

Designing an Orthotic Insole by Using Kinect® XBOX Gaming Sensor Scanner and Computer Aided Engineering Software

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Abstract. Healthcare and medical is one of the most expensive field in the modern world. In order to fulfil medical requirement, this study aimed to design an orthotic insole by using Kinect Xbox Gaming Sensor Scanner and CAE softwares. The accuracy of the Kinect® XBOX 360 gaming sensor is capable of producing 3D reconstructed geometry with the maximum and minimum error of 3.78% (2.78mm) and 1.74% (0.46mm) respectively. The orthotic insole design process had been done by using Autodesk Meshmixer 2.6 and Solidworks 2014 software. Functionality of the orthotic insole designed was capable of reducing foot pressure especially in the metatarsal area. Overall, the proposed method was proved to be highly potential in the design of the insole where it promises low cost, less time consuming, and efficiency in regards that the Kinect® XBOX 360 device promised low price compared to other digital 3D scanner since the software needed to run the device can be downloaded for free.

1. Introduction

Additive Manufacturing is a new technology introduced in the medical field of producing medical devices compared with other engineering field that already implemented the Additive Manufacturing technology long time ago. Nowadays, various researches have been reported on implementing Additive Manufacturing technology in the medical field [1-3]. There are some Additive manufacturing applications in medical field such as medical instrumentation design, tissue engineering (implantation), mechanical bone replication, anthropology, forensic, prosthetic and orthotic [4-7]. For prosthetics and orthotics, Additive Manufacturing technology is proven to be beneficial to the patients as the production of certain support devices which can help patients improve their comfort and stability [8]. These devices were designed based on patient anatomy and the foot problems characteristic. Usually, patient has their own specific size or special need cause by the foot problem or genetic. With the help of Additive Manufacturing technology, it would be easier to produce orthotics devices according to the specific size of the patient's foot with a reasonable price.

Most members of the population will experience foot problems at some point during their life's journey as shown in Figure 1. The foot bears the entire weight of the body and function as our



foundation. Some foot problems can be difficult to recognize. Patient needs to consult with a medical professional for diagnosis and it will cost a lot of money for the treatment and procedure. One of the treatments for orthotic foot problems is to custom made an orthotic insole for the patient.

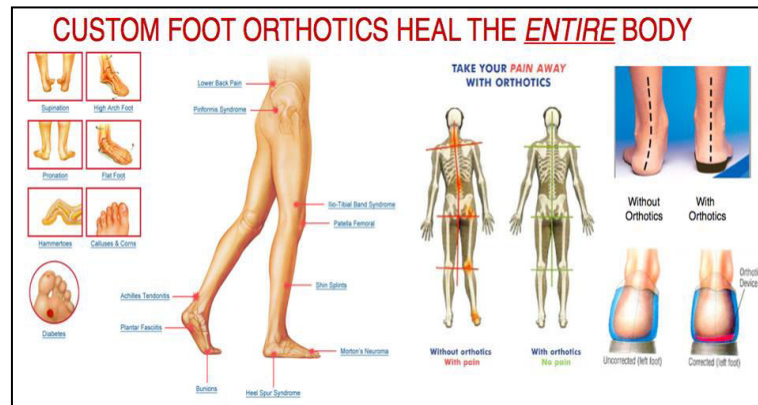


Figure 1. Type of foot problems related to Orthotics [9].

Some of the hospitals are still using the traditional method for custom made insole which is using Plaster of Paris and mold casting as in Figure 2 [10]. This kind of method requires a high skilled worker and the plaster and mold are not reusable. It will contribute to the inventory cost whereby the hospitals need to keep all the patient foot geometry in the form of plaster and mold in their storage. The cost for full MRI or CT scan system is totally expensive. Well established hospitals are afforded to invest but some other hospitals are lack of budget for investment and they prefer the traditional method rather than using Computer Integrated System (CIS). Thus, this research aims to design an orthotic insole by using Kinect® XBox gaming sensor scanner and Solidworks software.

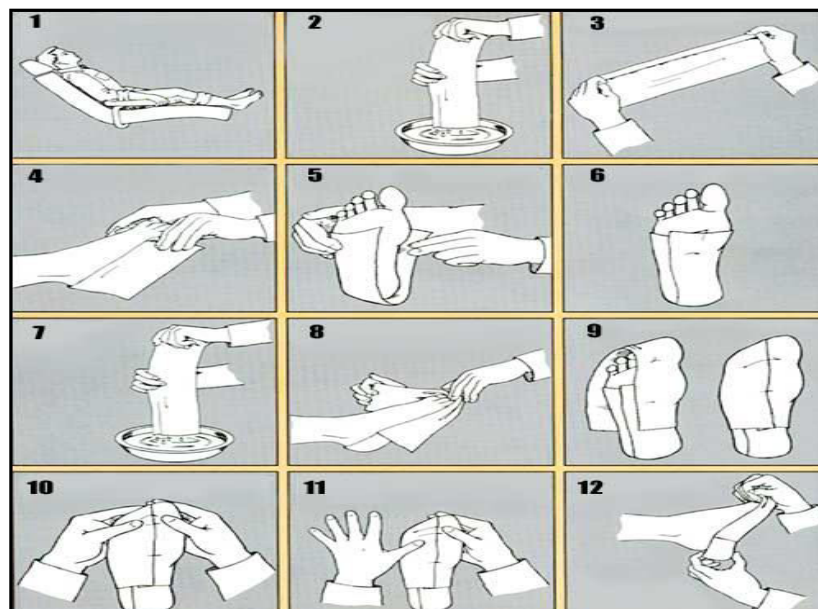


Figure 2. Process of obtaining the patient's geometrical foot structure by using Plaster of Paris [10].

2. Methodology

This research proposed a timeless and economical way on designing a customized orthotic insole by using Kinect® XBOX 360 as the 3D scanner, and CAE software for orthoses insole design. The Kinect® XBOX 360 device displayed in Figure 3 is a Prime Sense motion sensor embodied in a game controller for XBOX 360. It was 1st introduced in 2009 by Microsoft as a body tracking device for the XBOX 360 gaming console. The device contains RGB camera, infrared emitter projecting invisible dot-grid (IR projector), and infrared depth camera. The RGB camera is capable of streaming 640x480 images at 30 frames per second. The device can be connected to a PC using USB interface and the SDK driver provided by Microsoft for free download. In October 2011, Microsoft researcher has turned the device into real-time 3D reconstruction by introducing the Kinect® Fusion software [11].



Figure 3. The Kinect® XBOX 360 device

This research started with preliminary scanning process which was conducted for determination of the Kinect® scanner device accuracy. The object for the preliminary scan was the parallel bar with four different sizes as shown in Figure 4. The measurement were based on the parallel bar's dimension as shown in Table 1.



Figure 4. Parallel Bar.

Table 1. Parallel Bar Actual Dimension.

Bar	Width (mm)	Height (mm)	Length (mm)
1	15	20	150
2	15	30	150
3	20	30	150
4	25	50	150

The next process was the actual foot scanning process. After the actual foot geometry was obtained, the geometry was edited and enhanced by using Autodesk Meshmixer 2.6 and converted to

.STL format. Finally, based on the measurement, the orthotic insole was designed using Solidworks 2014 software along with the Autodesk Meshmixer 2.6 software.

3. Results And Discussion

3.1. Preliminary Scan

Autodesk Meshmixer 2.6 software had been used for dimensional measurement of width, height and length for each scanned parallel bar. The scanning process was done with 10 times repetition for each parallel bar and root mean square error (RMSE) was calculated for each scanned bar geometry. Results for the preliminary scanning geometry dimension are show in Table 2.

Table 2. Root Mean Square Error (RMSE) Percentages.

Bar	RMSE (mm)			RMSE Percentage %			
	Length	Width	Height	Length	Width	Height	% AVG
1	2.29	0.46	0.78	1.53	3.07	3.90	2.83
2	2.78	0.51	0.92	1.85	3.40	3.07	2.77
3	1.49	0.94	1.69	0.99	4.70	5.63	3.78
4	0.50	0.53	1.39	0.33	2.12	2.78	1.74

From the graph plotted in Figure 5 and 6, it shows that the Kinect® XBOX 360 can be used as a 3D scanner with the maximum and minimum error of 3.78% (2.78mm) and 1.74% (0.46mm) respectively. It shows that the higher the scanned model size, the lower error will be obtained. Besides, for the best scanning applications, the scanning distance recommended is in between 1m to 3m to the sensor [12]. At larger distances, the quality of the data is degraded by the noise and low resolution of the depth measurements.

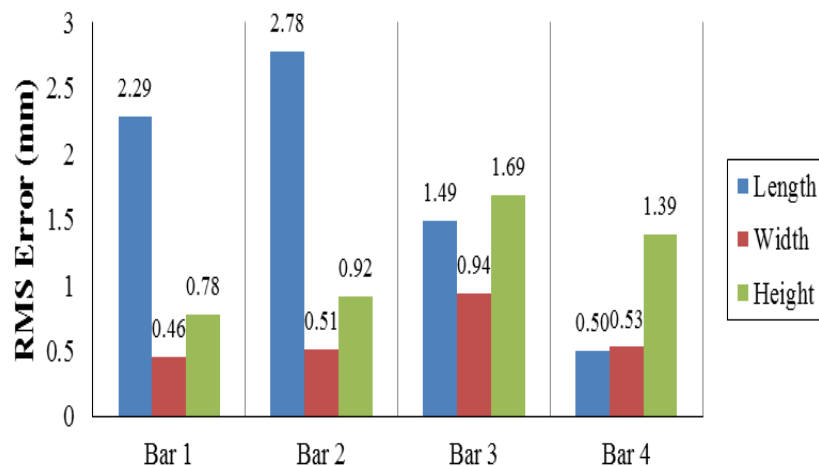


Figure 5. RMS Error of Length, Width, and Height for Bar 1, 2, 3, and 4.

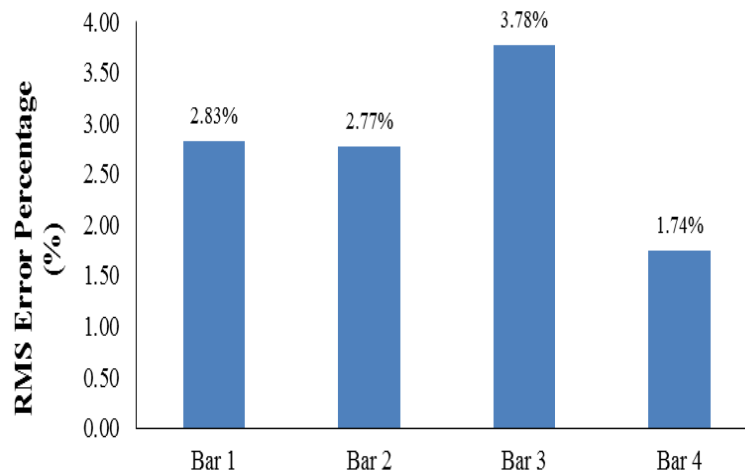


Figure 6. Average RMS Error of Length, Width, and Height for Bar 1, 2, 3, and 4.

3.2. Actual Foot Scanning Process

The foot scanning process begin with, the preparation of the scanning device which is the Kinect® XBOX 360 Gaming Sensor, software, and computer equipped with good graphic processing unit (GPU). Autodesk Meshmixer 2.6 had been chosen for the enhancement process which is to remove the unwanted geometry as shown in Figure 7.

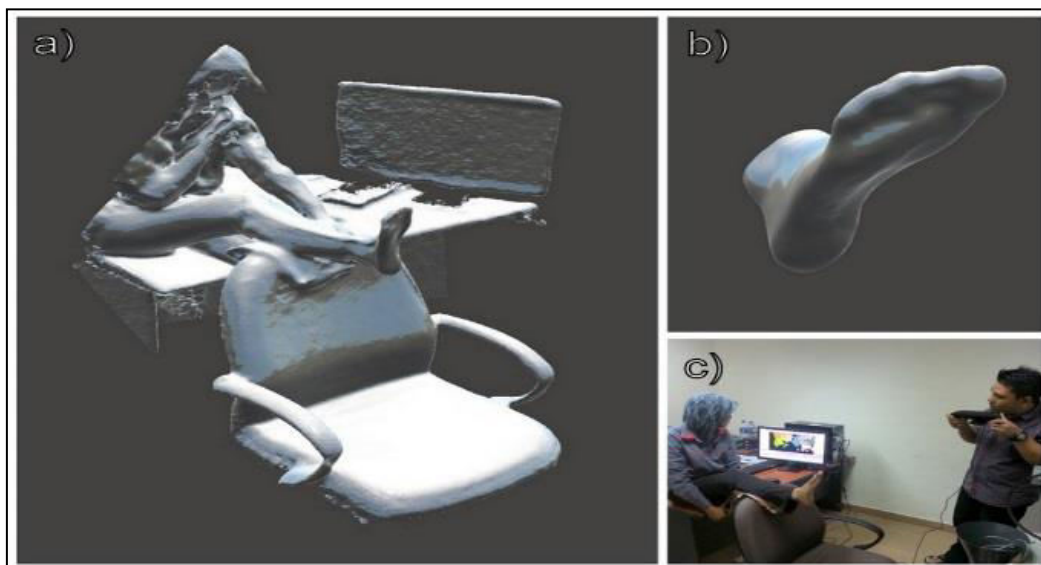


Figure 7. a) 3D geometry reconstructed. b) Unwanted geometry removal. c) Actual foot scanning process.

After the unwanted geometry is removed, the mesh size needs to be reduced in order for Solidworks 2014 to be capable of reading the mesh file. Autodesk Meshmixer provide feature of simplifying or reducing the mesh size without losing the complexity of the 3D foot geometry. The mesh size had been reduced from 54,088 triangles to 4,864 triangles. Figure 8 shows the raw mesh size before and after simplification or mesh size reduction. After the mesh size is simplified, the geometry will be exported into .STL and ready for insole design process.

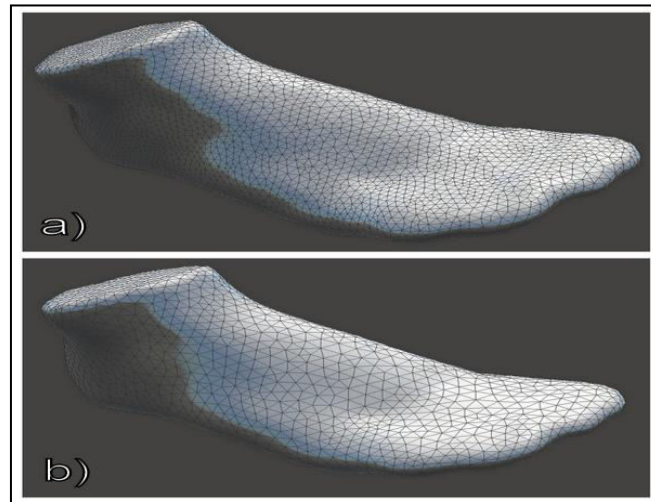


Figure 8. a) 3D foot geometry before the simplification (54,088 triangles). b) 3D foot geometry after simplification (4,864 triangles).

3.3. Orthotic Insole Design Process

Design process begins with importing the 3D foot geometry from the scanned process and the file was converted from mesh format into solid surface format. Solidworks 2014 is capable to do the process with surface wizard features. This feature can be used only when the scan to 3D features activated. The surface wizard features will convert the mesh file into solid surface where solid surface format can be edited accordingly. Figure 9 shows the 3D foot geometry from mesh format to solid surface format by applying surface wizard features.

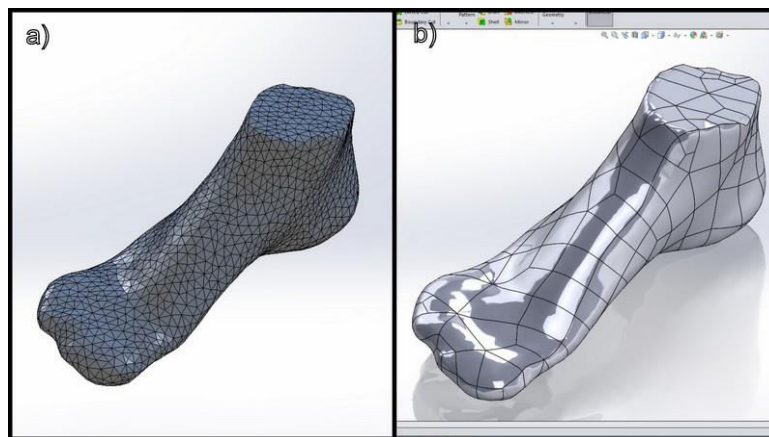


Figure 9. a) Initial mesh format. b) Solid surface model after surface wizard applied.

The next step is to draw a box from the bottom surface area and extrude the box up to the half of the foot area. The area must consist all of the arch support at the bottom of the foot surface. The extrude command need to set unmerge so that the extruded box and the foot geometry are not join together as a solid model. Then, both box and the foot geometry body is subtracted with the box as the main body and the foot geometry is the body that needs to be removed. Figure 10 shows the geometry before and after subtraction.

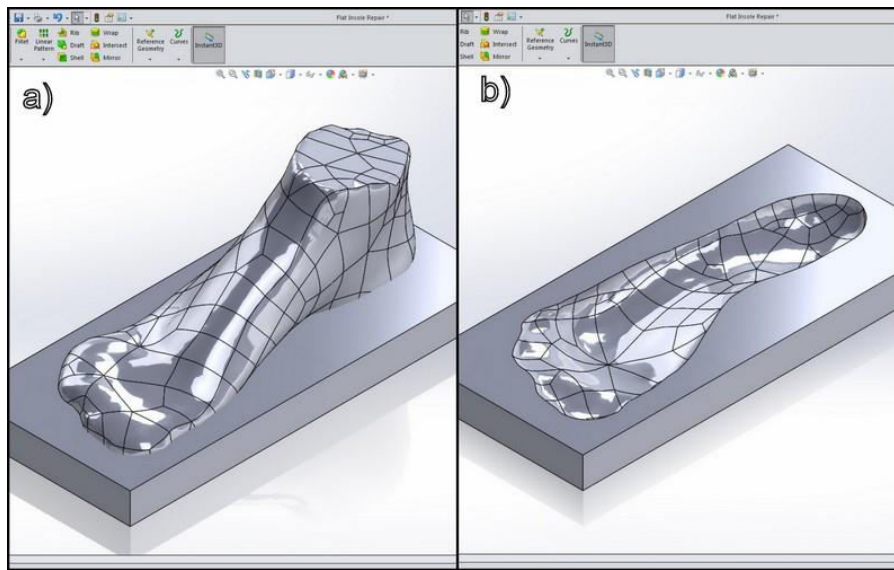


Figure 10. a) Before subtraction. b) After subtraction.

After the subtraction process, the box needs to be rescaled in order to add some clearance to the foot geometry size since the foot geometry was scanned in non-weight bearing (NWB) condition. The foot length and foot width under full body weight or full-weight bearing (FWB) will increase by 3.4% (8.0mm) and 6.0% (5.7 mm), respectively, compared with the NWB condition as shown in Figure 11 a) [13]. Therefore, the scaling had been done by adding multiplication of 1.034 in z-axis of the foot length and 1.06 in x-axis of the foot width for the clearance purposed as shown in Figure 11. After the scaling process, the box will be removed by preserving subtracted geometry with the offset of 3mm from the subtraction boundary.

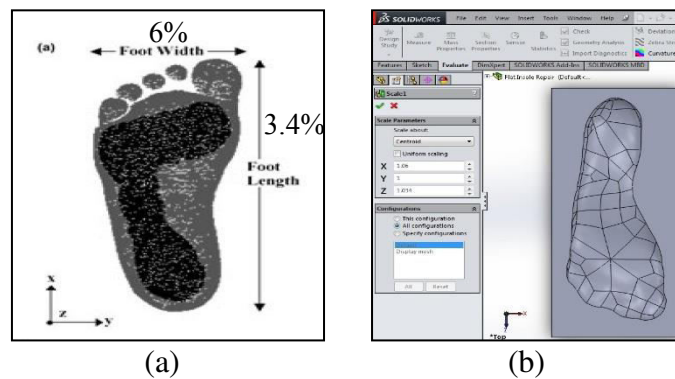


Figure 11. a) Foot length and width increment percentage in FWB condition. b) Adding clearance to the foot geometry using Solidworks scale feature.

In order to remove the unwanted areas from the insole, a reference line is drawn on the side of the insole. The reference line should be covered all the important area of the foot such as arch support and back bottom foot area. The authors had drawn the cutting line on the side of the geometry and preserving the arch support and the back bottom foot area as shown in the Figure 12. Upside area from the reference line will be removed.

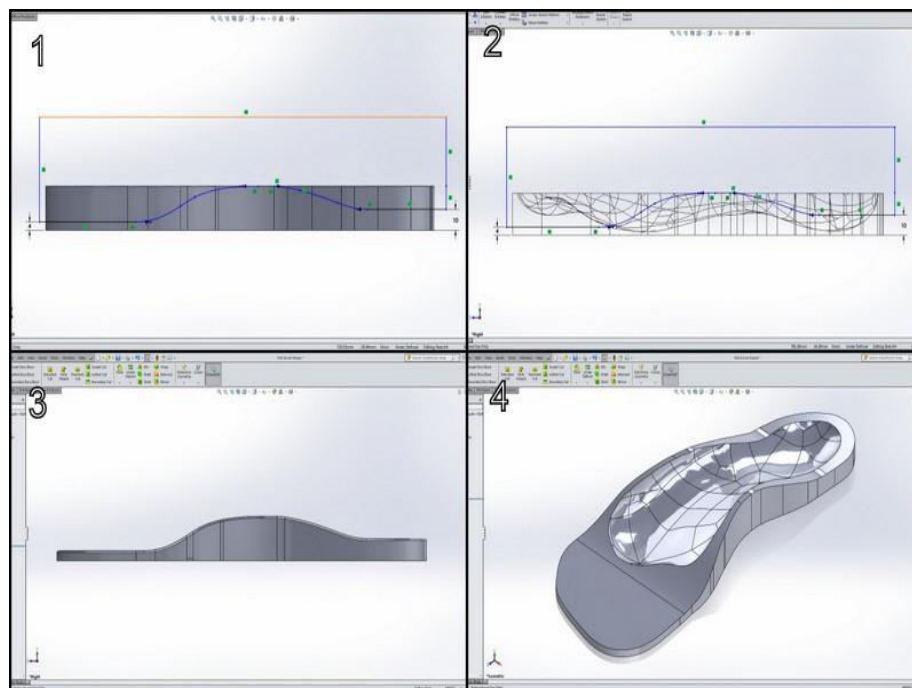


Figure 12. Preserving the foot arch support from step 1 to 4.

Next is to do the offset cut once again only at the back area of the insole in order to minimize the solid body of the insole geometry. The offset size is same as previous which 3mm offset dimension. Finally, all the sharp edges or highlighted area are totally removed to obtain the smooth insole surface by using fillet features.

Before move on to the fabrication process, the finished insole design had been assembled with the scanned foot geometry in order to visualize the feasibility of the insole shape and tested the suitability of the overall designed insole. Figure 13 shows the assembly model and there are no interference occurs between the insole and the foot geometry and the designed insole is fit very well.

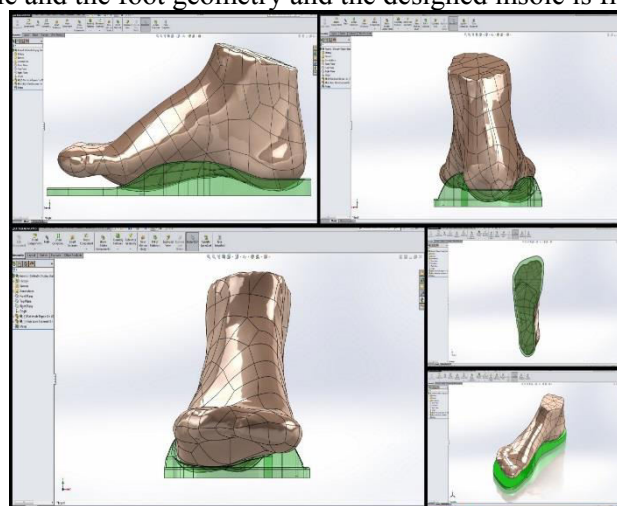


Figure 13. Insole assembly from different point of view.

4. Conclusion

The accuracy of the reconstructed geometry are taken into high consideration during this research since the geometry of the orthotic insole is 100% depends on the patient's foot shape or geometry. As

shown by the results, the Kinect® XBOX 360 device is capable of producing 3D reconstructed geometry with the maximum and minimum error of 3.78% (2.78mm) and 1.74% (0.46mm) respectively. Besides, the higher the scanned model dimension, the less error can be achieved. The Kinect® XBOX 360 device promises for low price compared to other digital 3D scanner since the software needed to run the device can be downloaded for free which provided by Microsoft® developers. The software required to run the Kinect® XBOX 360 device are Kinect® for Windows SDK Version 1.8, Kinect® for Windows Developer Toolkit Version 1.8 and Kinect® Fusion Explorer. Overall, the method proposed is expected to be highly potential in the fabrication of the insole where it promises low cost, less time consuming, and efficient.

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References

- [1] M. M. Ahmat, M. S. Wahab, N. Kassim, 2016. Parametric Modelling of Malaysian Teeth Template Using Computer Aided Design, *ARPN Journal of Engineering and Applied Sciences* 11 (8), 5269-5274.
- [2] M. Munsch, 2017. 15 - Laser additive manufacturing of customized prosthetics and implants for biomedical applications, In *Woodhead Publishing Series in Electronic and Optical Materials*, edited by Milan Brandt, Woodhead Publishing, 399-420.
- [3] Adindu Emelogu, Mohammad Marufuzzaman, Scott M. Thompson, Nima Shamsaei, Linkan Bian, 2016. Additive manufacturing of biomedical implants: A feasibility assessment via supply-chain cost analysis, *Additive Manufacturing* 11, 97-113.
- [4] Ian Gibson, Aniruddha Srinath, 2015. Simplifying Medical Additive Manufacturing: Making the Surgeon the Designer, *Procedia Technology* 20, 237-242.
- [5] Robert A. Watson, 2014. A Low-Cost Surgical Application of Additive Fabrication, *Journal of Surgical Education* 71 (1), 14-17.
- [6] Rengier F, Mehndiratta A, von Tengg-Koblighk H, Zechmann CM, Unterhinninghofen R, Kauczor HU, Giesel FL, 2010. 3D printing based on imaging data: review of medical applications, *Int J Comput Assist Radiol Surg*, 5 (4), 335–341.
- [7] Darpan Shidid, Martin Leary, Peter Choong, Milan Brandt, 2016. Just-in-time Design and Additive Manufacture of Patient-specific Medical Implants, *Physics Procedia* 83, 4-14.
- [8] Yu-an Jin, Jeff Plott, Roland Chen, Jeffrey Wensman, Albert Shih, 2015. Additive Manufacturing of Custom Orthoses and Prostheses – A Review, *Procedia CIRP* 36, 199-204.
- [9] The Center for Podiatric Care and Sports Medicine, Preserving Mobility: Foot Orthotics Benefit Injury Rehabilitation & Reduce Disability. Retrieved January 2, 2017, from <http://healingfeet.com/foot-care/preserving-mobility-foot-orthotics-benefit-injury-rehabilitation-reduce-disability>.
- [10] Kennedy, S., 2004. Casting for Foot Orthotics—What Works Best? Retrieved 27 Feb 2017 from http://www.oandp.com/articles/2004-08_08.asp.
- [11] Izadi, S., Kim, D., Hilliges, O., Molyneaux, D., Newcombe, R., Kohli, P., ... & Fitzgibbon, A. (2011, October). 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* (pp. 559-568). ACM.
- [12] Khoshelham, K., 2011. Accuracy Analysis of Kinect Depth Data. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume XXXVIII-5/W12, 2011. XXXVIII-5/W12. Calgary, Canada: ISPRS Calgary.
- [13] Tsung, B. S., Zhang, M., Fan, Y. B., & Boone, D. A., 2003. Quantitative comparison of plantar foot shapes under. *Journal of Rehabilitation Research & Development*, 517-526.