Fast Geometry Acquisition for Mixed Reality Applications Using Motion Tracking

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Abstract

Mixing real and virtual elements into one environment often involves creating geometry models of physical objects. Traditional approaches include manual modeling by 3D artists or use of dedicated devices. Both approaches require special skills or special hardware and may be costly.

We propose a new method for fast semi-automatic 3D geometry acquisition, based upon unconventional use of motion tracking equipment. The proposed method is intended for quick surface prototyping for Virtual, Augmented and Mixed reality applications where quality of visualization of objects is not required or is of low priority.

1 Introduction and related work

Capturing 3D shape of physical objects is a well established discipline with dozens commercial solutions and a large body of academic work. Typical applications are reverse engineering, realistic rendering by means of computer graphics and Augmented Reality.

Available off-the-shelf systems can be classified as contact and contactless. Methods that avoid contact include laser scanners based on triangulation and radar laser scanners, based on measuring time-of-flight. Examples are: NextEngine desktop scanner, the most affordable device in the first category; DeltaSphere 3D Laser Scanner is a typical representative of the second group [1]. Contact devices measure coordinates of points of contacts between the device and the object surface. Coordinates are obtained either mechanically or by tracking of the measuring tip. Mechanical devices are called touch probes or coordinate measuring machines (CMM). One example is a Microscribe series from Immersion [2]. Commercial devices are represented by laser trackers, that measure coordinates of mirrored spherical probe (e.g. FARO product line), or magnetic trackers (e.g. Polhemus Liberty with measuring Stylus).

Our solution belongs to this category as well. However, unlike Liberty Stylus, our method uses the same tracking sensor both for geometry acquisition and for the application which interacts with the geometry. This approach eliminates the need for additional equipment and calibration.

2 Motivation: augmenting human manikins

The surface scanning method presented in this paper was implemented as a satellite utility within our augmented manikin simulator. A medical manikin is a life size plastic replica of the human body equipped with electrical, mechanical and pneumatic sensors and actuators, that allow students to interact with the manikin and simulate various functions of a human organism.

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Using tangible user interface (TUI) techniques, we enhance manikin functionality by adding touch-sensitivity to arbitrary locations of the manikin. The manikin itself becomes a single interface object, providing realistic tactile feedback when students palpate in relevant locations. Student hands are tracked and checked for collisions with the 3D model of the manikin. Simultaneously, the system analyzes hand movements and determines which action is being performed. When a meaningful action-location pair is detected, the system triggers an appropriate response function. For example, the manikin groans with pain, when palpated or percussed at a designated tender location. Figure 1 shows the *SimMan* and *Anne Torso* manikins, touch-augmented for teaching palpation.

The abdominal 3D model for SimMan (Figure 1, top right) was constructed using the following steps:

1. measure the extent of the abdomen
2. approximate its surface by spheres, using Maya
3. export the spheres from Maya into the simulator
4. run the simulator, detecting hand-spheres collisions

Steps 2-4 were repeated, varying the number, locations and sizes of the spheres, until reported collisions matched the physical contacts between user hands and the abdomen module closely. The whole process did not take a very long time. However, when we had to go through the same routine for our second manikin, it became clear that there must be a better way of doing this.

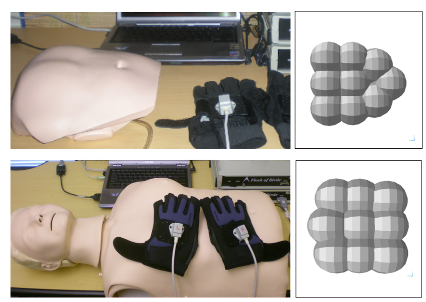

Figure 1: Augmented manikins. The system components: manikin objects from Laerdal [3], Flock of Birds tracking system from Ascension [4], a laptop PC (1.86 GHz CPU, 1G RAM, Linux OS).

3 Surface scanning, the basic algorithm

The main idea behind our method is to use the motion tracking equipment, already integrated into the simulator, to create 3D models of objects of interest, exemplified by the abdomen and torso. Both objects can be represented by a height-field on a plane; both are smooth and lack the necessity for representation of geometric detail less than 20mm. Thus, they can be conveniently built by sweeping a positional sensor along the surfaces and snapping vertices of some underlying grid to the sensor contact locations.

To improve the positional sensitivity of the sensor, which had a roughly cubical shape (25 x 25 x 20) mm, we placed it at the center of a Ping-Pong ball, as shown in Figure 2. The scanning process is described below.

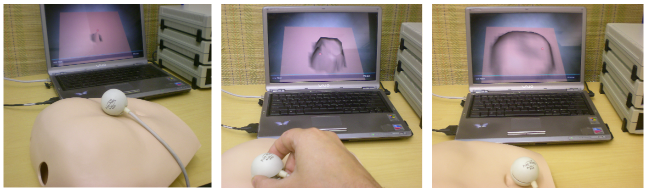

Figure 2: Scanning SimMan's abdomen module, left to right: sensor alignment; scanning in progress; completed mesh. Grid size 40 x 40 cm, 20 x 20 points. Scanning time: less than 2 minutes.

1. *Grid generation.* A regular grid of quadrilaterals is created in Maya and is used as a template to build the height-field. The dimensions and density of the grid are adjusted to match the size of the object to be scanned.
2. *Sensor-object-grid alignment.* A sensor is placed on top of the object (Figure 2, left); the system captures the sensor location and shifts its rest position to and above the center of the grid. Once all three objects are aligned, scanning is initiated.
3. *Surface scanning*. The user moves the sensor along the surface of the object in sweeping motions and the system updates the height-field, at the frequency of the graphics loop. On each cycle, the closest vertex is found and snapped vertically to the current sensor elevation. The process continues, until all vertices are elevated and the height-field is complete. Progress is monitored visually. as shown on Figure 2.
4. *Run-time operations on the mesh.* During scanning, the mesh can be saved, reset and convolved with a low-pass filter. Camera parameters (angle, zoom) and wireframe/shaded rendering modes can also be adjusted at run-time.

The second round of scanning tests used the Anne manikin (Figure 3). The density of the grid was doubled and an enhanced plastic easter egg sensor enclosure (5 x 3 cm) was used. The eggshell shaped sensor enclosure naturally conforms to high, medium and low precision scanning modes illustrated in Figure 4.

4 Discussion and Conclusions

The surface scanning method presented in this paper has several unique and attractive features. First, additional devices are not required, since the system utilizes motion tracking equipment that is already in place. Therefore, surface scanning cost is limited to the cost of adding one page of code to an existing system. Second, this system eliminates the need for special skills to create 3D content. Scanning can be performed by any person, after minimal user-interface control training. Finally, the scanning process is fast. The 3D models presented in this paper, were all created in minutes and exceeded the quality and fidelity required for their intended use (i.e., collision detection for palpation training).

In conclusion, our method naturally addresses the long-standing problem of distortions in the magnetic environment, that plagues most magnetic trackers. During scanning, distortions are imprinted into vertex positions of the surface. Normally, such artifacts are not welcome and may render the resulting mesh useless, if used elsewhere (i.e., under different magnetic environment). However, if the mesh is used with the same simulator at the same location, the distorted shape is perfectly preprocessed for correct hand/surface collision detections. The shape produced with our scanner is a reflection of the true surface of the physical object (a manikin) in the magnetic environment of the lab and its own inner 'organs'. A perfect surface model would require a complicated tracker calibration, to take magnetic distortion into account. Using the same equipment for surface acquisition effectively mitigates this problem.

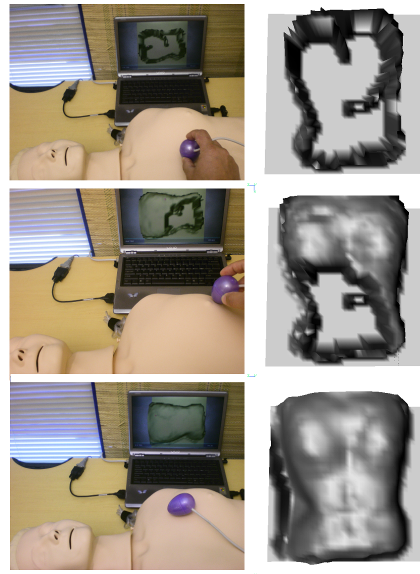

Figure 3: Scanning Anne torso: initial contour, intermediate, final mesh. Grid: 40 x 40 cm, 40 x 40 points. Scanning time: 8 minutes. The 3D snapshots are shown "as is", without retouching.

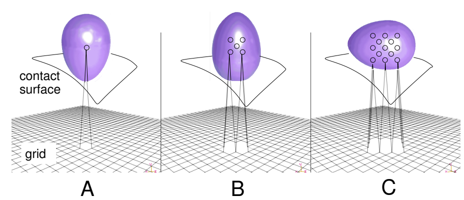

Figure 4: A plastic eggshell provides three intuitive scanning positions: (A) contact with the pointed end moves one vertex; (B) the obtuse end moves the vertex and its closest neighbors (5 points per move); (C) contact with the elongated area makes the system to iterate on vertex neighbors twice (13 points per move).

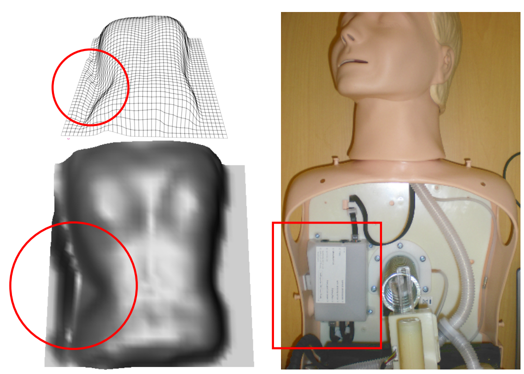

Figure 5: Distorted surface area, denoted by a circle. A 'postmortem' examination revealed that Anne was engineered asymmetrically: a metal switchbox installed in her upper right abdominal area, caused distortions in the magnetic field. Embedding these distortions into the model effectively cancels their effect during model use.

References

[1] A. Cracknell and L. Hayes. *Introduction to Remote Sensing*, (2 ed.), London: Taylor and Francis, 2007.

[2] Immersion Corporation, www.immersion.com/digitizer/

[3] Laerdal Medical Corporation, http://www.laerdal.com

[4] Ascension Technology Corporation, http://www.ascension-tech.com