South Bohemia Mathematical Letters
Volume 18, (2010), No. 1, 17-22.

BODY MOTION VISUALIZATION IN VIRTUAL ENVIRONMENT

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Abstract. We present a system for real-time tracking and visualization of body motion in semi-immersive virtual environment. Several parts of user's body are tracked simultaneously. For each tracked part, a so called "motion trail" is rendered in real-time. After capturing the desired motion, the user can further customize the visualization of individual motion trails. Several types of visualization are available, based on computed geometrical characteristics of motion trails. The whole interaction between the user and the system takes place directly in the virtual environment.

In this paper we introduce a concept of motion trails, their characteristics and visualization capabilities. We also describe our virtual environment and used interaction techniques.

Introduction

Movement of human body is a subject of research in several fields – medicine, sport and even criminology (gait analysis). Body movement is also an essential part of many artistic activities such as dancing, theater, performance art, etc. Motion itself is a dynamic and transient process, and therefore the basis of any analysis or artistic representation is motion capture and visualization.

There are several basic approaches to visualization of motion, both static (like photography, pictures) and dynamic (film, animation). Our work was inspired by a "Light writing" technique. The single photography captures the motion of a light source as a bright trail on a dark background. See works of Gjon Mili and Pablo Picasso, or Pavel Korbička (Figure 1) for more information.

Like in "Light writing", our application also generates trails of movements. Instead of photography, we are using semi-immersive virtual environment (VE), where both motion capture and visualization is realized in 3D space and in real-time. VE provides an easier work-flow and enables to create more interesting results.

1. Virtual Environment

User movements are tracked by an optical system with twelve infrared cameras. Several parts of body can be tracked simultaneously, using small reflexive marks attached to user's body. Optical system provides high accuracy (in the order of millimeters) and speed (100 samples per second) of tracking. System control tasks (start/stop motion capture, menu items clicks, manipulation with objects in VE, etc.) is realized by using a pair of wireless hand-held devices.

For output we use a large scale stereoscopic projection wall based on polarization. This facilitates the spatial perception of incipient artwork. Stereoscopic imaging

Received by the editors 2010-16-11.
1991 *Mathematics Subject Classification.* 68U05, 65D17.
Key words and phrases. Motion visualization, motion capture, virtual environment, human computer interaction.

FIGURE 1. Light writing technique: "Dance calligraphy – series A", Pavel Korbička, 1996. Used with permission.

by Nvidia 3D vision system and monoscopic rendering are also available. Figure 2 illustrates the working environment. The only thing the user has to do before using our system is fastening tracking marks (triplets of bright spots in the photo), putting on a stereoscopic glasses and grabbing control devices. Then he can move freely (no wires required) in the tracked area (about $6m^2$).

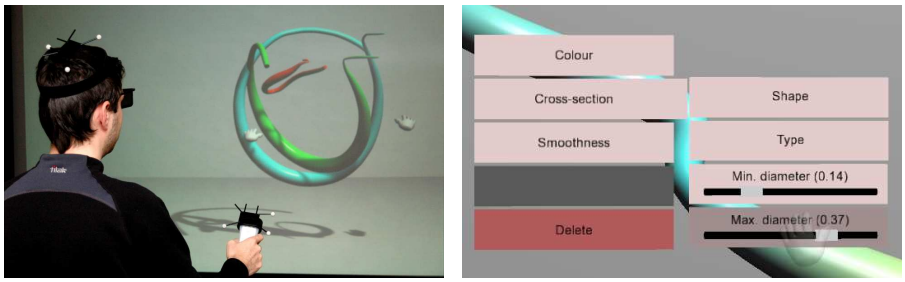
To create a motion trails, user takes a start posture, presses a button on a control device, performs a desired motion and releases the button. Processing of samples obtained from the tracking system as well as rendering of motion trails is performed in real-time. Therefore, user can see motion trails immediately during movement.

Our VE application is build upon VRECKO – virtual reality framework [3]. Human-computer interaction is based on the "virtual hands" technique [1]. One hand is dedicated for application control, second hand for manipulation with a virtual scene. Utilizing this technique, a user can simply manipulate (translate, rotate and scale) a virtual scene or change settings of motion trails via context menu (see Figure 2) by moving his hand and using buttons of the control device.

2. Motion Trails

We have implemented a concept of motion trails. One trail represents the movement of one part of user's body over a certain period of time.

Motion trails can be tracked successively – user can gradually capture several attempts of a particular movement and immediately see the differences between them. Resulting virtual scene may contain any number of motion trails, each one with its own settings. Trails are rendered as swept volumes where both the path and the cross-section curves are Catmull-Rom splines.



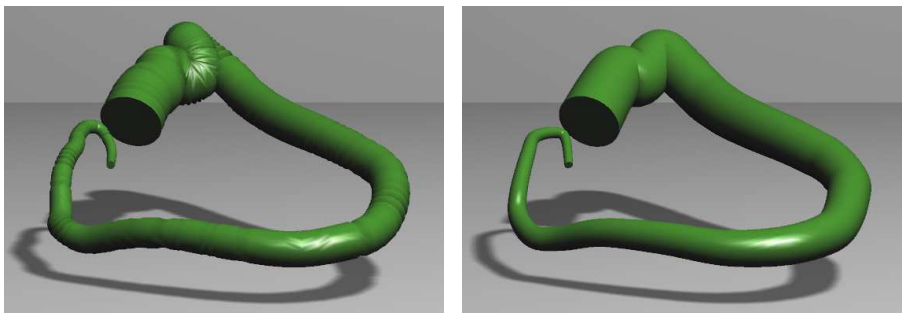
(A) (B)

FIGURE 2. Virtual environment: (A) the user wears reflexive marks, control devices and polarized glasses for interaction with VE; (B) the context menu of motion trail.

2.1. **Geometrical Characteristics.** The basis of each trail is a set of samples – positions in 3D space received from tracking device. These samples are used as control points of motion trail's path spline.

For each sample, the following is computed: Frenet-Serret frame [2]; curvature and torsion; arc length and speed; priority. The priority is a combination of arc length and curvatures, and determines the influence of one point to the global shape of the curve. These characteristics are used during optimization and rendering of the motion trail.

2.2. **Optimalization and Customization.** High accuracy of the motion tracking system may cause an unwanted jitter in the sampled data, e.g. when tracking marks are not fastened properly or when user's hands are shaking. To eliminate this jitter and to render even smoother trails, we have implemented a curve optimization algorithm based on repeated removal of points with the lowest priority. (see Figure 3).



(A) (B)

FIGURE 3. Motion trail with high input jitter: (A) without reduction, 170 points; (B) with high reduction, 24 points.

Additional information about movement may be visualized by coloring motion trails. User may choose "constant color", "start-end gradient" and "speed-based gradient" for differentiation of individual trails, representing direction of movement or indicating speed of motion, respectively. The color selection is realized via a spatial color chooser widget.

The same gradients (from start to end, from slowest to fastest) may be used for changes in diameter of cross-section. Different cross-section shapes may also be used for distinguish individual motion trails. Figures 4 and 5 show examples of different visualization possibilities.

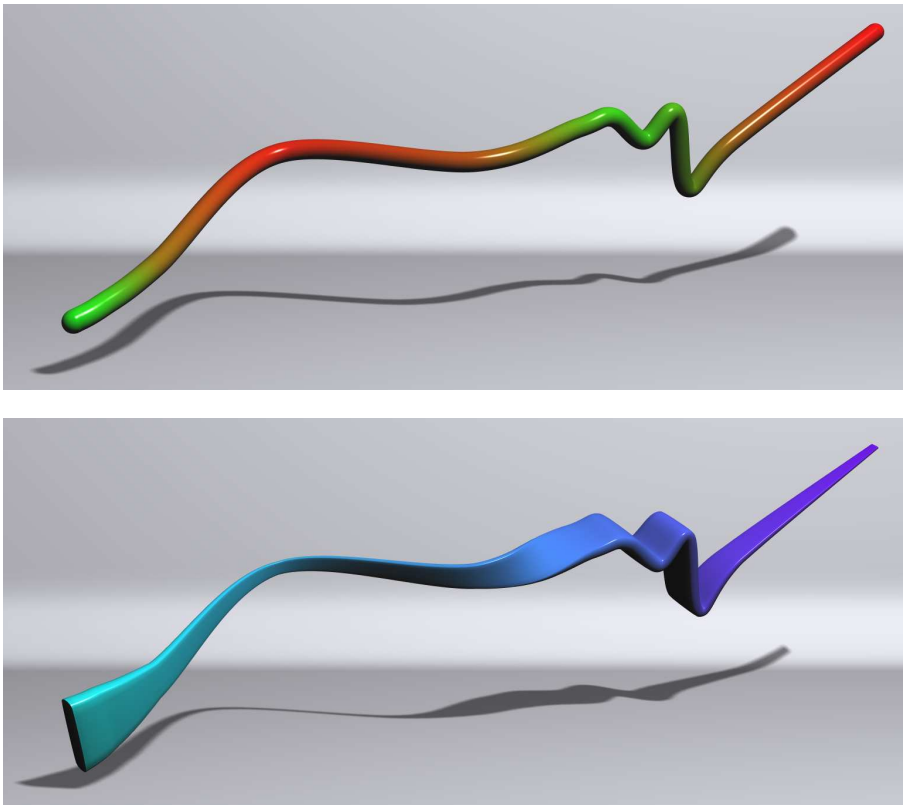


FIGURE 4. The same motion trail rendered with: (top) round cross-section, constant diameter and speed-based color gradient (green as slow, red as fast); (button) rectange cross-section, speed-based diameter (the faster motion, the smaller diameter) and start-end color gradient (light blue at start, dark blue at end).

2.3. **Rendering and Export.** As already mentioned, trails are rendered as swept volumes. Given that both path and cross-section curves are Catmull-Rom splines, a triangulation of swept volume is straightforward. An orientation of cross-section curve is defined by the Frenet-Serret frame (already computed for all control points). Therefore, rotation of the cross-section is minimal and optimal tube-like shape is generated.

To increase the smoothness of rendering, Catmull-Rom splines may be interpolated with arbitrary precision before triangulation. Quality of real-time rendering is further improved by capabilities of VRECKO framework (Phong shading, soft shadow casting).

It is possible to export the resulting triangulation of motion trails in obj file format. Thus, the user have possibility to post-process and render motion trails in virtually any 3D modeling software (see Figure 5 for examples).

Conclusion

We have implemented an application for capturing and visualizing human body motion in VE. Figure 5 shows several results of our application. Real-time tracking and rendering allow us to quickly and easily display one or more user movements in a single virtual scene. Stereoscopic rendering and possibility of free manipulation with virtual scene greatly improves spatial perception of motion trails in 3D space.

In the future, the application could be extended to a dynamic visualization tool. User would be able to "replay" his motions or display virtual actor which will perform captured movements.

Acknowledgments

This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic under the research program LC06008 (Center for Computer Graphics).

An essential part of this article has been presented at 30th Conference on Geometry and Graphics, and published in Proceedings of this conference (available on http://www.csgg.cz/30zlenice/sbornik2010.pdf).

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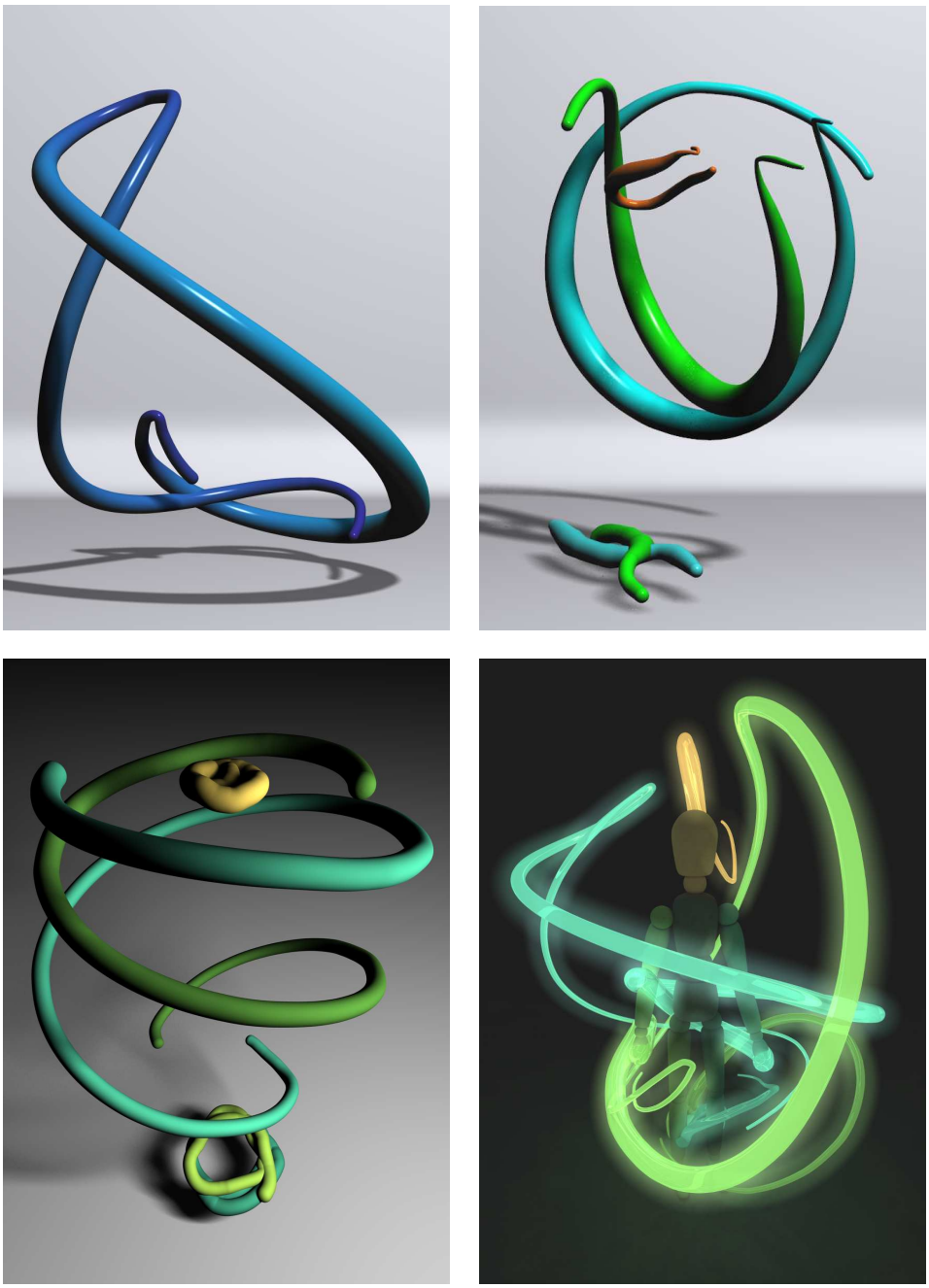

FIGURE 5. Results: top row: the speed of movement is visualized by colors (left) and by diameter changes (left and right) – snapshots from our application; bottom row: the direction of movement visualized by diameter changes – external renderings, Cinema4D software used.