A Soft Haptic Interface for the Recreation of Realistic Vibrotactile Sensations

Abstract— **Whilst common in devices ranging from smartphones to game controllers, vibrotactile feedback has generally been limited to providing a sensation indicative of some significant event in a virtual information space. This project proposes a novel mechanical technique for generating realistic vibrotactile feedback using the principle of particle jamming. This paper discusses the major design features of a proof-of-concept prototype. Some initial physical observations are presented as well as a programme of the work that will be undertaken to apply this concept to application domains including virtual reality experiences and remote operation of robots.**

I. Introduction

Particle jamming, the physical effect of compacting, and thus stiffening, a viscous body of particles [1] has known applications in the design of haptic devices[2]. The body of particles can be made to react differently to physical stimuli such as a user's touch, making it possible to dynamically control tactile sensations across a surface. One such sensation is the vibrotactile response, commonly employed in video game controllers and smartphones, in which a computer-controlled device vibrates to convey a physical signal to the user.

This project combines the known principle of using an array of jamming-controlled cells to create spatial resolution in a haptic device with that of using jammed particles to dampen felt vibrations. In this way, the device's vibrotactile response can be concentrated in a particular area or areas depending on the virtual event being replicated. This has applications in virtual reality games and other experiences where vibrating gloves and vests can present information about a user's tactile interactions with virtual objects.

One area in which particle jamming has been shown to have great potential is in the development of large-area, low resolution tactile displays. Here, a soft cell filled with small particles can be hardened by evacuating the air from it, affecting their resistance to the user's touch [3]. Since these cells operate independently of each other, they can be built up into an array in much the same way as the pixels in a visible light display [4]. Examples of such tactile displays have been used to control medical robots [5] and as sculpting tools [6]. Vibration progagation through a jamming structure has been investigated in the past for very large format devices but not desktop scale interfaces, and in a more complex technical configuration [7].

Jamming has also been applied to more conventional wearable devices. By placing jamming cells along a user's finger, a resistive force can be created to give the impression that the user is grasping an object [8]. This principle can be further integrated into the device by jamming layers of material in the device itself to create mechanical resistance, rather than packages of a fluid [9].

This project has received funding from the IEEE RAS Technical Committee on Haptics under the "Innovation in haptics" research programme.

II. Motivation

This project aims to produce a system capable of generating more realistic haptic responses than are currently used in conventional haptic devices. This means giving the designers of virtual experiences control of both the amplitude and frequency in various areas of the haptic device. This will make it possible to simulate different fingers stroking different surfaces in a glove type device, or for a strong wind to affect the front of a vest whilst the back goes unaffected. Similarly, different sectors of the circumference of a steering wheel could be made to emit different vibrotactile responses to replicate the different haptic phenomenon experienced whilst driving, such as rough terrain or wheel slip which can often be felt through the steering wheel of a real car. Whilst there is existing research investigating how haptic information is obtained through force feedback and resistance [10], the information contained in vibrations transferred from direct interactions with the road is still an open question and equally relevant to driving simulators and mobile robot control.

III. Proof of Concept Prototype

As an initial proof of concept to evaluate the technology behind this idea, a prototype haptic surface was produced to enable a rigorous study of the effect of jamming on the vibrations felt by a user. This comprises a small, rigid box to hold the particulate fluid, in this case we use quinoa seeds of about 1mm in diameter, with a soft silicone touch pad (fig. 2). An ERM (Eccentric Rotating Mass) vibrating motor was suspended in this container to provide the vibrations. This was connected to a computer-adjustable power supply which provides a second layer of control over the haptic sensation. A very small MEMS accelerometer was glued to the topside of the haptic surface to record the vibrations that would be felt by a user. In a future revision of the prototype, this will be attached to the underside to enable feedback control without affecting the surface texture. The low pressure in the device is achieved with a small vacuum pump and controlled by an electronic pressure regulator.

This prototype has been used to perform an experimental characterisation of the effect of adjusting air pressure and

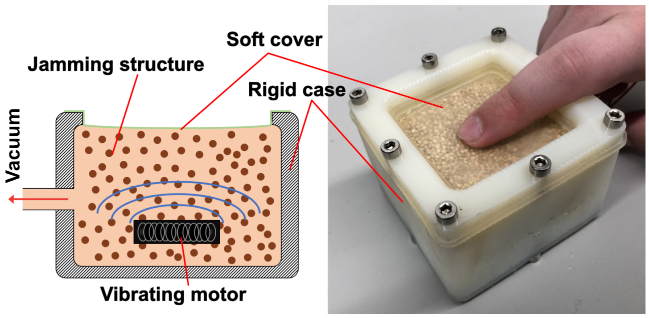

Fig. 1. Left: Physical schematic showing the key components of the jamming device. Right: A simple prototype device consisting of a single jamming cell.

source motor power in order to inform the design of electronic feedback control which will allow accurate setting of the parameters of the vibrotactile effect.

IV. Preliminary results

Two experiments have already been performed as an initial investigation into the physical properties of the device, a selection of results from which are described below and shown on the accompanying poster. Firstly, the haptic surface was set to cycle through air pressure and vibration power signals in order to establish the effect of varying each, both independently and together. This determined that, whilst adjusting each input parameter affected both output quantities, an increase in vacuum pressure most strongly adjusted the amplitude of vibrations whilst an increase in motor power most strongly affected frequency.

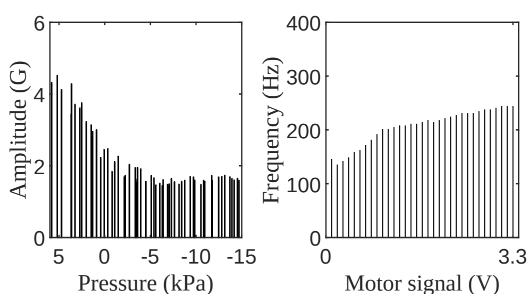

Fig. 2. Experimental data showing effect of air pressure on vibration amplitude (left) and motor voltage on frequency (right).

Secondly, the device was set to vibrate at a static pressure and power whilst a person pressed down on it with increasing force. This revealed an important phenomenon, as the mechanical interactions with a user appeared to manually actuate the jamming effect but also greatly reduce the 'smoothness' of the vibrations. One theory for why this would happen is that the indentation in the fluid caused by the finger had a pronounced effect on the interactions between the particles and the vibrations were either unable to propagate uniformly or experienced a series of superposition effects as they reflected through the misshapen fluid. Quantifying and modelling this behaviour is important in designing a control scheme that can account for physical interaction with the user.

V. Discussion and Future Work

This project is still in its early stages and there are a number of avenues for future development. The proof of concept prototype demonstrated very clearly that controlling air pressure in a viscous fluid does affect the amplitude of vibrations transmitted through that fluid and that controlling the electrical power of the source vibrations from an ERM motor affects frequency. This enables applications in simultaneous rendering of surface textures, objects and shapes in virtual reality games and simulations, such as training systems for medical and driving scenarios.

Future progress is anticipated in two directions. Firstly, a robust study into the performance of the prototype needs to take place. This will comprise both user tests and detailed measurement to determine clear standards of performance for the particle jamming system. Secondly, a programme of hardware development will take place. This will begin with refinements to the single cell prototype to resolve the issues already observed, followed by expansion and integration of the revised design into human-computer interface devices for the eventual control of mobile robots.

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