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USE OF ALTERNATIVE SCANNING DEVICES FOR CREATION OF 3D MODELS OF MACHINE PARTS

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Preliminary notes
Capturing of 3D information about any kind of surface is currently a big challenge. A few proven commercial techniques and technologies are in use for a couple of years, but needed hardware and software are still too expensive for ordinary users of PC. This article provides a few cheaper alternatives based on open source elements to commercial non-contact 3D scanners and proves that the obtained data are suitable not only for hobby home spatial digitization but also for requisites in the industry. In various parts of the contribution there is a brief description of digitization process with mentioned freeware and shareware applications.

Keywords: *digitization, software David, software Kinect, 3D scanner*

Uporaba alternativnih skenera za izradu 3D modela strojnih dijelova

Prethodno priopćenje
Snimanje 3D informacija bilo koje površine i danas je još uvijek veliki izazov. Neke komercijalne tehnike i tehnologije snimanja u uporabi su nekoliko godina, ali je potreban hardver i softver koji je još uvijek preskup za korisnike. Ovaj članak daje nekoliko jeftinijijih alternativnih postupaka snimanja površine, na temelju "open source" elemenata za komercijalnu uporabu beskontaktnih 3D skenera i dokazuje da su dobiveni podaci pogodni ne samo za hobi prostornu digitalizaciju, nego i za uporabu u industriji. U dijelu rada ukratko je opisan proces digitalizacije s nekoliko freeware i shareware programa.

Ključne riječi: *digitalizacija, softver David, softver Kinect, 3D skener*

1 Introduction

The most effective and often also the quickest way to recreate a digital copy of an object is not the usage of advanced measurement tools as measuring tape or calliper, but the usage of 3D scanner. Advanced digital mapping with the use of 3D scanners allows an effective improvement of e-planning during the optimization of workplaces by fast creation of accurate copies of real environments, what is very important in the area called "Digital manufacturing". The level of computer visualization and simulation nowadays allows for significant reduction of the time needed for positioning of equipment in new factory buildings in terms of saving space, optimizing the working times and other purposes. 3D visualization of machine parts with a considerable degree of abstraction leads to identification of potential problems that might occur after the launch of operations, where even a smallest change in the production line has a disproportionate delay leading to financial losses.

At the Faculty of Manufacturing Technologies we try to create cheap techniques which would allow us to recreate currently used working areas accurately and as fast as possible. Of course the commercial shelled devices are very precise but their purchase price is too high for small businesses. This article points to the more affordable solutions of 3D digitization by using the motion sensing sensor Kinect and for high resolution scans software solution David. These devices together with a few shareware software programs start a new trend that leads to disclosure of 3D digitization for everybody at home.

As previously mentioned, there are few different types of 3D scanners on the market therefore every user should know the size of objects intended for scanning together with desired accuracy of final 3D model and also some other characteristics of the scanner and relevant digitization technique. The digitization process as shown in Fig. 1 begins by specifying the tasks.

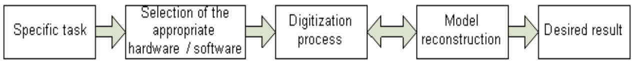

Figure 1 Simple block diagram of processes needed for accurate 3D digital reconstruction of objects

If a customer or constructor knows the objects body he can easily choose the right device, additional equipment (if he has the choice, Fig. 3) and methods for shape digitalization relative to the final desired outcome whether it is the digitization of parametric CAD model or just obtaining and simple presentation of point cloud. Also we cannot forget that the overall result of digitization depends on the mastery of hardware as well as software for subsequent data processing.

2 3D digitization devices

Various professional digitization machines have a big disadvantage – close specialization to the capturing of object of a certain size. For example FARO LS 880 in Fig. 2 is designed to capture surfaces of larger scope that means internal and external areas of buildings.

Figure 2 a) Farp LS 880, b) Kinect, c) ZScanner 700

The FARO Laser Scanner produces three dimensional black and white point cloud data and for enhanced realism an additional colour camera can capture the texture of surface. The maximal view of LS 880 is seventy-six meters where the accuracy can fall to 3 mm [11]. That is more than enough for our purpose of creation models of machine parts. By one scan from centre of a room we obtain partial data from surrounding machines.

As an alternative device we use Kinect (Fig. 2) primary designed by PrimeSense as a motion game controller for XBOX 360 gaming console. Basically the Kinect is a device utilizing the depth sensors. Depth cameras do not present such a novelty but Kinect has made these sensors accessible to all. Kinect consists of two cameras (RGB and infrared) and one infrared transmitter. To obtain 3D data camera uses a structured light technique to generate real-time depth maps containing the discrete range measurements of the physical scene with the frame rate of 30 Hz [6, 10]. Kinect is dimensioned to recognize a predefined area of about 6 m^2 at the distance of three meters or by newer version for windows only about 2 m^2 but this area can be changed by using a kind of "glasses" for Kinect like the ZOOM [10]. This lens reduces the sensing range of Kinect by up to 40 % by shorting the view distance while making the angle wider. Similar optical system can also be used to increase the scan distance which is one of the subjects of research at our faculty. According to the range of view Kinect can catch 3D data only at a distance of few meters and thus cannot compete with LS 880 in this field. Currently, to capture as many space points as possible Kinect must be moved more than Faro LS but using it we can obtain more detailed models and avoid blind spots which are usually manually recreated in CAD. For use of Kinect also speaks the fact that it can be worn in hand of the user and it can scan also in tight spaces, while catching the area from the distance of forty centimetres (accuracy 1 mm). On the other hand with LS 880 it is sixty centimetres [11]. Kinect does not have a rotating base as Faro LS, it can only move up and down by twenty seven degrees. To obtain three hundred sixty degree rotation in horizontal plane an external moving system must be added to ensure correct measurement, what means investment in additional hardware. This can also depend on used software because Kinect can track its own position through three built-in accelerometers.

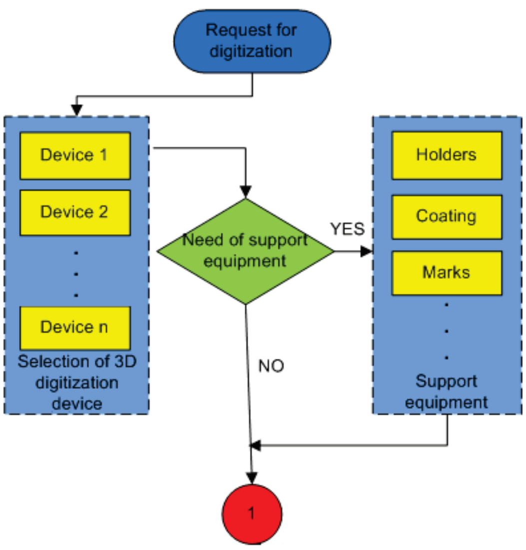

Figure 3 Scheme of preparation phase

All these previous pieces of information lead us again to think about the process described in Fig.1. Fig.3 graphically in more details represents the preparation phase where the right choice of sensing device significantly affects the duration of the scanning process and can lead to reduction of digitization costs needed for additional support tools.

Due to the fact that Kinect captures data with resolution of only 1 mm, for realization of precise high-resolution scans we used handheld ZScanner 700 which can provide scans of machine parts and also cutting tools (they must be prepared, without any bright spots). While user is carrying ZScanner in his hand he is limited only by the reach of provided firewire cable. Another disadvantage of this device is use of reflecting markers placed on scanning object or surrounding area in view field of scanner. These points (minimally three of them) are necessary for recognition of scanner position and accurate registration of captured point cloud. As a cheaper alternative we use software David laser scanner (hereinafter David LS) which needs only ordinary web camera that can capture at least fifteen frames per second and a single linear laser pointer. Working with DAVID software can be described as utilization of a modular concept to 3D space digitization since each part can be varied for specific tasks, while the only unchanging element is DAVID itself. From the version 3.0 David uses also better and in particular faster scanning principle of structured light scanning where function of laser pointer is replaced by projector light (hereinafter David SL). In the process of capturing the light pattern consisting of horizontal and vertical stripes of different widths is projected on the top of scanned object. Through the light bands copying the surface the optical system obtains the shape of the scanned object. The accuracy of this concept is up to 2 % of object size what could be less than 0,1 mm depending on the camera used [7]. Fig. 4 presents our experiences with different non-contact scanners.

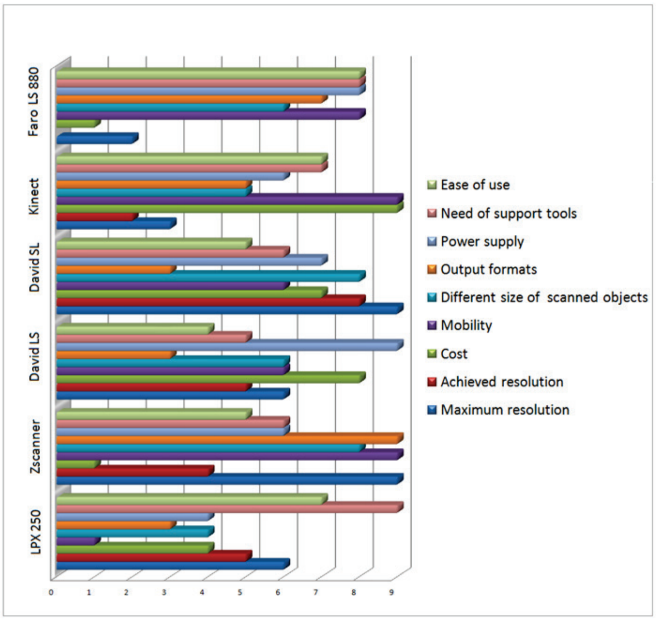

Figure 4 Graphical comparison of the basic features of digitization realized by concrete devices

3 Software support

Every digitization device needs an adequate relevant software support to run its effective operation. In professional applications users can use for example Rapid form which includes all necessary modules needed for control of the scanning device starting from mesh recreation and parametric modelling going to inspection of recreated surfaces (Fig. 5). For our purpose of a cheaper alternative way of digitization we try to use the software based on open source principle which is more time consuming but cheaper for over a few thousand euros.

Usually every scanner has its original basic controlling software like ZScanner's VXelements. For Kinect there are many programs that can use data obtained by the device mainly due to the fact that the communication with PC is possible through USB port. For example Kinect can be used for videoconference calls because besides the webcam there is also integrated multi array microphone and Geeks daily create a lot of entertainment freeware applications. A few of them are programmed so they can be used also in mechanical engineering applications [1].

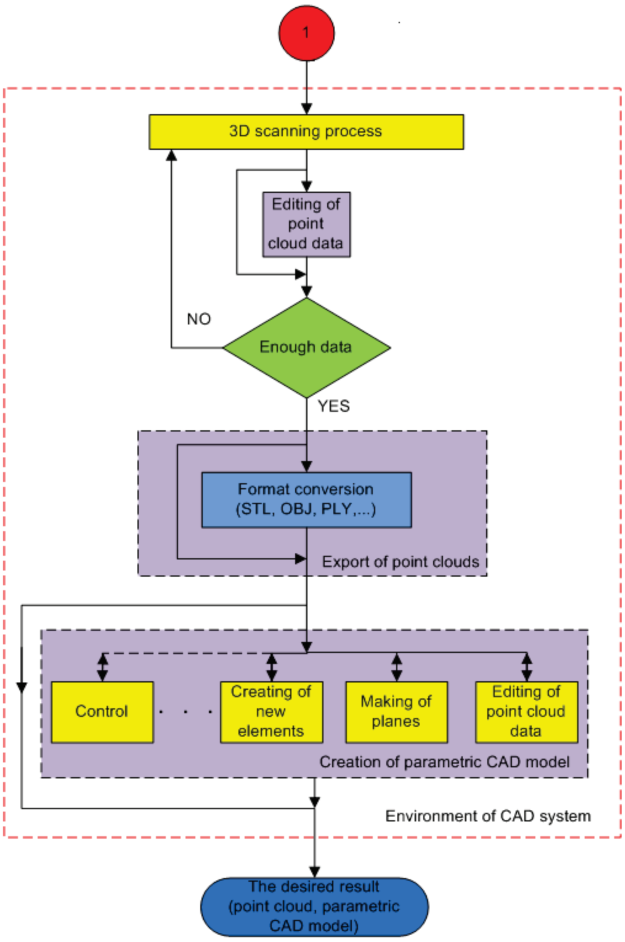

Figure 5 Scheme of necessary steps in process of object digitization based on 3D scan

We use two different applications: Skanect and ReconstructMe. For 3D digitization of interior and included devices currently the best solution presents free application for non commercial use called Skanect created by Manctl Comp. which allows capturing 3D space of digitized environment in real colours in either point and polygon PLY format. The software has very user friendly interface consisting of three preview windows (Fig. 6) as in most similar applications, two of them showing an area seen by an infrared depth sensor and RGB camera, the third previewing real-time generation of the scan.

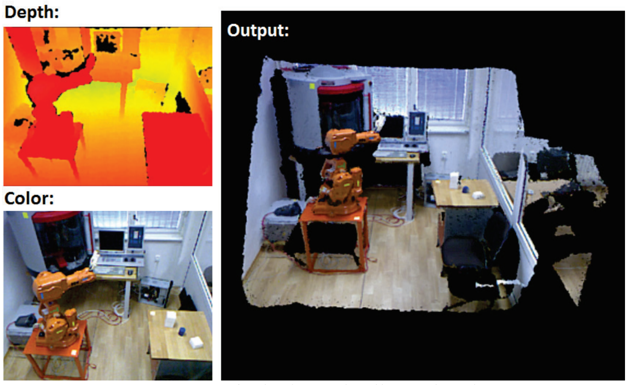

Figure 6 Part of robotic workcell seen by Skanect

For more precise capturing of larger machine parts we use ReconstructME which in addition to the sensing of environment in real time can detect also the changes in scanned environment and automatically re-modify the captured scene (useful by moving parts) although it does not allow direct capturing of the texture.

Figure 7 Raw scan data from ReconstructMe

The applications can for the calculations use PC's processor or graphic cards core. Point polygon mashes can be stored in STL, PLY, OBJ and 3DS format but since the software is limited by the amount of graphics memory, millions of obtained points from digitizing of larger objects (more than three meters in diameter) cannot be saved in a single process.

4 Digitization of machine environment

We decided to virtually recreate our robotic workstation for the purpose of optimal collocation of all machines and ABB manipulator. Digitization was performed because of the absence of the machines models which were later remodelled in a significantly shorter time based on the utilization of 3D scan. The orientation of machines was also realized by 3D scan with Kinect but only the key points were digitized for a correct placement. All models were imported into ProEngineer's environment and a few times replaced to get the optimal use of space while considering the reach distance of robot´s working area. While realizing this task we also noticed that this basic model could be used for offline programming and testing of the programs for manipulator IRB 140 although we would need more precise 3D scans of inner machine parts [2, 3]. The interiors of the machines were captured with high accuracy very fast with David structured light scanner. Camera and projector were mounted on tripod and calibrated. For scanning of the pre-calibrated construction we simply turned the tripod from the calibration corner to the scanned object at exactly same distance.

In Fig. 8 there are simple partial 3D scans of small gearbox (ten centimetres in diameter) done with scanners mentioned in this article. For demonstration of bad conditions digitalization was made through protective plexiglass and David software used just an ordinary webcam (not high-resolution as usually used). In Fig. 8 we can clearly see that David (basic cost max. 220 €) had no problems with digitization. The calibration was time costly but without need of another repeats and time needed for this referential scan was only ten seconds. By ZScanner (device for about 3100 €) it took fifteen minutes and we had to place a lot of reflecting markers while obtaining no data through a non-removable protective plexiglass.

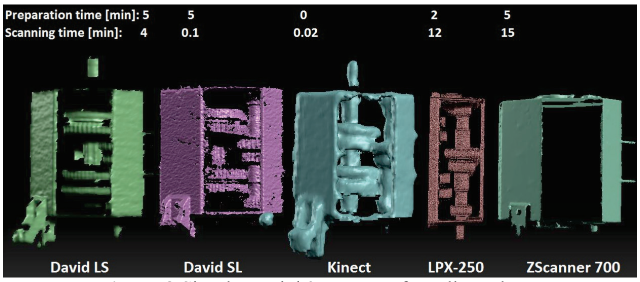

Figure 8 Simple partial 3D scans of small gearbox

After capturing a sufficient number of points (depending on the desired quality) the point clouds must be cleaned and adjusted as required for future use. One of the best professional software for manipulation with point clouds is Geomagic. Freeware applications like Meshlab and Blender can do the same job, although not so elegantly, fast and also manipulation with the data is a bit difficult for novice users. When digitizing with David for simple cleaning of meshes we use its implemented module 3D ShapeFusion where we also align the scans from various points of view what is in most other programs a complicated operation. To make the necessary reductions of needless points on different polygon meshes from multiple scans of parts with complex shape, it is necessary to unify them into one reduced point cloud. After import of each part of the scanned area into the work environment it is possible to manipulate with the individual points clouds manually or using automatic positioning and shooting around the *X*, *Y*, *Z* axes or by default angle. This last alternative is best for us as we use precise turntable control from PC [4, 5]. Each polygon mesh has different colour to preserve the clarity. The software looks for the optimal location of each view with regard to common elements, at least three identical points in space. If the result of unified views is consistent with the real object, with fusion we create a unified network of polygons that can be re-edited again [8, 9].

5 Conclusion

All mentioned alternatives, either hardware or software, provided in this article offer powerful tools for the creation of virtual 3D models what means that everybody has the possibility to create realistic models with minimum investment (around 100 €). We demonstrated that ordinary user of a personal computer can create 3D models of machines in useful quality although for results suitable for industrial application we need to invest into additional equipment. With costs around maximum of 1000 € we can create very accurate models of machine parts. Of course, there is still potential for improvements but all the mentioned applications are still being developed and every day new ideas are transformed into reality by a wide user community.

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