Creating light-weight virtual humans for Virtual Environments

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Abstract

With the advent of whole body, 3D electro-optical scanners, a new range of applications are emerging that exploit the availability of personalised, realistic human models. However, realistic rendering of such models usually entails a large number of polygons which can be unacceptable in many applications. We present a framework that exploits the approximate cylindrical and spherical symmetry of human body parts to create light-weight representations that retain the overall dimension of body parts, even at very low polygon counts.

Keywords: avatars, level of detail, features

1. Introduction

Currently, several types of avatar are available, from faceless simple box-like figures to avatars with eyes, mouth and limbs that can move. Personal details, peculiarities and imperfections of the appearance and movement of the avatars are important for a high degree of realism. Work has therefore been carried out on creating articulated models from static scanned figures that carry the required details and peculiarities [1]. For realistic movement, the vrml h-anim [2] specification gives some guidance as to the number of joints needed for an avatar, although it is likely that more articulations will be needed when using scanned data from real human subjects, since user's expectation of the behaviour will probably increase

Other attempts to create more realistic humans have been by Thalmann et al [3] who tried to personalise avatars built using metaballs by scaling the model via five or six parameters. Their models were further personalised by use of distinctive clothing [4]. However, people are very good at recognising each other and important cues can be gleaned from simple features such as body outlines and the way people move. It is therefore attractive to think of using scanned models of real people in virtual reality work, especially as accurate, personalised surface representations of humans have recently become available with the development of simple, reliable electro-optical 3D whole body scanners [5]. Examples include the Cyberware scanner and the Hamamatsu Body Lines scanner. The latter offers 1-2 mm accuracy over a sample spacing of approximately 5 mm over the body [6], ideal for applications such as clothing size and fit and body volume measurement for diet, and health monitoring.

However, these scanners typically produce only a cloud of 3D points that, for adequate visualisation, have to be meshed by means of surface fitting techniques such as those described in [7,8]. The meshed body scanner (BS) representations can be comprised of tens of thousands of polygons, putting them beyond the capabilities of many currently available machines which cannot render such large numbers of polygons at interactive, real-time frame rates. Current level of detail representations don't allow a very great reduction before artefacts begin to become apparent. On most systems, it is therefore not possible to render a scene containing several BS virtual humans in real-time with a convincing degree of realism. In particular, at the very low polygon counts required in such systems, there are often gross errors in the shape of the models. This is especially unfortunate as such errors prevent the possibility of using texture mapping techniques that might be implemented on graphics pipeline hardware and could, otherwise, restore much of the realism. To overcome this problem, we present a method that introduces global feature and symmetry constraints into current level of detail representations, enabling a simplification process to reduce BS representations of tens of thousands of polygons down to a few hundred while still preserving their apparent width and other proportions.

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2. Previous approaches

There has been a lot of work on level of detail representations recently [9]. It may be divided into four main categories:

I. multiresolution analysis (MRA) methods,
II. methods based on local geometry and topology, for example by vertex removal, possibly in combination with the use of crease and edge boundary constraints,
III. topological methods based on complete polyhedral structure removal,
IV. geometric methods based on vertex removal by clustering.

DeHaemer & Zyda [10] present two geometric methods (iv), that work well in oversampled, flat regions of real life scanned objects. In a similar way, Schaufler [11] and Rossignac [12] have developed a hierarchical clustering method which quickly creates coarser representations by grouping vertices that are close to each other. However, approaches based on 3D space clustering[11] require very well balanced octtrees to insure graceful degradation of electro-optical body scans.

In multiresolution analysis (i), DeRose et al [13] have developed a level of detail system that works on arbitrary meshes. Their method generates good, low complexity representations of curved objects, but considerable detail needs to be present in the way it approximates flat surfaces. Recent work by Lee et al [14], alleviated this problem by use of an angle tolerance measure to detect creases. The boundaries of surface patches were then aligned with creases which might indicate the start of a flat region. However, to make the scheme, work, adaptive tolerance thresholds are required as surface creases may subtend different angles in different parts of an object and at different levels of detail. This is difficult to achieve automatically. Furthermore, although this approach produces good low level of detail representations of curved objects, it does not do so in a view independent manner. The quality of the coarse approximation of, for example, a cylindrical shape, will therefore be biased to one view. At run time, with a wide field of view containing several BS models, this will result in their legs (say) appearing to be thinner and thicker within the same rendered frame, and more noticeable from frame to frame in an aliased manner.

Cohen and Varshney [15] developed a method of type (ii) in which they use the geometry of an object to create "simplification envelopes". A good characteristic of their method is that it allows the simplified mesh to have different error bounds in different parts of the model, but it appears that self intersection of the envelopes may give rise to artefacts and the techniques does not appear to preserve apparent dimensions very well below a thousand polygons. Los Alamos Laboratories [16] and Kalvin [17] have also presented methods of type (ii) for simplifying flat or homogeneous areas of objects, implicitly these boundaries of these areas dictate the shape of the object at low levels of detail. Since only local geometry measures are used, the apparent non-local width can't be preserved. Schroder [18] uses type (ii) methods successfully to remove noise peaks in scanned surfaces by classifying the local structure of the surface into five categories and removing sudden peaks by means of an appropriate decimation strategy.

Hoppe [19] also adopts approach (ii), but transforms the mesh simplification into a minimisation problem. For each simplification step, all potential post-simplification geometric errors across the model are analysed, the operation that yields the least error is chosen, and the function recursively minimised for coarser meshes. Specific labelled creases and other edge boundaries may be retained by penalising their removal in the error cost function, thereby preserving discontinuity curves in lower level of detail representations. Results presented by Hoppe [figure 5 in 19] show that the introduction of labelled boundary edge penalties can help ensure good quality approximations at low levels of detail. In this paper, we focus on a particular type of edge penalty that ensures the preservation of apparent width and can be used with additional discontinuity constraints such as those discussed by Hoppe. Garland [20] uses a quadric error measure to build his levels of detail. Very good results have been obtained, but in the context of low level of detail for BS, the size of a polygon is not taken into account, therefore at lower LOD there is no guarantee on the position of polygons that would keep the apparent width. Finally Varshney et al [21] (iii), look for salient individual parts of an object's surface, and decide to remove individual parts entirely at lower LODs.

3. Width preservation

The importance of apparent width can be seen from the attenuated example shown in [Plate 7, in 22] where the busy scene makes the level of detail controller choose a very coarse level of detail representation of parts of the submarine room, even though they are being viewed close up. For example, the cylinder head in [Plate 7, right, in 22] clearly has enough polygons to be better approximated, but the local vertex neighbourhood operations have failed to ensure overall graceful degradation of its shape. This also highlights the importance of good, view independent representations, as failures of this kind cannot be compensated at run-time by the level of detail controller.

4. The proposed framework

As stated earlier, we adopt Hoppe's progressive mesh approach [19] and add connected feature edge constraints to preserve apparent width at low level of detail. The importance of apparent width may be seen by considering what is the best, very small, polygon configuration for approximating a given, highly symmetrical object such as a sphere, as illustrated in figure 1.

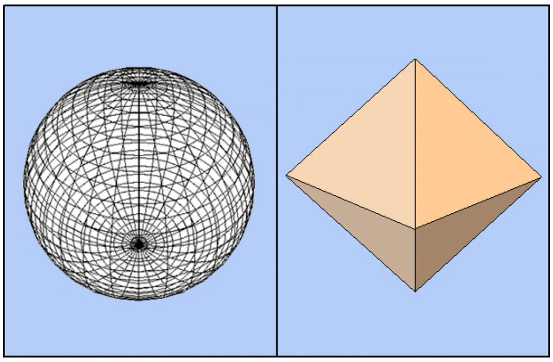

Figure 1: *"Sphere simplification", left: over 208 polygons, right: 8 polygons*

Although all points on a sphere are equivalent, some are singled out as soon as a decision on where to place the polygons is made. If the object has a high degree of point symmetry, we use a polygon with as a high a degree of similar symmetry as possible. If, like a cylinder figure 2, it has an axis of symmetry, we align the coarse polygons with the axis and choose a discrete model with as high a degree of symmetry as possible commensurate with the original model.
The objection might be raised that the polygonal approximation will itself single out preferred views. Whilst this is theoretically correct, in practice many objects like the human body with cylindrically symmetric parts may be approximated with a very small number of polygons which preserve the object's apparent width from any view, to a reasonable approximation as sketched in figure 2.

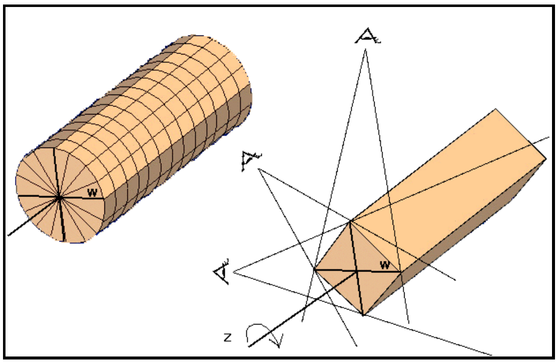

Figure 2: *view independent, apparent width preservation*

However, we have to find the local symmetries of an object. Fortunately in the case of the BS models, the human subjects have markings on the scanner floor, that ensure pose and symmetry of both the sample (x,y,z) point values and their number on the 3D axis used for measurement. We can then use a simple approach based on a global frame of reference which we call the RegionSphere, to label the surface normal symmetries. In this representation, the normal to each polygon is classified as belonging to (ie pointing into) one of twenty-six regions on the surface of a unit sphere. Eight of these are conventional octants, whilst the remainder represent the six points and twelve line segments connecting the octants. These point and line regions are required in principle to express the connectivity required, but in practice they are not used since they cover regions of zero area. When all polygons have been classified in this way, we simply group those with the same label, and record the boundaries of these clusters as feature edges.

5. Results

Examples of the results obtained on human body data from a Hamamatsu Body Line scanner [6] are shown in figure 3.

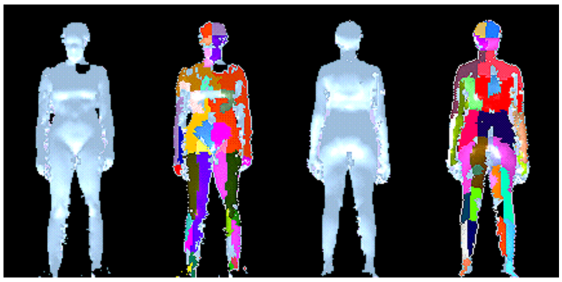

Figure 3: *Body Scanned model of 24.000 polygons, 119 regions with boundaries labelled as feature edges*

The reduction in the polygon count and location of the surface patches so as to preserve the gross shape of the body and apparent width of the limbs, torso and head, and, in particular, the spherical segmentation of the head and cylindrical segmentation of the limbs, is very promising. Colour coding of these segmented regions as in figure 3 could then be used to derive hard constraints to be incorporated into a simplification algorithm, such as that described by Hoppe [19]. The boundaries of many of the patches, however, are rather jagged, suggesting that it would be profitable to use, as a second step, Kalvin's boundary straightening technique [17] better to position the polygons at the lowest level of detail. This is currently in progress, although the segmentation can be dramatically improved by using a smoother fitted surface to the scanner data as shown in figure 4. We are also implementing Hoppe's progressive mesh scheme so that we can use it as a baseline for demonstrating the performance of the method described and assessing the quality of the results obtained.

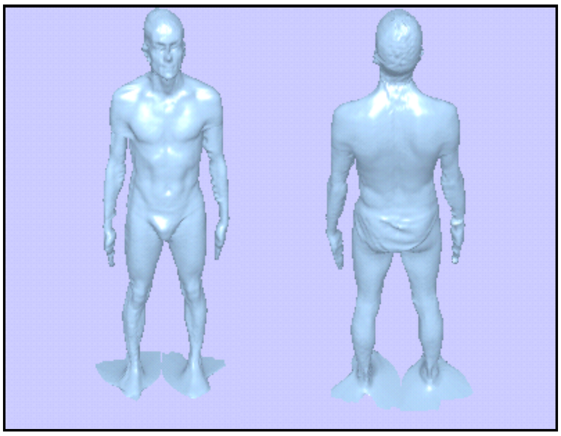

Figure 4: *Body Scanned model of 74.000 polygons*

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