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SCANNING OBJECTS WITH A LOW COST DEPTH SENSOR

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Rezumat. Lucrarea abordează scanarea 3D şi reconstrucţia virtuală a obiectelor mici utilizând senzorul de adâncime Kinect şi un program de reconstrucţie. Sunt cunoscute aplicaţii în diverse domenii în care obiectele cu o suprafaţă complexă trebuie să fie reconstruite, ceea ce însemnă timp consumat cu măsurarea şi conversia numerică a suprafeţelor, activităţi realizate cu dispozitive de scanare comerciale. Senzorul de adâncime Kinect utilizat în această lucrare se bazează pe un dispozitiv de tip cameră web, care funcţionează cu ajutorul luminii structurate, dezvoltând suprafeţe 3D descrise prin intermediul norilor de puncte definite prin coordonate 3D. Senzorul de adâncime Kinect permite rotirea utilizatorului în jurul obiectului pe o rază de la 400 până la 1000 mm. Datorită preţului scăzut, senzorul Kinect poate fi un dispozitiv atractiv în diverse aplicaţii cu scanări 3D. Scanarea şi reconstrucţia au fost aplicate în această lucrare la reconstrucţia unui vas. Studiul descrie fazele de lucru de la scanare până la reconstrucţia obiectului. Rezultatele studiului arată că scanarea cu ajutorul senzorului Kinect are performanţe bune în cazul vaselor cu găuri şi suprafeţe concave dar nu este o tehnică potrivită în cazul obiectelor mici cu muchii ascuţite şi detalii multiple. Dezvoltarea în continuare şi îmbunătăţirile aduse senzorilor de adâncime ieftini va permite în viitor o extindere a ariei de aplicaţii.

Cuvinte cheie: scanare 3D, senzor de adâncime, Kinect, reconstrucţie, vas.

1. Introduction

Scanning and 3D reconstruction and generally the use of CAD/CAM and Rapid Prototyping techniques are necessary for the obtaining of the 3D model of different artefacts, objects or anatomic surfaces. The most known techniques used in scanning are: Computed Tomography (CT), Magnetic resonance imaging (MRI), Laser scanning, Structured light scanning and, Photo-based scanning.

Computed tomography (CT) and Magnetic resonance imaging (MRI) are useful in the investigation of soft tissues in medicine.

3D laser scanners are also active scanner that use laser light to probe the objects. The laser detects the distance of different points from object surface using triangulation or time-of-flight methods.

Structured-light scanners project a pattern of light on the object and use a technique similar to triangulation or to or time-of-flight to calculate the distance of every point.

Photo-based scanning allows the three dimensional position of each point in the picture to be identified. In this technique, the light is coming from the object and is captured by the camera from different positions and a specialized software reconstructs the 3D object.

There are a lot of applications of the professional 3D structured light scanners. The team lead by Berthold Shin[1] had studied the accuracy of the Kinect sensor and found in 2013 that the reconstruction errors were between 2 and 3 mm for human surfaces when sensor was placed at 500 and 2000 mm distance. These errors permit the use of Kinect sensor in a lot of bioengineering applications including prosthetics and orthotics. Reconstructing geometry using depth sensors are well-studied areas of research in computer graphics[2,3,4] etc.

2. Material and method

Paper approaches a study of structured light scanning technique and 3D reconstruction of small objects using the Kinect device. There are described the phases from data acquisition to 3D reconstruction.

The Kinect depth sensor is an input device for Microsoft Xbox gaming console. It is used for different applications including measuring the three-dimensional coordinates of the points of an object surface (point clouds). Kinect projects light patterns over objects and a camera system measure distances. The Kinect sensor (Fig. 1) develops virtual 3D surfaces described by a multitude of point clouds defined by x, y and z coordinates of the physical objects. The depth sensor allows the user to rotate around the object with a radius between 400 and 1000 mm.

Fig. 1. Kinect for Xbox 360.

[1] Shin *et alii*, 2013.
[2] Camplani, Salgado, 2012.
[3] Dutta, 2012.
[4] Henry *et alii*, 2012.

Kinect projects infrared points onto 3D surface and the surface produces distorted points that are read using a 2D infrared sensor. Although many other variants of structured light projection are possible, infrared dot patterns are as in Fig. 2.

The projected dots changes size and position based on how far the faces of the objects are away. The color camera also transmits data that are processed and used to reconstruct the textured 3D model of the scanned object. The color camera has an infrared lens filter. The infrared dots create a depth map, and the distances to dots are calculated in real time by trigonometric triangulation.

As the user and camera describe a trajectory in the space around the object, data of the physical object are assembled. The system assembles depth data into a single 3D model. A scanning system consists of depth sensor and 3D reconstruction software.

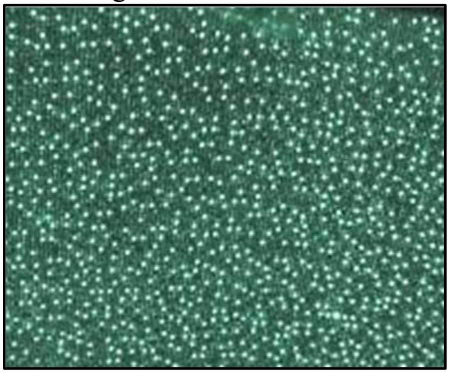

Fig. 2. Infrared dots projected by Kinect seen with a night vision camera.

The Kinect for Xbox 360 sensors have many functions, including a color camera, a multi-array microphone, an accelerometer, an infrared emitter and an infrared depth sensor.

Depth cameras like Microsoft Kinect, Asus Xtion and Primesense Carmine have similar characteristics. For working with Kinect a PC needs next resources: 2 GB RAM, Quad core processor, Windows 7 or later, graphics card with Cuda function and minimum 1 GB of memory.

The Kinect sensor works with Windows Software Development Kit (SDK) which includes Windows 7 compatible PC drivers for Kinect.

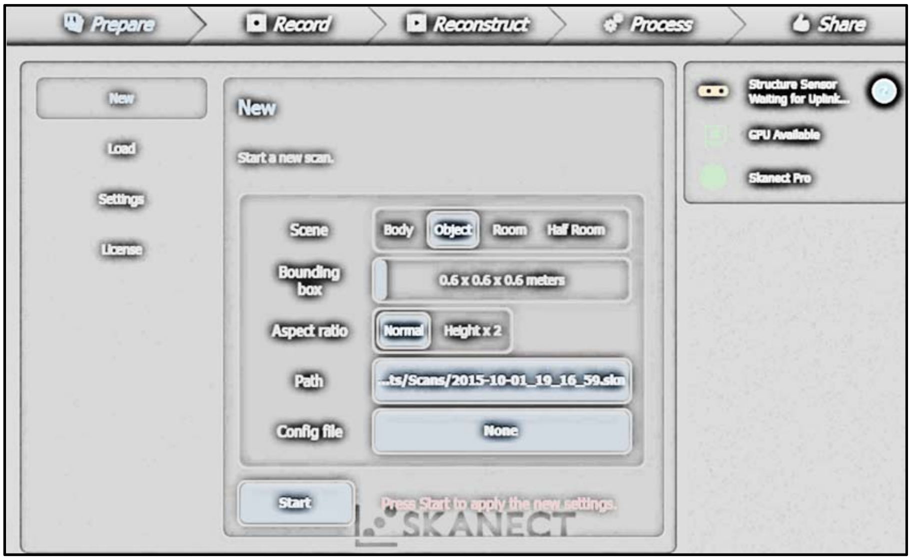

Fig. 3. The interface of 3D reconstruction Skanect software.

Kinect also needs OpenNI, open-source software that is able to read 3D data from depth camera. For the reconstruction of the 3D model, a reconstruction software it is necessary, specially developed for depth sensors. There are several software for 3D reconstruction using depth camera: Skanect (Fig. 3), Kscan3d, Fablitec, Blender, ReconstructMe etc.

3. Results

There are two options when scanning: rotating depth sensor around the vessel or rotating the vessel in front of depth sensor (Fig. 4). Best results were obtained during rotating depth sensor around the vessel at 400 or 500 mm distance. The trajectory of the sensor was a circle around the object and a half circle on the top of object at 400 mm distance.

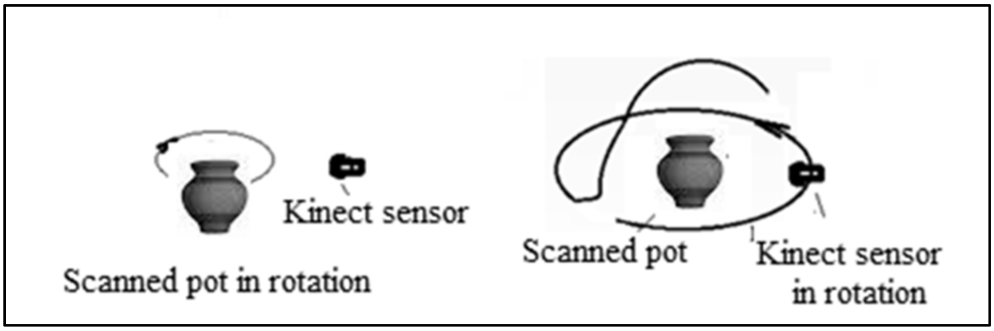

Fig. 4. Kinect sensor positions during scanning.

The study was performed on a vessel (Fig. 5) with a inner blind hole in order to estimate the capabilities of the Kinect depth sensor and of the Skanect reconstruction software.

The frames scanned by Kinect were reconstructed with Skanect software. The final model may be exported in *obj*, *stl*, *vrml* and *ply* formats. The result was a 3D surface model that may be viewed using different software. Figure 6 shows the 3D model of a vessel visualized with Deep Exploration software.

The Kinect sensor may see inside blind holes and the 3D reconstructed model with Skanect shows a lot of details from the inner parts of the vessel (Fig. 7). The textured 3D model vizualized with Skanect is showed in Fig. 8.

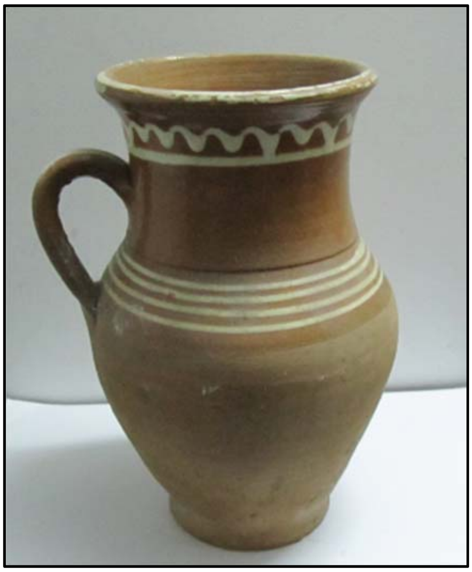

Fig. 5. The vessel used in 3D scanning and reconstruction

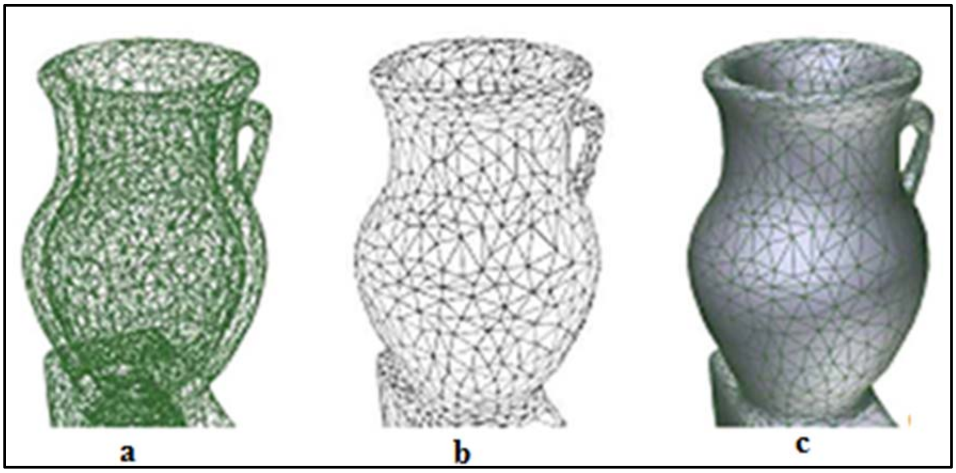

Fig. 6. Visualization with Deep Exploration software: transparent wire-frame (a), c-hidden wire-frame (b) and solid wire-frame (c).

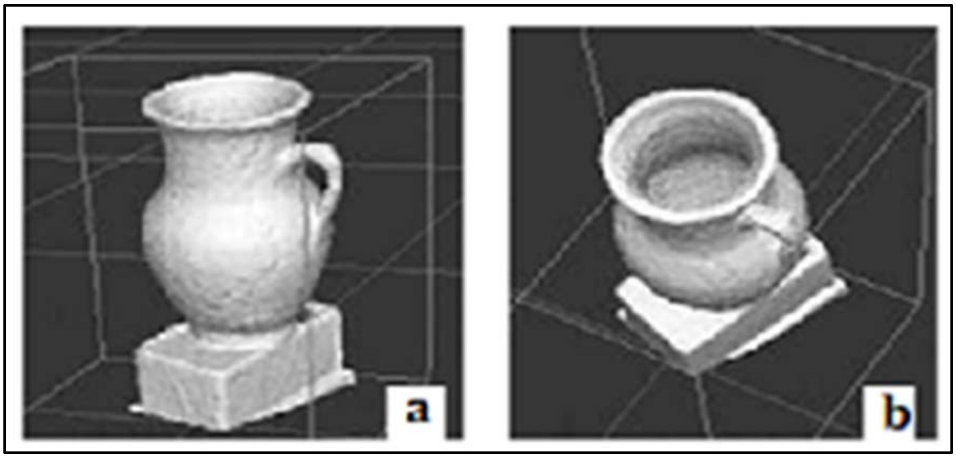

Fig. 7. Visualization of the inner parts with Skanect software (a and b).

Fig. 8. Visualization of the texture.

The reconstruction performances may be observed better making sections in the 3D model. Fig. 9 shows horizontal and vertical sections performed with Deep Exploration software.

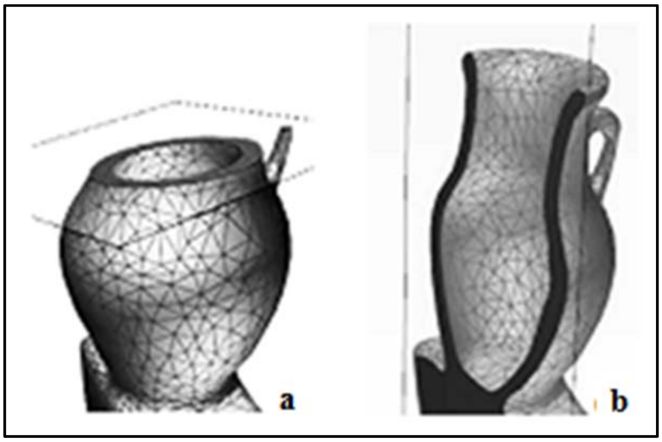

Fig. 9. Visualization with the Deep Exploration software, with horizontal (a) and vertical (b) cross sections.

Another scanned object was a wrench with a lot of sharp edges and multiple details as in Fig. 10. The study showed the reduced capabilities of the Kinect sensor and of the 3D reconstruction software in the case of small objects with sharp edges. The reconstructed 3D model is presented in Fig. 11and contains rounded edges and a lot of unclear surfaces.

The wrench was scanned with Kinect using a circular trajectory at 300 mm distance.

Fig. 10. The skanned wrench.

The reconstruction was performed with Skanect software and vizualization with MeshLab software.

The sharp edges of the object were clearly rounded and this may be an important drawback when scanning.

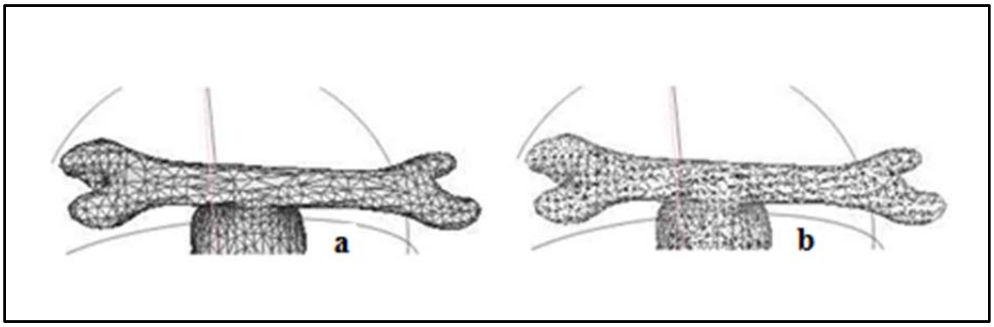

Fig. 11. The reconstructed 3D model of the wrench visualized with MeshLab software with low (a) and high density of polygons (b).

4. Conclusions

This study showed that Kinect depth sensor may be used as a low-cost alternative to other traditional 3D surface imaging systems. The study showed the results of the use of a Kinect depth sensor in the 3D scanning of rounded and straight surfaces.

The scanning with Kinect sensor produces good performances, especially in the case of rounded objects with blind holes and surface concavities but this technique is not suitable for the scanning of small objects with sharp edges and multiple details.

Possible applications are in the area of virtual catalogues, virtual exhibitions and virtual museums.

Kinect depth sensor requires a powerful PC with an advanced graphics card. The cost of depth sensors and associated software are constantly decreasing, but the performanes are increasing.

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