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1999年 総合大会講演論文集

基礎・境界

一般講演

- A-1．回路とシステム
- A-2．非線形問題
- A-3．VLSI 設計技術
- A-4．ディジタル信号処理
- A-5．スペクトル拡散
- A-6．情報理論
- A-7．情報セキュリティ
- A-9．信頼性
- A-10．応用音響
- A-11．超音波
- A-12．コンカレント工学
- A-13．思考と言語
- A-14．ヒューマンコミュニケーション基礎
- A-15．ヒューマン情報処理
- A-16．マルチメディア・仮想環境基礎
- A-17．ITS 基盤技術

シンポジウム

- SA-1．高性能低消費電力電子回路
- SA-2．VDEC によるチップ製作事例
- SA-3．携帯通信のための適応信号処理技術
- SA-5．量子コンピュータと量子カオス
- SA-6．音響の数値シミュレーション
- SA-7．工学におけるコンカレンシー
- SA-8．福祉工学とヒューマンインターフェース
- SA-10．Augmented Reality とナビゲーションへの応用
- SAB-1．光通信におけるスペクトル拡散／CDMA 技術

ソサイエティ企画

- パネル討論 PA-2．大学における集積回路設計に適した設計フローのあり方と相互協調
  —VDEC を通じた集積システムの設計から試作・テストまで—
- パネル討論 PA-3．誤り訂正符号の復号アルゴリズム
- チュートリアル講演 TA-1．精度保証付き数値計算の入門から実際まで—非線形現象の不思議 I—
- チュートリアル講演 TA-2．ブロックソーティングと文脈ソーティングによるデータ圧縮
- チュートリアル講演 TA-3．安全に関する国際規格の状況
- チュートリアル講演 TA-4．セルラ電話普及率の先進国，北欧の動向—固定電話を越える日—

1999年 3 月25日～28日　慶應義塾大学　横浜市

March 25～28, 1999, KEIO UNIVERSITY, YOKOHAMA

THE INSTITUTE OF ELECTRONICS, INFORMATION AND COMMUNICATION ENGINEERS

社団法人 電子情報通信学会

1999年電子情報通信学会総合大会

A-16-2

Nonlinear Viewpoint Control Technique for Desktop VR Applications

非没入型VRのための非線形視点制御技術

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1. Introduction

This paper describes a novel interaction technique for viewpoint control in non-immersive desktop VR interfaces that uses head orientation tracked by a single camera as input. In contrary to previous attempts of using head tracking for viewpoint control [1], our technique offers a solution to an important problem: the limited range of head rotations that can be used for interaction in desktop environments. Indeed, in context of desktop interaction even small head rotations would make viewing the screen uncomfortable and, after a certain angle, impossible. Furthermore, head rotations are restricted by anatomical constraints because our joint can only rotate up to a certain angle. Finally, since most of the current computer vision algorithms use facial features for tracking, excessive head rotations increase tracking error as fewer features are visible to the camera.

2. Interaction technique

Our interaction technique overcomes these limitations by using non-linear Control-Display (C-D) gain mapping functions for spatial rotations, derived using quaternions. The technique non-linearly amplifies head rotations so that the user can flexibly control a large range of viewpoint rotations within VE using only slight head movements. In 3D rotations, the basic equation of C-D gain links rotations of the control device, i.e., the head tracked by a camera, and rotations of the viewpoint in VE as follows:

$$q_d = q_c^k, \qquad (1)$$

where q_c is the head rotation, q_d is displayed rotation, and k is a ratio of gain. Quaternion q_c specifies head rotation from some initial orientation. However, in many cases, the zero orientation returned by tracking algorithms may not be the desired initial head orientation. The following equation allows to explicitly specify the initial orientation q_0:

$$q_d = (q_c q_0^{-1})^k q_0. \qquad (2)$$

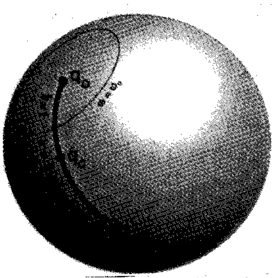

Figure 1: Non-linear C-D gain on quaternion sphere: as long as rotation path stays within area $\omega \le \omega_0$, C-D ratio is linear; if rotation path leaves this area the C-D ratio is a non-linear function $f(\omega)$.

These equations uniformly scale head rotations. In viewpoint control, however, it might be useful to use non-uniform mappings that maintain a small ratio close to the initial head orientation q_0, and increase it as the user rotates her head further. To introduce non-uniform mapping we first define distance measurement between rotations as the cosine of angular separation between two quaternions on the quaternion 3-sphere $d(q_c, q_0) = q_c \cdot q_0 = \cos\Omega$. The actual angle of rotation connecting q_c and q_0 is $\omega = 2\Omega$ and it will be used a distance measurement.

Now, to develop a non-uniform mapping function we simply replace the C-D gain coefficient k in Equations 2 and 3 with the function of the form:

$$k = F(\omega) = \begin{cases} 1 & \text{if } \omega < \omega_0 \\ f(\omega) = 1 + c(\omega - \omega_0)^2 & \textit{otherwise} \end{cases}, \qquad (3)$$

where ω_0 is a threshold angle and c is a coefficient. This equation has a very simple interpretation that can also be visualized on the quaternion 3-sphere (Figure 1).

3. Application

We used the original method for estimating the 3DOF of user head orientation using single uncalibrated camera [2] and implemented using the SGI O_2 workstation and a standard CCD camera. The Equations 1, 2, and 3 define a general form of mapping between the tracked head orientation and the controlled viewpoint in VE that were implemented as interaction techniques. The resulted interaction was natural and none of the users had difficulties with understanding and using the technique.

4. Conclusions

We presented a simple method that allows the user to control a large range of virtual viewpoint 3D rotations using only slight head motion in the physical world. The technique can be applied to the design of a variety of 3D user interfaces such as for navigating VRML worlds and 3D computer games, controlling avatars, interacting with smart digital kiosks, etc. Moreover, the technique provides an important design blueprint so that interface designers can develop a variety of interaction techniques for computer based desktop 3D interactivity.

5. References

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