [9].

In addition to establishing and arranging landmarks, lines such as Shoulder Tilt and Hip Tilt should be graphically painted on the patient's back for raster stereography. The Cobb angle should also be computed using the Shoulder Tilt and Hip Tilt [4][9]. The estimated Cobb angle and Shoulder Tilt and Hip Tilt should be recorded in the database and displayed in a window in the application. The inner line's determination of the vertebral (see Figure 4) bodies' coordinates might be transferred to the 3D model. The individual vertebral bodies could then be moved based on these coordinates.
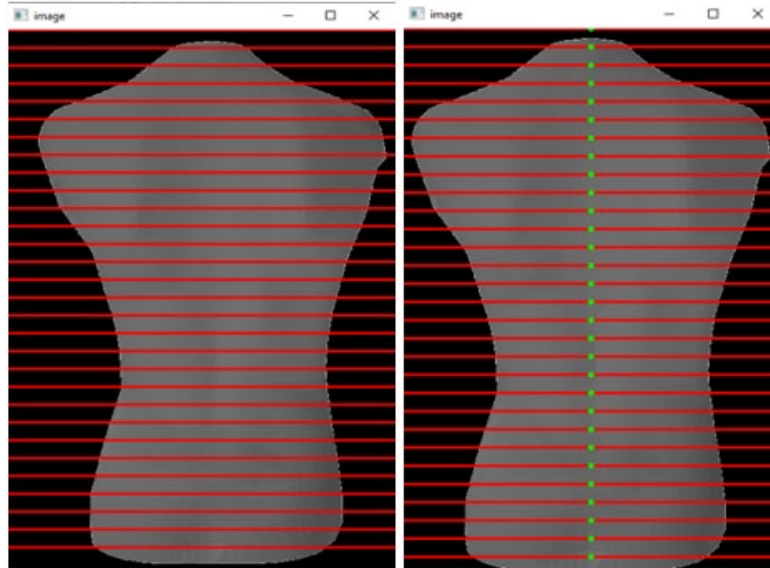

Figure 4: inner line determination of vertebral body [10].

Figure *5* shows the individual steps of the application, which are explained in more detail below.
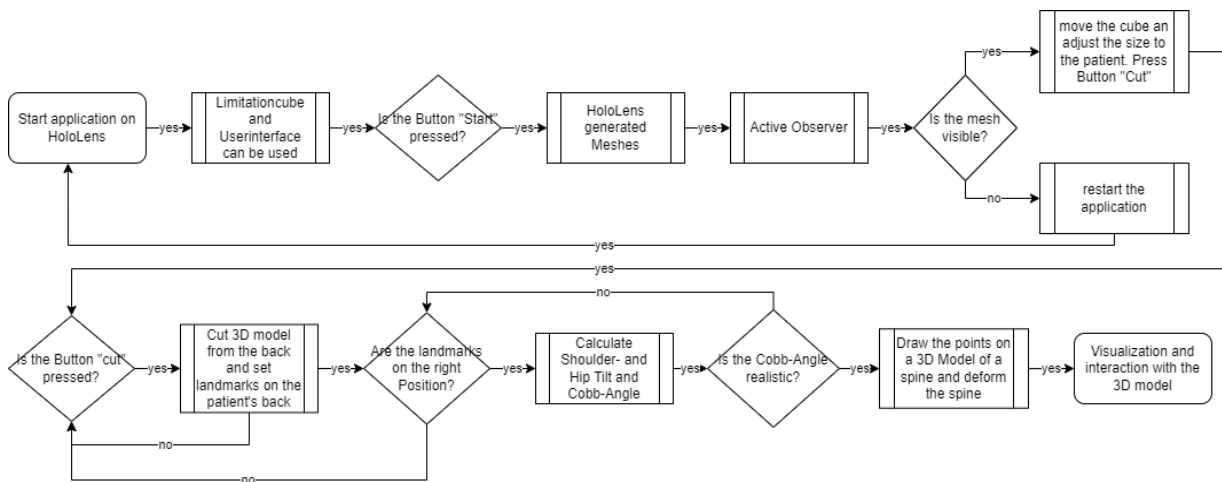

Figure *5*: Flowchart for creating the 3D Model on HoloLens 2.

After the application is started on the HoloLens 2, a cube is visible in the user's field of view, which can be adjusted to the desired size by gestures. This Selection Area delimits the field for a cutting algorithm [11], which is triggered by the "Cut" button. Also, after starting the application, the "Start" button is selectable in the menu. This must be pressed first so that the

HoloLens 2 can create a mesh of triangles and scan the entire room. This mesh is created and viewed by so-called observers. An observer is a functional unit in Unity that provides the ambient mesh data of the HoloLens 2 spatial mesh so that it can be processed further. When this observer is active, a visible mesh is generated, which can also be seen in Figure 6 by the black unfilled triangles. This mesh regenerates itself in a certain interval and can thus generate different patterns. When the mesh is visible, a cube can be dragged onto the patient and the "Cut" button can be pressed. Once the button has been pressed, a 3D model of the patient's back is created on which the landmarks are placed. If the landmarks are in the correct position, the shoulder and hip inclination can be calculated. If the landmarks are not in the correct position, the cutting must be repeated to obtain a different mesh. If the landmarks are then in the correct position and the calculations are realistic, they can be visually represented in a 3D model of a spine.

2.4 Integration of patient-specific data into AR for HoloLens 2

In our prototype, to safeguard the application, the username and password are prompted in the login box after starting the application from the Windows menu like an app. The application must be registered through the Universal Windows Platform (UWP) application on the HoloLens 2. It is possible to successfully log in to the Unity application after enrolling for the UWP application. If the credentials entered match those in the database, the user will be connected to the application and can begin the examination after providing the patient's information. The database was outsourced to a USB stick for technical reasons, as the data can become very large and good performance had to be ensured. In later version the application should be integrated into the clinical IT environment.
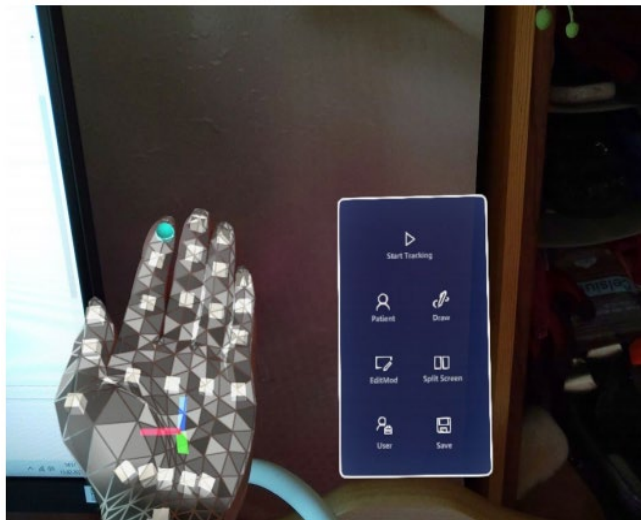

Figure *6*: The application menu is called up with a hand movement.

3   RESULTS AND DISCUSSIONS

The prototypical application has two scenes to make things easier for the user. A portion of the final hologram is generated in this scene. For the resultant hologram to be complete, this scene must be finished in a single run of the application. The observer pattern is all about entity interaction, exchanging data, and doing it in a way that isolates the object giving the information from the objects that might need or utilize it.

Square vs. Cube Plan

We used a two-dimensional plane to pick the patient's trunk, and to chop the rear section of the trunk. When we clicked the 'cut' button, half of the room was sliced, and the other half was covered with meshes (see Figure 7). This is because the plane is represented by a 3D surface which splits space into two regions referred to as half-spaces. It is simple to identify which of the two half-spaces a given point is in, as well as how far away the position seems to be from the plane. When we utilized the cube to cut the rear section of the patient's trunk, it only chopped the volume that we chose.
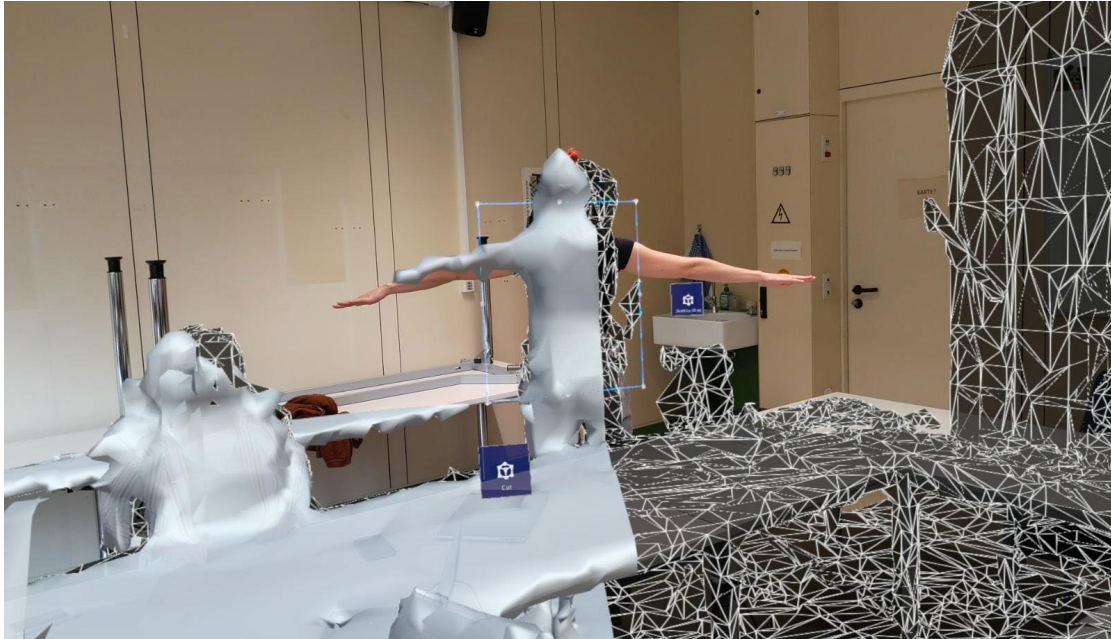
Implementation with two Observers

We put our program through its paces with the help of two observers. Observers with Spatial Meshes were given varied configurations (type of the observer we used for this project). We examined one instance with 3000 triangles with intervals of 0.5 and 0.6 for both observers (see Figure 8:A). In the other example, 5000 triangles were used, and the intervals remained constant for the observers (see Figure 8:B). When we compared these two situations, we discovered that a higher number of triangles causes the mesh to produce faster and more efficiently.
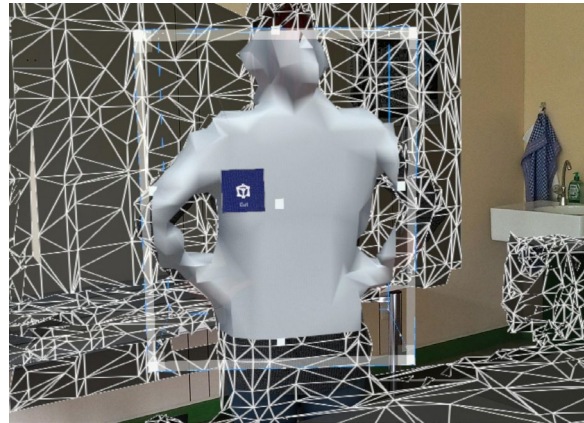
Figure 8: A. 3D model side view with two observers. B. 3D model back view with two observers.

Implementation with three Observers

We tried our application also with three observers to see if increasing the number of observers improved the efficiency of the sliced volume. We assigned distinct configurations to observers (observer types). We attempted both scenarios with 5000 triangles, however the intervals were different. The intervals for the first example were 0.5, 0.6, 0.7. In the second example, the first observer had an interval of 0.5, while the other two observers had the same interval of 0.6. Based on these two examples, we discovered that increasing the number of observers makes the mesh generation faster and more efficient; moreover, observers with the same intervals work better. In this project, the dimensions of the surface that the meshes cover are x=2, y=2, z=2. Our software's most recent release includes four observers with the same interval of 0.3 and spatial meshes with a total of 10.000 triangles. We utilized a user aligned cube or an axis aligned cube for the observer's shape and a mesh extent of no more than 2m³ for the meshes (specifically with dimensions 1, 1, 2 for x, y, z) (see Figure 9:A and Figure 9:B). Even though the Spatial Object Mesh Observer provides the software for the complete 3D mesh. The shape and extent of the observer are not considered [9]. We aggregated the best instances from all previous trials for the final trial, increased the number of observers, triangles, and utilized the same interval for all observers. This helped the mesh produce faster, and the sliced section was clean of gabs.
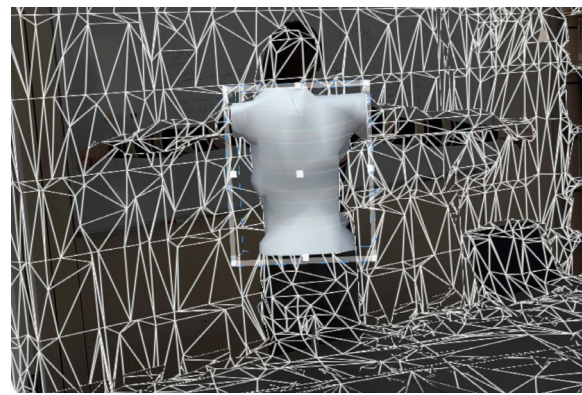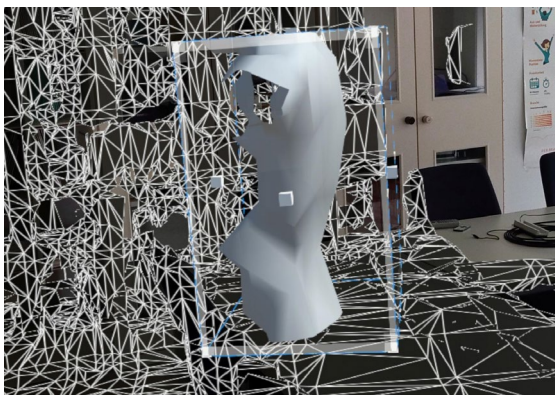

Figure 9: A. 3D model side view with three observers. B. 3D model back view with three observers.

Expert Interviews

During this trial-and-error approach, several questions arose for the project team. Here, a contact was established with the Microsoft support team, and it was discovered that the use of HoloLens 2 is not optimal for scanning the back of patients. Instead, other external professional scanners were suggested that could be considered in Future Work, e.g., Photoneo MotionCam 3D or Artec Eva 3D scanner.

4   CONCLUSIONS AND FUTURE WORK

The aim of this work was to create an innovative and novel application to help medical professionals detect, document, and monitor the progression of idiopathic scoliosis in children and adolescents, and to accompany the examination. This was partially achieved. Even though a 3D model of a patient's back is generated, the Unity application, which includes tracking, landmark recognition, and calculations, cannot be used with the existing hardware. The HoloLens 2 is specifically designed to track rooms and enable interaction with them. More detailed tracking of objects and especially people is not in the product's focus. Likewise, discussions with Microsoft developers showed that this will not be possible in the foreseeable future. Despite extensive testing and optimization attempts, no meaningful calculations can be performed based on the resulting 3D model. The tracking produces too many artifacts and inaccuracies, which negatively affect all further steps. Thus, a clinical evaluation was not possible with the HoloLens 2.

While the Microsoft HoloLens 2 is well suited for viewing and AR imaging, a new solution must be found for scanning the patients back. Due to the current limited technical capabilities of the HoloLens 2, an external professional 3D scanner would be helpful to pass the scanned 3D-data to the HoloLens 2 for processing and displaying. This could increase the quality of the model in future work and lead to more meaningful results. Thus, in the future, X-rays should be avoided as much as possible and provide the specialist with a new technology to perform faster, more accurate and lower risk examinations for the patient.

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