Data-Driven Haptic Rendering with Multimodal Improvements for Highly Realistic Virtual Experiences

Workshop at AsiaHaptics 2018, Songdo, Korea
November 14, 2018

This workshop is to share recent progresses on the methods and algorithms for data-driven haptic modeling and rendering aiming to provide highly realistic virtual experiences to users. As such, appropriate topics include:

- Devices for measuring the haptic responses of real objects
- Haptic modeling methods to account for the relationship between the input and output variables of measured data, either physics-based or data-driven, or hybrid
- Haptic rendering algorithms of such haptic models for highly realistic recreation of haptics dynamics in virtual or augmented environments
- Any other visual or aural rendering methods that enhance the realism of haptic interaction in virtual/augmented environments

We solicited speakers who are working on research topics relevant to the workshop's theme. As a result, we will have 13 very interesting presentations that report the state of the art of data-driven haptic modeling and rendering. This workshop will also be accompanied with selected on-site hands-on demonstrations and discussion among attendees. We hope that this workshop could be a forum that triggers more active and intensive research efforts about data-driven haptic rendering, which may advance the state of haptics to the next level.

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* Upon the presenters' agreement, some presentation slides used during the workshop will be uploaded to the workshop website (http://hvr.postech.ac.kr/AsiaHaptics2018Workshop).

Program Overview

Time	Title	Presenters
9:30 – 9:40	Introduction	Seungmoon Choi
9:40 – 9:55	Modeling and Rendering Viscoelastic Deformable Objects Using Random Forest Regression	Hojun Cha and Amit Bhardwaj
9:55 – 10:10	Hybrid Haptic Texture Modeling and Rendering Framework for Inhomogeneous Texture	Sunghwan Shin
10:10 – 10:25	Multi-modal Data-driven Haptic Rendering Combining Force, Tactile, and Thermal feedback	Seongwon Cho
10:25 – 10:40	The Proton Visuo-Haptic Surface Interaction Dataset	Katherine J. Kuchenbecker
10:40 – 11:00	Break	
11:00 – 11:15	Modeling Tactile Contact: Contact Shapes, Forces, and Transmission	Yon Visell
11:15 – 11:30	Data-Driven Haptic Modeling and Rendering of Objects' Plastic Deformation	Seokhee Jeon and Arsen Abdulali
11:30 – 11:45	Multi-modal Haptic Controller & Wire Driven Haptic Device for High-Definition Haptics.	In-Ho Yun
11:45 – 12:00	Unsteady Simulations of Liquid Flow around a Moving Object	Junseong Lee
12:00 – 12:15	Real-time Simulation of Non-Newtonian Fluid for Haptic Rendering using Smoothed Particle Hydrodynamics	Youngho Kim
12:15 – 13:30	Lunch	
13:30 – 13:45	Unsteady Simulations of a Quadcopter with an Actuator Disk Model	Junseong Lee
13:45 – 14:00	Contactless Haptic Modeling Using Infrared Thermography and Machine Learning	Tamas Aujeszky
14:00 – 14:15	PlayLiquid Virtual Lab: Simulation of Pouring Viscous Fluid and Whole Hand Grip	Jaehyun Jang
14:15 – 14:30	Real-time Synthesizing Sound Effects & Experiment on the Effect of Using Onomatopoeia in the Virtual Environment on the User Experience.	Gerard J. Kim
14:30 – 15:00	Discussion and Demonstration	Seungmoon Choi

Detailed Program

Data-driven Modeling and Rendering Viscoelastic Deformable Objects Using Random Forest Regression

Hojun Cha, Amit Bhardwaj, and Seungmoon Choi
POSTECH

We will introduce a random forest method for modeling and rendering viscoelastic deformable objects. Data-driven haptic methods for modeling viscoelasticity using machine learning techniques have been researched. In this study, we adopt a well-known machine learning technique, a random forest regression method, to model the viscoelasticity of deformable objects. We collect data using a force-feedback device and a load cell, and construct a random forest model and render it at 1 kHz. We tested our model on 5 different materials of cube-shaped objects. In our further study, extremum sets from the collected data are chosen and used for a model, and it significantly reduces the amount of data required for modeling without losing accuracy. We are now on the way to extend this random forest regression method to inhomogeneous objects and multi-finger environments. Some of the modeling results will also be presented in the live demo presentation sessions.

Hybrid Haptic Texture Modeling and Rendering Framework for Inhomogeneous Texture

Sunghwan Shin and Seungmoon Choi
POSTECH

In this talk, we present a hybrid framework to acquire and provide a realistic sensation of inhomogeneous haptic texture. Our framework consists of a data-driven model based on contact-acceleration and a height map of a textured surface. The height map, which encodes the inhomogeneity of the texture, produces a perturbed normal force to deliver macro-roughness of the surface. The data-driven model uses the magnitude of the normal force as one of the input parameters to generate a position-dependent vibration signal. To eliminate beat phenomenon between the vibration and the force-feedback signal, we apply band-pass filters to each signal. Our framework can render inhomogeneous texture more realisticakky by using a force-feedback device equipped with a voice-coil actuator.

Multi-modal Data-driven Haptic Rendering Combining Force, Tactile, and Thermal feedback

Seongwon Cho, Hyejin Choi, Sunghwan Shin, Amit Bhardwaj, and Seungmoon Choi
POSTECH

This session will focus on multi-modal data-driven haptic rendering that simultaneously presents force, tactile, and thermal feedback. To handle force, tactile, and thermal feedbacks all together, we attached a vibration actuator and a Peltier module to a force-feedback device. We consider texture, friction, viscoelasticity, contact transient, thermal properties as components of multi-modal haptic rendering. We collected data from real situations to generate accurate models in a data-driven manner for each modality. Force data during interaction are collected to estimate friction and viscoelasticity parameters. A micro-geometry structure of an object is reconstructed by a photometric stereo algorithm. Heat flux and temperature profile between the skin and an object are collected to interpolate thermal responses. We expect that our multi-modal haptic rendering system improves the realism of haptic sensation in the virtual environment.

The Proton Visuo-Haptic Surface Interaction Dataset

Alex Burka and Katherine J. Kuchenbecker
Max-Planck Institute for Intelligent Systems

We hypothesize that the association between how surfaces look and how they physically react during contact can be learned from a database of matched haptic and visual data recorded from the interactions of various end-effectors with many real-world surfaces, such as wood flooring, upholstered fabric, asphalt, grass, and anodized aluminum. We previously designed and built a portable human-operated visuohaptic sensing device, the Proton, which we recently used to collect such a database. The provided data includes haptic recordings of interactions between 357 surfaces and one or more of three end-effectors, plus camera images.

Modeling Tactile Contact: Contact Shapes, Forces, and Transmission

Yon Visell
University of California, Santa Barbara

A major challenge in haptic rendering is to understand the dynamics of tactile contact between the skin and touched surfaces, and the influence it has on perception. A close examination of ordinary tactile interactions reveals complex phenomena that span multiple length scales and physical regimes. In this talk, I will discuss new methods we have used to capture and model tactile interactions, and their implications for tactile rendering.

Data-Driven Haptic Modeling and Rendering of Objects' Plastic Deformation

Seokhee Jeon and Arsen Abdulali
Kyung Hee University

This work presents our initial efforts to build a novel framework to capture, model, and render haptic responses due to objects' plastic deformation. We first introduce our approach for collecting displacement vectors of particles in a real deformable object during compression. Then, a novel plasticity-included FEM model and its measurement-based parameter estimation method are presented. Finally, our real-time FEM simulation based on ADMM optimization and GPU-based parallel processing are introduced along with examples of initial simulation results. To our knowledge, this is the first practical haptic rendering framework that can provide real-time (up to 500 Hz) rendering of plasticity in FEM-level accuracy and in measurement-based manner.

Multi-modal Haptic Controller & Wire Driven Haptic Device for High-Definition Haptics.

In-Ho Yun and Sang-Youn Kim
KoreaTech

Here we show a strategy to expand the applications of High-Definition (HD) haptic controllers for emerging realistic virtual reality (VR) contents. We have successfully designed and executed the development of HD haptic controller and a wire-driven haptic module. The developed haptic controller can create multi-modal haptic sensation and a wire-driven haptic module for interacting with realistic VR contents through force feedback. The haptic controller equipped with thermal display using water-cooling based Peltier module, a vibration module based on linear resonant actuator (LRA), a haptic wheel using tiny torque display based on magneto rheological (MR) fluids and shape changing module with pneumatic shape-changing interfaces. The generated wire-driven haptic module mechanism with three degrees of freedom (DOF) force feedback between a user and realistic VR contents demonstrated to be a well-performing haptic device, ensuring a good impressionability in a wide array of domains.

Unsteady Simulations of Liquid Flow around a Moving Object

Junseong Lee, Youngho Kim, Junkyu Kim, Taesoon Kim, Jeha Ryu, and Solkeun Jee
Gwangju Institute of Science and Technology

Virtual cooking situations are simulated in a simplified, two-dimensional liquid container with a moving object. The purpose of the current study is twofold: (1) to obtain the hydrodynamic drag force on the moving object and (2) to provide accurate flow fields for a real-time approach explored in the parallel study [Ref, Y. Kim et al., 2018, Asia Haptics]. In the current study, the Navier-Stokes equations are numerically solved for both Newtonian and non-Newtonian fluids. A cornstarch solution is selected for the non-Newtonian fluid with the power-law model for the viscosity. Water is chosen for the Newtonian fluid. A circular cylinder with a linear motion, representing a stirring stick, is simulated in a rectangular container. Due to the motion of the cylinder, computational grids are re-generated every time step. The range of he Reynolds number, which helps to characterize the flow field, is below 1,000. The hydrodynamic force and the flow fields are com-pared between the Newtonian (water) and the non-Newtonian (cornstarch solution) fluids.

Real-time Simulation of Non-Newtonian Fluid for Haptic Rendering using Smoothed Particle Hydrodynamics

Youngho Kim, Junseong Lee, Solkeun Jee, Jeha Ryu
Gwangju Institute of Science and Technology

In haptics, real-time fluid simulation and haptic rendering are challenging tasks. Especially, non-newtonian fluid is hard to simulate due to non-linearity and high computational cost. SPH (Smoothed Particle Hydrodynamics) is parallel computing method of fluid simulation to accelerate computational speed using GPU (Graphics Processing Units). In this presentation, non-newtonian fluid is simulated in real-time using SPH method. Then, the result force between haptic interaction point and particles is also displayed using haptic device such as Omega-7.

Unsteady Simulations of a Quadcopter with an Actuator Disk Model

Junseong Lee, Taesoon Kim, Junkyu Kim, and Solkeun Jee
Gwangju Institute of Science and Technology

Computations of air flow around a quadcopter are conducted using an actuator disk model. The purpose of the current study is to investigate the actuator disk model for cost-effective simulations. Details of the blade geometry are not required for the current approach. Instead, thrust and torque on the rotor disk are approximated based on a control volume analysis. It is anticipated that the computational cost would be significantly reduced, while the flow field is reasonably reproduced. Computational results will be com-pared with relevant test data.

Contactless Haptic Modeling Using Infrared Thermography and Machine Learning

Tamas Aujeszky and Mohamad Eid
New York University - Abu Dhabi

Modeling the haptic properties of unknown objects without coming into contact with them is important in a number of fields, such as robotics and tele-operation, where the right amount of contact force needs to be known prior to establishing contact, or in a haptic scene recording where a multitude of objects needs to be scanned without manually moving a sensing unit around. This presentation introduces the Haptic Eye, a functional haptic modeling system. The Haptic Eye uses active excitation infrared thermography to acquire and process the thermal signature of objects and feeds it to a custom multi-channel neural network. Depending on the use-case, the system is capable of classifying the material of objects or predicting some of their physical properties such as thermal effusivity.

PlayLiquid Virtual Lab: Simulation of Pouring Viscous Fluid and Whole Hand Grip

Jaehyun Jang, Youngjin An, Hyunyul Cho, and Jinah Park
KAIST

When we bring a real task into virtual environment, there are many aspects to consider including the variety of objects to be handled and the way to handle the object. We have investigated how to represent fluid object in a container for basic interactions of pouring into a vessel for example. In order to manipulate a virtual object, like in the real world, the grip action must be accompanied. When a user manipulates a grounded haptic device, the tracking points are mapped to major fingertip points – usually a thumb and an index finger of a virtual whole hand model. We have defined hand rigging for extent of grip so that the rest of fingers of the hand model are repositioned in a natural manner. For each demo scenario, we define unit events which branch out according to finite state machine. The transition condition is based on the factors of gripped object and the result of the progress. In the event of gripping a container object, collision points are detected and proxy contact points are created on the surface of object for preventing visual penetration. We represent fluid using both SPH model and height field depending on the task to simulate. While the state changes are simulated using SPH, volume changes within a container are rendered by height field and parallel mass-spring system. As the container is tilted the amount of flow is calculated based on contact points with container. The resulting weight force and adaptive gripper force are computed according to dynamic model of the object with respect to multi-contact points. These force feedbacks are delivered to the user to enhance immersive experience in handling liquid.

Real-time Synthesizing Sound Effects & Experiment on the Effect of Using Onomatopoeia in the Virtual Environment on the User Experience.

Gerard Jounghyun Kim, Minwook Chang, Jiwon Oh, and Hyunah Choi
Korea University

We propose to apply deep learning approach to generate sound effects in virtual environments. The perceptual test revealed that the subjects could not discern the synthesized sounds from the ground truth nor perceived any noticeable delay upon the corresponding physical event.

We conducted an experiment on the effect of using onomatopoeia in the virtual environment on the user experience. The results show that accompanying onomatopoeia have a great effect on presence and object attention, and it is confirmed that onomatopoeia has different effects depending on scene characteristics. And it shows that the use of onomatopoeia can alter and add on to the perceive realism/naturalness of the virtual situation and the perceptual experience of the single representative sound added with the onomatopoeia and realistic sound were comparable.