The Virtual Crepe Factory: 6DoF Haptic Interaction with Fluids

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Figure 1: *The Virtual Crepe Factory allows users to interact with different viscous fluids to achieve a crepe preparation recipe. The user follows the different steps of the crepe preparation process (stirring and scooping the dough, pouring the dough into the pan, flipping the crepe, spreading the toppings) and feels corresponding force and torque feedback through two haptic devices, one in each hand.*

Abstract. The Virtual Crepe Factory illustrates our novel approach for 6DoF haptic interaction with fluids. It showcases a 2-handed interactive haptic scenario: a recipe consisting in using different types of fluid in order to make a special pancake also known as "crepe". The scenario guides the user through all the steps required to prepare a crepe: from the stirring and pouring of the dough to the spreading of different toppings, without forgetting the challenging flipping of the crepe. With the Virtual Crepe Factory, users can experience for the first time 6DoF haptic interactions with fluids of varying viscosity. Our novel approach is based on a Smoothed-Particle Hydrodynamics (SPH) physically-based simulation.

Introduction. Fluids are present in many applications such as for industrial or medical manipulations - involving for instance blood flow and natural liquids. The haptic simulation of fluids is particularly challenging, especially to achieve realistic, stable and real-time force feedback. Previous methods for haptic fluid interaction [Baxter and Lin 2004] [Dobashi et al. 2006] were limited to 3DoF, simple objects or pre-computed forces. Thus, as for today, there is a lack of haptic rendering techniques handling complex interactions with viscous fluids. Our approach allows real-time 6DoF haptic interaction with fluids of variable viscosity, through arbitrary shaped rigid bodies and 6DoF haptic devices. Particularly, fluid containers can be created to hold fluid, hence transmiting to the user strong forces such as fluid resistance and weight, as well as light forces like the inertia of the fluid inside the container.

Virtual Crepe Preparation Scenario. As shown in Figure 2, the user holds a 6DoF haptic device in each hand. The scenario can be divided in 4 distinct consecutives stages. The first stage requires the user to stir and scoop the dough from a bowl on the table with his scooping object. It enables the user to feel the torque generated by the resistance from a highly viscous fluid opposing his stirring movement, and the weight and inertia of the fluid inside the hand-held object. In the second stage, the content of the scoop is poured into the pan held with the second hand. The user feels the weight transferring from one hand to the other. The third stage is the solidification and flipping of the crepe. The user feels how mass shifts slow down as the viscosity of the dough raises with the solidification process. When the crepe is ready, it becomes a deformable object, and the user can try to flip the crepe by throwing it into the air, illustrating the underlying phase-change capabilities of our model. The fourth and last stage is the spreading of toppings on the crepe, which combines all the previous haptic interaction possibilities by making the user scoop, pour and spread a low viscosity fluid (maple sirup) and a high viscosity fluid (Brittany's salt-butter caramel).

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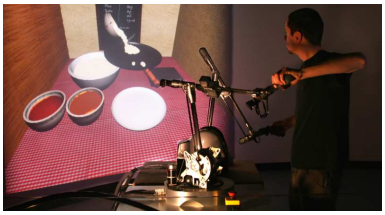

Figure 2: *Setup: Bimanual interaction with two 6-DoF haptic devices (Virtuose, Haption). Left hand for virtual bowl manipulation, Right hand for virtual pan manipulation.*

Technical Description. Our approach is based on an SPH physically-based simulation. We use a unified model to achieve a real-time simulation by using SPH particles for both fluids and rigid bodies. Our approach allows real-time simulation of solid-fluid interactions with arbitrary-shaped rigid bodies and fluids of different viscosities. Furthermore, we use a novel 6DoF haptic rendering based on SPH, providing a soft and continuous haptic feedback particularly well suited for the haptic interaction with fluids. This allows the seamless 6DoF haptic coupling between a haptic device and any rigid body of the virtual scene, but also between N haptic devices and the same rigid body (as holding a bucket with two hands). Our method is implemented on GPU and preliminary testings with standard PC led to 170Hz with 25,000 particles.

Vision. The Virtual Crepe Factory proves that fluids are now ready for complex 6DoF haptic interactions, and opens a new horizon of applications in Virtual Reality. Applications span from the medical field (organic fluids) to industrial scenarios (painting, manipulating dangerous fluids) and entertainment simulations (natural scenes, water sports). We challenge the SIGGRAPH audience: are you a good crepe maker... or a bad one?

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