TESSA - Toolkit for experimentation with multimodal sensory substitution and augmentation

Conference or Workshop Item

Published Version

TESSA - Toolkit for Experimentation with Multimodal Sensory Substitution and Augmentation

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CHI'15 Extended Abstracts, Apr 18-23, 2015, Seoul, Republic of Korea
ACM 978-1-4503-3146-3/15/04.
http://dx.doi.org/10.1145/2702613.2725451

Abstract
TESSA is a toolkit for experimenting with sensory augmentation. It includes hardware and software to facilitate rapid prototyping of interfaces that can enhance one sense using information gathered from another sense. The toolkit contains a range of sensors (e.g. ultrasonics, temperature sensors) and actuators (e.g. tactors or stereo sound), designed modularly so that inputs and outputs can be easily swapped in and out and customized using TESSA's graphical user interface (GUI), with "real time" feedback. The system runs on a Raspberry Pi with a built-in touchscreen, providing a compact and portable form that is amenable for field trials. At CHI Interactivity, the audience will have the opportunity to experience sensory augmentation effects using this system, and design their own sensory augmentation interfaces.

Author Keywords
sensory augmentation, sensory substitution, haptics, audio, toolkit, modular design

ACM Classification Keywords
H.5.2. [Information interfaces and presentation (e.g., HCI)]: User Interfaces – Prototyping, Auditory (non-speech) feedback, Haptic I/O

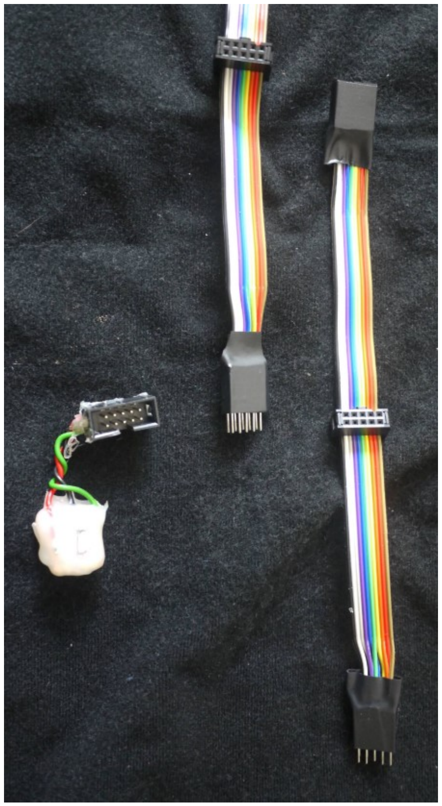

Fig. 2 TESSA module connectors. Each cable can accept up to 2 connections, which can be another cable or a I/O module.

Introduction

Since Bach-Y-Rita's original experiments with sensory substitution in the 60s and 70s [2], a number of systems have demonstrated the ability of the human brain to interpret sensory stimuli received via one modality (such as audio) as information from a different modality (such as vision) [1,3]. These systems have been shown to provide sufficient substitution of the senses to facilitate independent navigation for people with vision impairment, giving them greater freedom and improved quality of life [6].

Sensory Augmentation via Substitution (SAS) extends this work and applies similar principles, taking advantage of the brain's ability to adapt, with the aim of enhancing the natural human senses. For example, SAS devices have been used experimentally to provide an enhanced sense of direction [5], proximity or distance [4] by enabling the person to "feel" this information subconsciously, instead of consciously extracting it from their natural senses.

While SAS technology has many applications, these are currently difficult to explore, since existing SAS devices are application-focused and provide only a single type of sensory substitution. TESSA aims to make it easier to experiment with SAS by removing the need to construct a new device for every type of substitution.

TESSA Hardware Overview

TESSA's main control module (fig. 1) runs on a Raspberry Pi with a touchscreen and battery pack, allowing for self-contained, portable, and untethered operation. This unit also powers and sends signals to and from the sensor and actuator modules, which plug into connection slots on either side of the main unit.

As its input modules, the toolkit currently includes an infra-red sensor which provides temperature sensing at a distance, and an ultrasonic rangefinding package which detects distance to objects. The control module also contains an internal 3D gyro-compensated compass, which provides the system with information about its spatial orientation.

Fig. 1 The control module runs on a Raspberry Pi with a touchscreen and battery pack.

The output modules currently include individual haptic actuators built from PMD-300 "pancake" vibration motors, which are small but powerful enough to be felt through clothing. These are driven with pulse-width modulation, meaning the intensity of the vibration can be altered dynamically in software. Additionally, the

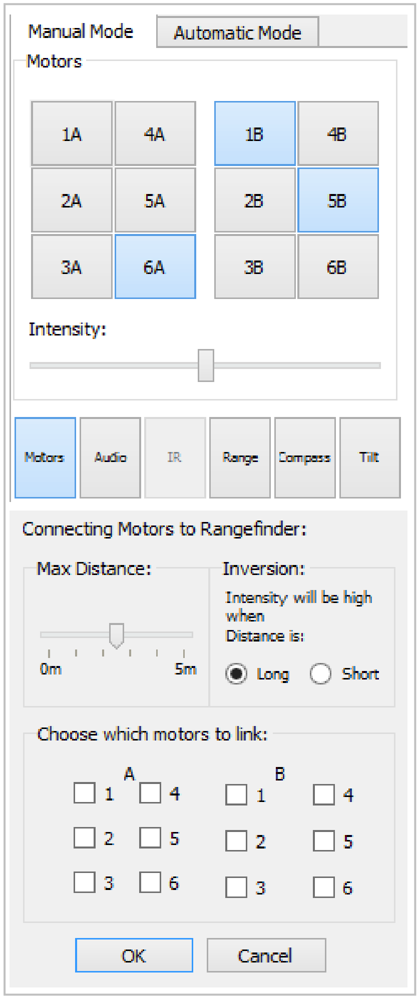

Fig. 3 The GUI in manual mode (top) and automatic mode (bottom)

system supports stereo audio output through a 3.5mm jack

Each input and output module is wired with a common arrangement of power and signal wires such that any module can be plugged in in place of any other module, making it easy to swap modules in and out. The user has flexibility in choosing how many modules to use and where to place them (e.g. where on the body). The modules can be plugged together in a serial chain or in parallel branches, which facilitates experimentation with different structural configurations.

Software Operation

TESSA is used and configured through a graphical user interface (GUI) running on the control module. The software auto-loads when the system is powered on.

The GUI has two modes of operation: manual and automatic. In manual mode, all output from the device is directly controlled from the GUI, and the user can select which output devices are to be active and change their parameters manually. For example, the user can select a particular haptic actuator to be turned on, and using slider bars, adjust the intensity of the vibration, whether the vibration is continuous (and its frequency, if not) and feel the changes in "real time." The data from the sensor modules can also be displayed on the screen in "real time". We envisage that this mode will provide a hands-on way for users to acquaint themselves and experiment with the behavior of the modules, as a first step toward designing a SAS application.

In comparison, automatic mode is intended for designing functional applications. In this mode the user can "tie" input devices to output devices, and specify how the system should convert and transmit the sensory input from the sensors to the user through the chosen actuators. For example, using the GUI, the user can tie an IR sensor to a collection of haptic actuators, and specify whether these should vibrate when the temperature detected by the sensor is high versus when the temperature is low, and also set the temperature thresholds for maximum and minimum vibration.

TESSA is designed to be multimodal and so permits multiple sensory substitution channels to be active simultaneously. For example, a single input channel could be mapped to multiple displays simultaneously, or two independent input-output mappings could be active at the same time.

Preset Modes

In order to illustrate some of TESSA's applications, a number of preset modes of operation are programmed into the device. These are the following:

- *Compass Belt Mode:* Inspired by the feelSpace belt among others [5,7], this mode uses the tactile actuators in a belt-type configuration around the user's waist to continuously signal the direction of magnetic north
- *Distance Glove Mode:* This mode uses the ultrasonic sensor and a single tactor mounted on a glove. The tactor is inactive at long distances, and vibrates with increasing intensity as objects come nearer to the sensor.

Fig 4. TESSA in glove configuration (top) and belt configuration (bottom)

Discussion

TESSA is a sensory augmentation toolkit that has been designed to be:

- *Multi-modal* in that it supports haptic and audio feedback, which can be linked to a range of sensor inputs;
- *Modular*, which provides flexibility and an ability to reconfigure a sensory augmentation system "on the fly"; and
- *User-friendly* in that the modules are physically straightforward to connect together, and the GUI provides intuitive controls for configuring the system parameters.

TESSA is intended to make it relatively fast and easy to prototype and experiment with sensory interfaces without needing a high level of technical expertise, and hence we hope it can benefit broad audiences and accelerate research and development in a range of areas. For example, the toolkit could potentially be used in researching new interfaces for assistive technology and rehabilitation, situational awareness in military contexts, automotive user interfaces, and digital arts.

We anticipate that TESSA will undergo further iterations and improvements, and that this would benefit from a community effort. The system's hardware and software are designed to be easily updated and extended, with the intention that users could build their own custom modules to interface with the existing system.

Acknowledgements

We would like to thank Sam Alexander and Nic Hollinworth from the University of Reading, for their participation in the discussions that helped shape the TESSA project. We would also like to thank Ioannis Zoulias, Philip Kunovski and Ian Harrison for their assistance with storyboarding and testing the GUI.

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