

論文 / 著書情報  
Article / Book Information

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種別(和文)	論文要旨
Type(English)	Summary

## 論文要旨

THESIS SUMMARY

専攻 : Department of	知能システム科学	専攻	申請学位 (専攻分野) : Academic Degree Requested	博士 (工学)	Doctor of
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### 要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

A haptic VR system, which presents hand force feedback of the touch interaction and manipulation, can provide high fidelity simulation while integrating with physics simulation. The calculation of the VR environment and the force feedback based on the hand motion is called haptic rendering, which is a popular research topic from the 1990s. This dissertation points out the challenges of haptic rendering during interactions with dynamic deformable objects and proposes a solution.

In the first chapter “Introduction”, the background and the challenges of the previous work are introduced. The haptic system requires real-time simulation and such a simulation generally samples phenomena on the continuous time by discrete time-steps for efficiency, and discrete collision detection (DCD) is a straightforward method to identify contacts in the virtual environment. However, previous studies on haptic rendering with DCD suffer from the “tunneling” problem, which causes pop-through phenomenon between the haptic tool and the virtual object. This is because DCD only detects the intersection between objects in the time-steps. Continuous collision detection (CCD), which checks all possible contacts on the path of the motion, can solve the “tunneling” problem. Nevertheless, previous studies of CCD limited with 6-Degree-of-Freedom (DoF) and they could not eliminate the force artifacts, i.e., the feeling of inertia, which will reduce the haptic transparency. This study is aimed to solve those limitations by proposing new methods. At last, the contribution of this thesis is presented.

The second chapter “The Context” introduces technical backgrounds and previous researches. It includes methods for haptic rendering, deformation simulation with haptics, haptic interactions with CCD, multi-rate haptic rendering, and the simulation method. Those introductions show that this thesis provides state-of-the-art on all the aspects of the knowledge related to the main topic.

In the third chapter “Overview of The Proposals”, an overview of the proposal is presented. For a better understanding of the structure of the proposal, the idea and the relation of the two proposals are summarised. After that, an overview of the system structure and the simulation scheme is illustrated.

The fourth chapter “Three-Degree-of-Freedom Haptic Proxy with Dynamic Deformable Objects” introduces the first proposal. This is a CCD method of the virtual proxy for 3-DoF haptic rendering. The virtual proxy method uses a sphere to represent the haptic device in the virtual environment. Compared to a mesh sphere model, an ideal sphere model can provide smooth haptic probing interactions and reduce the computation cost. Therefore, this study employs triangular mesh models as the object shape model and proposes a triangle-proxy CCD method for haptic interaction with virtual proxy. Since the virtual proxy method handles a moving proxy against static triangles, the proposal solves the problem by securing the start of the proxy update calculation against the moving triangles. To detect collisions between the static proxy and the moving triangles continuously, the contact moment is computed using the equation of coplanar condition. To reduce the computation cost, only the contact moment between the proxy center and the moving triangle is computed. The detection for the rest cases of potential contact is solved using Proxy Pop-out, an iterative DCD method, where iterations are needed because one DCD operation may trigger another intersection when dealing with multiple triangles. A triangle-based multi-rate haptic rendering is also proposed for stable haptic interactions. The result of the experiments shows that the proposed CCD method can catch a fast dropping cloth even the cloth went through the proxy sphere completely, the computation of the proposed CCD method is efficient. In addition, a simulation of a complex scene that consists of multiple dynamic deformable objects is presented with stable haptic interactions.

In the fifth chapter “Extension to A Six-Degree-of-Freedom Deformable Haptic Proxy”, an extension of the 3-DoF method is proposed to achieve 6-DoF haptic rendering. A multi-sphere model is assigned to the particles from the deformation model, i.e., the Oriented Particles model, and used as the proxy particle. For each proxy particle, the virtual proxy method is computed by searching potential contacts from the current position to the corresponding device-posed particle. The input from the device is applied to the proxy as an infinite-stiff and position-based haptic constraint to eliminate the force artifacts. To solve the “tunneling” problem caused by position-based constraint calculation, additional proxy collision detection is performed on the route of the update of constraint calculation. A multi-rate haptic rendering that synchronizes the tool particle position is proposed for stable haptic interactions. The evaluations show that the force artifacts of the object inertia are eliminated, and user can choose whether to use a single-rate haptic rendering with no force artifacts or multi-rate haptic rendering which has limited force artifacts but stable haptic rendering. A scene including the haptic rendering of a deformable hand interacting with a complex deformable cloth was presented using the methods introduced in this thesis.

The last chapter “Conclusion” presents a short summary of the proposals. as well as the perspective of future research on haptic systems that can present various physics phenomenon and applications of transparent haptic operation.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

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(博士課程)

Doctoral Program

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