# A Visio-Haptic Wearable System for Assisting Individuals Who Are Blind

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## Abstract

Computer vision algorithms for visio-haptic information analysis, i.e., the conversion of visual data into haptic (tangible) features, can be utilized in wearable assistive devices for individuals who are blind. Touch is an important modality for individuals who are blind, but it is limited to the extent of one's reach. By estimating how an object feels from its visual image, we are able to overcome this limitation. This paper proposes a wearable assistive device to estimate haptic features from visual data to enable users to feel objects from a distance.

## Introduction

Individuals who are blind rely on their sense of touch for perceiving their proximal environment. Unfortunately, this modality is limited to the extent of one's reach, thereby limiting haptic perception of objects in the distal environment. This paper proposes a wearable system to estimate haptic (tangible) features from visual data (i.e., visio-haptic information analysis or simply visio-haptics) to enable users to feel objects from a distance.

Haptic features are perceived through touch, but humans can visually estimate haptic features through intermodal processing and transfer [2]. Similarly, computer vision algorithms can be utilized to estimate an object's haptic features including shape, size, texture and material. Once haptic features have been estimated, they may be presented to the user through a haptic user interface.

We propose the integration of Radio-Frequency Identification (RFID) technology and computer vision for visio-haptics. RFID tags may be placed on objects in the environment, and their haptic and visual features stored in a central database. As tagged objects are encountered, a memory map is built using Multidimensional Scaling (MDS) where objects are clustered based on salient, haptic features. Utilizing this ground truth, we may tune a learning system for intermodal transfer, i.e., the prediction of haptic features from visual input. Essentially, the learning system provides a mapping between visual input and haptic concepts stored in memory.

Computer vision algorithms often work fine in controlled settings, but good performance in uncontrolled environments can become challenging. Rather than have the system entirely handle the task of analysis, it is important to utilize human capacity and involve the user in this process, creating a human-in-the-loop system. The system design we present here is unique in that it incorporates confidence measures to communicate to the user how confident it is about its decisions regarding how an object feels. For example, if confidence is poor because of a dimly lit scene, the user is informed and may find a way to improve lighting to assist the system in analysis.

## Related work

There have been several attempts at developing algorithms for estimating haptic features from visual data. One wearable system for individuals who are blind is the Tactile Vision Sensory Substitution System (TVSS) [1]. An image is first divided into blocks, and the average intensity value of each block is computed. These values are then converted directly into vibro-tactile stimulations delivered to the user through a grid. However, this approach merely presents visual features, i.e., illumination values, to the haptic modality, which is a major design flaw, as the haptic modality should receive haptic features.

Kahol [3] developed a wearable assistive device for individuals who are blind that utilizes visio-haptic algorithms to enable users to feel from a distance. The conceptual framework outlines two types of algorithms: those that operate at a perceptual level, and those at a physical level. The perceptual algorithms classify features into predetermined classes, and subsequently, these features are conveyed to the user through a haptic glove in the form of tactile cues, which Kahol shows are capable of invoking concepts in a user’s mind. While the algorithms achieve high accuracy in controlled environments, uncontrolled environments present a problem. A novel approach to visio-haptics is presented here that utilizes a unique framework for wearable computing that integrates computer vision and RFID. Further, the use of confidence measures is proposed to enhance the system’s use in uncontrolled environments.

## Conceptual framework

The goal of my research is to design and develop algorithms for estimating haptic features from visual images, which will be utilized in a wearable system for individuals who are blind, depicted in Fig. 1.

Computer vision algorithms for visio-haptic information analysis may operate at either a perceptual or physical level [3]. At a perceptual level, haptic features are classified into predetermined classes, e.g., the texture of an object may be classified as rough, medium or smooth. At a physical level, haptic features such as texture or shape are reconstructed from an object’s image. Haptic user interfaces are limited for haptic presentation of physical information, and hence our wearable system will utilize algorithms that work at a perceptual level. Haptic information will be delivered to the user using the tactile cueing methodology of [3], which has been shown to invoke haptic concepts. A concept is an average representation of a category; for example, the object category dog invokes an image in our minds that is an average of all the different types of dogs we’ve encountered.

We propose a novel framework, depicted in Fig. 2, to integrate RFID and visio-haptics. RFID provides a method to easily learn about objects in the environment to create a memory map through Multidimensional Scaling of haptic features. Using computer vision, we may estimate haptic features from visual data through intermodal transfer, and recall from memory haptic concepts. A learning system may be trained for intermodal transfer using ground truth provided by RFID and the visual input of tagged objects.

Perceptual visual and haptic ground truth for RFID may be collected using human participants.

A human-in-the-loop paradigm is crucial as computer vision is much more challenging in uncontrolled environments. Scale changes, pose changes, illumination changes, blur, occlusion and noise are often encountered when using a vision-based wearable computer. Rather than have the system entirely handle the task of analysis while ignoring the user, it is important to involve the user in the process, creating a human-in-the-loop system to take advantage of human capacity. The system communicates to the user how confident it is about its decisions regarding how objects feel. Confidence will depend on a) environmental cues, e.g., illumination, motion blur, etc.; b) context-dependent cues, e.g., the object was recognized as a bowl, but this conflicts with its material, which was recognized as cloth; and/or c) algorithm-dependent cues that rely on training data.

Lastly, the usability of the wearable system will be extensively tested using a group of participants who are blind. The system will be judged on its ease-of-use, comfort and usefulness. Changes will be made to system design based on user comments.


**Figure 1:** Wearable system

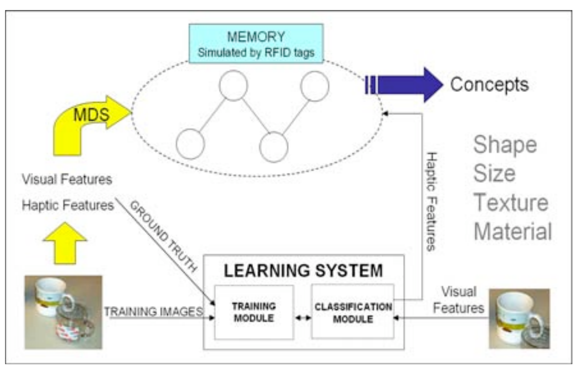


**Figure 2:** Framework for visio-haptics and RFID

## Current status of research

A methodology to collect ground truth for computer vision algorithms for estimating haptic features from visual data was developed [4]. Perceptual ground truth in both the visual and haptic modality was collected from participants. Physical ground truth was collected utilizing stereo analysis and 3D tracking equipment. Confidence measures based on illumination and motion blur were developed [4]. Illumination is classified as poor, good or great by computing the mean pixel value of a grayscale image, then classifying the sample mean using a Bayesian classifier. Accuracy on novel test images was 96%. For motion blur classification, a metric based on average line width computed from a difference image is classified as no motion blur, small motion blur, large motion blur or extreme motion blur using thresholds found through experimentation. Accuracy on novel test images was 95%.

A wearable system capable of video processing and RFID sensing has been built. Video is captured using a small, hidden camera built into a pair of ordinary sunglasses, and is sent to a wearable computer for processing. Confidence measures based on illumination and motion blur may be accessed by the user at any time. RFID sensing is performed using an RFID reader contained in a lightweight carrying case with shoulder strap. Once a tag is read, it is sent to the wearable computer through 802.11. An object's haptic features are accessed through a database, and presented to the user through audio output or vibro-tactile stimulations using a haptic glove and the cueing methodology of [3].

## Conclusion and future work

This paper proposes a wearable system to estimate haptic features from visual data to enable users to feel objects from a distance. This research will make several important contributions: 1) Visio-haptic algorithms for estimating haptic features from visual data that are robust enough to use in uncontrolled settings. 2) Confidence measures for conveying to the user how confident the system is about its decisions. Further, the measures will inform the user how he or she may increase confidence, further improving the reliability of the system. 3) The final contribution is a framework for combining computer vision with RFID technology where RFID builds a memory map and computer vision invokes concepts from memory. Future work will involve 1) the development of a learning system for intermodal transfer of visual shape, size, texture and material to their haptic counterparts contained in memory; 2) development of confidence measures based on video noise and out-of-focus blur; and 3) usability testing.

## References

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