3D Human Scanning Solution for Medical Measurements

Balázs Sütő, Zsolt Könnyű, Zsolt Tölgyesi, Tibor Skala, Imre Rudas, Miklos Kozlovszky

3D Human Scanning Solution for Medical Measurements

Balázs Sütő[1], Zsolt Könnyű[1], Zsolt Tölgyesi[1], Tibor Skala[3], Imre Rudas[4] ,Miklos Kozlovszky[1,2]

[1] Biotech Laboratory, Óbuda University, Bécsi út 96/b, 1034 Budapest, Hungary
[2] MTA SZTAKI, H-1518 Budapest, Pf. 63., Hungary
[3] Faculty of Graphic Arts, Zagreb, Croatia
[4] Óbuda University, Bécsi út 96/b, 1034 Budapest, Hungary

suto.balazs@biotech.uni-obuda.hu, konnyu.zsolt@biotech.uni-obuda.hu, tolgyesi.zsolt@biotech.uni-obuda.hu, tibor.skala@gmail.com, kozlovszky.miklos@nik.uni-obuda.hu, rudas@uni-obuda.hu

Abstract. Today anthropometry can be performed with three-dimensional scanners. Our aim is to establish a low-cost, easy-to-use hardware and software solution, which is capable to do automatic, computer-based anthropometry and medical measurements for health care. We have designed and build a large, remote controlled turntable and a 3D scanner application, which can be used to digitalize 0.2-2,6 m tall real world objects into 3D models. With the turntable a 360° field of view can be reached even when using completely stationary, static sensors. Our software uses RGBD sensors for data acquisition, however it can be combined with other image sensors. With our solution prosthesis design can be more accurate and simplified, and we can provide for 3D modelers an efficient, real time method to scan and visualize human scale 3D objects. The scanned models can easily be used for rapid prototyping and 3D printing. The models can be exported into the most popular 3D modeling file formats for further analysis. Our solution decreases significantly the time, effort and cost of the clean up process of the 3D scanning. In this paper we provide information about our 3D scanning solution's design, and implementation, and we also describe its accuracy. The realized hardware and software solution provides a cheap and sufficiently reliable method to gather real time 3D depth and RGB data from human size objects for 3D reconstruction.

Keywords: 3D reconstruction, RGBD, 3D human scanning.

1 Introduction

Today anthropometrical data is used in a great variety of projects. Examples include designing [1], somatotyping [2] and face measurement [3]. Traditionally data were collected using measure tapes and other measurement tools which was a physically exhausting task both for the subjects and for the staff. Since taking the measurements required physical contact with the subjects, obtaining data from many different geographical locations posed a problem and prolonged project time. With the appearance of 3D anthropometry these issues were solved but due to the additional hardware the cost of the projects increased significantly. Thanks to the popularity and evolution of RGBD sensors now they provide a cheap and reliable marker-less solution for 3D scanning. The scanned body models generated by 3D surface reconstruction based technologies can be used for anthropometrical data collection The goal of our project is the design and development of a 3D anthropometrical scanner system which can be used to scan human bodies for medical purposes. The proposed solution must have a low implementation cost. The scanner system must support dynamic and static camera settings, therefore scanning with a moving and a fixed camera must both be possible. Initial versions of the scanner application have to be compatible with the Kinect for Windows V1 and V2 sensors while later versions should also support other RGBD cameras. To create a technology independent software an application layer which hides the differences between the mentioned frameworks must be developed.

2 Relationship to Cloud-based Solutions

Data clouds can be used to store anthropometrical data and models collected by our software. By uploading the data to the cloud we are able to create a global database and share the data among a large group of users. A cloud-based database also enables the users to access the models and measurements without regard to their physical location.

The data cloud solves the problem of managing geographically distributed work. Due to the low priced nature of the solution, building huge networks with globally distributed measuring sites becomes a possibility.

3 Description of a Problem Solution

Our proposed solution for the problem is an anthropometrical scanner system based on a self-developed 3D body scanner application and an electronic hardware turntable.

Among the state of art algorithms we considered choosing the ICP algorithm due to its impressive speed, robustness and popularity. We selected two framework libraries which implement ICP, Kinect Fusion and the Point Cloud Library, because after some research they seemed to be the most suitable implementations to meet our goals.

The current version of our program uses the aforementioned frameworks, their data structures and algorithm implementations, but the whole process of 3D reconstruction can only be completed by using Kinect Fusion. The application builds a volumetric model from the RGB and depth data acquired from the sensor by integrating them into the model as sequence of frames. The model can be visualized in 2D using ray casting. Our program performs a 3D surface-reconstruction on the model, creating a triangle based polygon mesh, which can be exported into ply, stl or obj file formats. The RGB and depth frames can be saved with their associated camera pose and imported into Blender using a Blender script to create an UV mapped model.

Our system supports dynamic and static camera settings. To create a technology independent software we developed an application layer that hides the differences between the mentioned frameworks.

To automatize the scanning process we created an Arduino based scan turntable. The turntable can be accessed and controlled from the application by setting up a virtual COM port. By using the turntable, 360° scanning of objects becomes possible without actually moving the sensor around. Thanks to this possibility the scan process can be made more comfortable, faster and the number of possible errors due to manual scanning can be reduced.

It is also possible to use multiple stationary RGBD sensors for scanning [4], however this results in increased computation time and hardware costs. If this approach is used the sensors must be well placed around the subject so while providing the 360° FOV they would not interfere with each other. Compared to the turntable based method this solution is less mobile because if the scanning hardware are moved, the cameras always need to be recalibrated before scanning.

The application uses multiple threads, and is capable of vertex-color based color reconstruction. UV mapping and Infra camera support are currently in development. In later versions we would like to make other RGBD sensors compatible with our software. The 360° angle of view could also be provided by using multiple sensors.

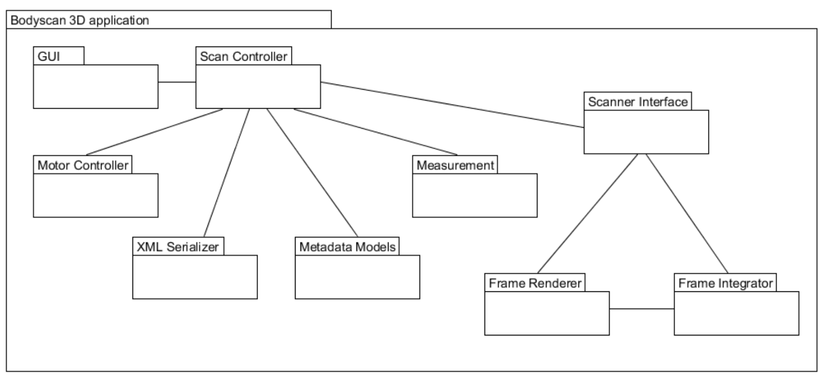

Fig. 1. The architecture of our application solution.

The application itself consists of a modular backend and user friendly GUI. The backend supports the most popular 3D scanner software frameworks (Kinect Fusion [5], Point Cloud Library [6]) and a variety of 3D RGBD cameras. The aforementioned libraries provide the essential data types and algorithms for data acquisition and 3D surface reconstruction of 3D objects. Modularity means that in addition to being able to fine-tune the scanning settings, like the camera resolutions and properties of the 3D model, the data acquisition, data types, 3D modeling and reconstruction algorithms can also be changed if needed, to provide a highly customizable software.

Fig. 2. The Arduino based scan turntable designed and constructed at Biotech Laboratory for 3D body scanning.

By using an additional HD camera it is also possible to obtain high definition RGB data for the scene which can be integrated into the 3D model by utilizing UV mapping to provide high definition textures. These HD textures can be stored with the exported surface-reconstructed body model and can later be used for a variety of medical purposes like automatic skin cancer detection. This technology is currently being implemented using Blender scripts.

The algorithm for projecting the HD texture on the 3D mesh:

1. Running a retopology script to normalize the mesh
2. Unwrapping of the mesh and generation of the UV map. This provides the coordinate mapping which transforms the acquired RGB values into the coordinate system of the mesh.
3. Iterating the camera poses (Each pose has an attached RGB frame.)
4. Using the 3D mesh to separate irrelevant data of the RGB frame, eroding it and applying a filter at the edge of the relevant area to prevent overlaps at the projecting process
5. Projecting the RGB data on the texture in the created UV system from every camera position.

4 Results

For testing we first measured certain body proportions of our test subjects like neck, hip and waist size by hand using a tape measure. After the scanning finished we exported the models from our software and measured the same proportions on the captured models using Meshlab. In the predefined scan space we managed to scan people in relatively good quality using a low-end desktop PC. By utilizing the maximum scanning precision and resolution of the Kinect sensor and choosing the correct parameters for the scan the errors of the scan were under 0.8 cm-s in all cases.

During testing we used a volumetric model constructed from 512 × 512 × 512 voxels and a model resolution of 256 voxels/meter. Using the same settings on a high-end desktop PC we were able to process 30 depth frames/second allowing real-time reconstruction. We also tested different indoor lighting and camera setups, including stationary and dynamically moving Kinect sensors. While we found the reconstruction algorithms to be more robust by using a stationary sensor and the turntable, illumination only affected the quality of the RGB colors and captured textures, but not the quality of the mesh models.

Fig. 3. 3D scanned mesh model of man with a crutch.

5 Conclusions and Future Work

While the RGBD based technologies and methods cannot produce the same quality models as other approaches, they provide an affordable alternative. From the list of currently available RGBD hardware sensors we chose the two versions of the Microsoft Kinect sensor due to their high compatibility rating with other systems. Compared to other RGBD devices the Microsoft Kinect is relatively cheap and reliable. After normalization it can provide the necessary precision for 3D body scanning.

The Arduino [7] based scan turntable in coordination with the well-placed RGBD sensors provide the 360° FOV which is necessary to scan the whole human body. The rotation speed and direction can be controlled from the scanner application. While it is also possible to scan without using the turntable, in that case the comfort and reliability of the scan process is reduced. Currently our system is fully compatible ith the Kinect for Windows V1 and V2 sensors and uses a single camera for RGBD data acquisition, but we have plans for using additional cameras in the future.

During testing using the aforementioned devices and technologies we managed to scan 3D human bodies, and we found that errors of the scan were always below 0.8 cm-s. Color and colorless reconstruction were also tested. While minor movement errors were mostly mitigated by the ICP algorithm, generally the subject had to stand still during the whole scanning process. This was due to the limitations of the ICP and Kinect Fusion based real-time scanning approach. [5]

In the future intelligent marker management could be used to increase tracking and reconstruction precision and performance. We are also planning to extend sensor compatibility to other RGBD devices and making a variety of medical sensors compatible with our system to increase sensor modality.

References

1. .J. Niu and Z. Li, „Using Three-Dimensional (3D) Anthropometric Data in Design," in Handbook of Anthropometry, V. R. Preedy, pp. 3001-3013, Springer New York, (2012).
2. O. T, J. Daniell N FAU Petkov, A. Petkov J FAU David Stewart and D. S. A, Somatotyping using 3D anthropometry: a cluster analysis., UniSA, Health Sciences, GPO Box 2471, Adelaide 5001, Australia. tim.olds@unisa.edu.au FAU - Daniell, Nathan, pp. --.
3. C. Loconsole, N. Barbosa, A. Frisoli and V. Costa Orvalho, „A New Marker-less 3D Kinect-based System for Facial Anthropometric Measurements," in Proceedings of the 7th International Conference on Articulated Motion and Deformable Objects, Berlin, Heidelberg (2012).
4. M. Robinson and M. Parkinson, „Estimating Anthropometry with Microsoft Kinect," in DIGITAL HUMAN MODELING SYMPOSIUM, (2013).
5. S. Izadi, D. Kim, O. Hilliges, D. Molyneaux, R. Newcombe, P. Kohli, J. Shotton, S. Hodges, D. Freeman, A. Davison and A. Fitzgibbon, „KinectFusion: Real-time 3D Reconstruction and Interaction Using a Moving Depth Camera," in Proceedings of the 24th Annual ACM Symposium on User Interface Software and Technology, New York, NY, USA (2011).
6. R. B. Rusu and S. Cousins, „3D is here: Point Cloud Library (PCL)," in IEEE International Conference on Robotics and Automation (ICRA), Shanghai, China (2011).
7. Arduino Uno, http://arduino.cc/en/Main/ArduinoBoardUno.