u-Texture: A Self-Organizable Material for Building Smart Furniture

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ABSTRACT
This paper proposes "u-Texture", a new form of material with sensing, actuating, computing, and communicating capabilities. u-Textures can be assembled into various types of "Smart Furniture" (e.g., chairs, tables, shelves, or partitions) or furniture that supports everyday human activities with embedded computers. u-Texture's software support senses the form of the furniture and determines which cooperative function should be performed. Thus, u-Texture can help change our everyday environment into smartly furnished space effortlessly. Following the illustration of possible classroom applications of u-Texture, its hardware configuration and middleware support will be presented.

Keywords
u-Texture, Smart Furniture, self-organizing, reconfigurable

RESEARCH GOAL
"u-Texture" aims at realizing "Smart Space" or space that supports everyday human activities with embedded computers. As a "building block" with a self-organizing capability, u-Texture can be assembled to form various types of furniture and sense the shape of the entire furniture as well as its relative location and gradient. Based on such information, u-Texture determines and adapts a function it should perform.

Our ultimate research goal is to develop a new easy-to-use Smart Space material. Thus, we have selected a flat square shape for u-Texture so that it can be easily incorporated in existing types of furniture. We have also decided to provide u-Texture with a self-organizing capability so that it can support existing ubiquitous applications and run in any environment.

APPLICATIONS
One possible application of u-Texture is its classroom use.

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During a lecture, each student is seated at a desk equipped with a u-Texture unit. The desk works as a receiver that obtains information from the podium or blackboard. In a discussion where students are expected to exchange their ideas more freely, they can connect their desks to form a table (as shown in Figure 1) which can display discussion materials. After class is over, u-Texture components of the desks can be mounted on the classroom wall to serve as a bulletin board.

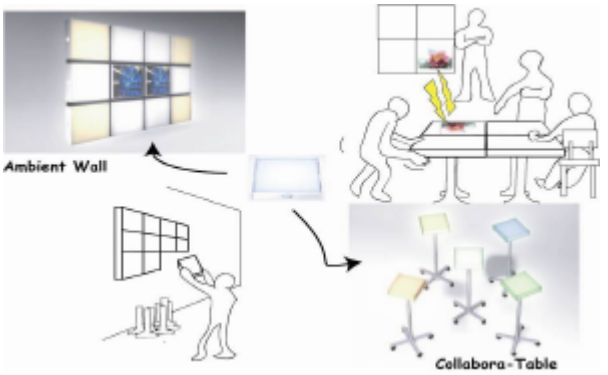

Figure 1. Classroom applications of u-Texture: "Ambient Wall" and "Collabora-Tables."

DESIGN OF U-TEXTURE
u-Texture consists of hardware and software components to autonomously identify its functions and collaborate with surrounding devices.

Hardware
u-Texture is 38-cm (15-in.) square, approximately the size and shape of a pizza box and contains three types of devices: a) basic computer components (e.g., CPU, touch display, and sound device) and self-identification devices (e.g., accelerometer), b) internal communication devices (e.g., serial interface and wired LAN), and c) external communication devices (e.g., embedded infrared interfaces or wireless LAN interfaces to communicate with other Smart Furniture; RF-ID readers to communicate with items such as tugged objects). With the help of these hardware components, u-Texture can create Smart Space individually (i.e., as a standalone u-Texture), collectively (i.e., as a piece of Smart Furniture built of a set of u-Textures) or in

conjunction with other devices. Figure2 shows u-Texture prototypes which works collectively.

Figure 2. Flatly connected u-Texture prototypes

Software

Each u-Texture is equipped with: a) a self-identification framework which helps u-Texture sense its relative location within a given piece of furniture by gathering connection information from surrounding u-Textures over a multihop wired network and by drawing a 3D map of the entire furniture based on the gathered information; and b) an application adaptation framework which selects appropriate applications for each u-Texture so that the u-Texture can adapt to the size and shape of the furniture. Applications can be installed or downloaded on demand. If multiple applications are selected as appropriate, users can be given choices.

RELATED WORK

Various approaches for building Smart Space have been investigated. One such approach is to add computational functions to existing furniture [1-3], which allows a tailor-made design for each and every piece of furniture but is highly time-consuming and costly. Another approach is to scatter sensor nodes throughout our environment in an effort to continuously gather information from the physical world[4,5], which mainly focuses on sensing—but not actuating—capabilities. Yet another approach is to assemble smart materials to form a larger device[6-9]. This last approach has, so far, only been implemented for certain specific purposes (e.g., for toys[6], pixels[7], interface[8], or PCs[9]), but not for general use. Our work is intended to fill this void by offering innovative and ease-to-use Smart Space material that can be assembled intuitively and used to support everyday activities unobtrusively.

RESEARCH DIRECTIONS

Three major issues should be addressed in future research on u-Texture. First, u-Texture needs to possess increased sensing capabilities. Given the space limitation, it makes more sense to embed a small number of multifunctional sensors in the texture than to install a large number of single-purpose sensors. Second, u-Texture should be made of material durable enough to be used pervasively throughout our environment (e.g., floor or ceiling). Finally, in addition to these hardware developments, software support which enables easy u-Texture cooperation (e.g., a coordinating framework for u-Textures or APIs of various u-Texture functions) needs to be developed.

SUMMARY

In this paper, we introduced "u-Texture." With the help of this new form of material, building Smart Space should be considerably easier: all we need to do is simply form a shape of furniture we would like to use at any given moment. With its shape similar to that of various types of furniture commonly found in homes or offices, u-Texture can ensure hassle-free replacement of existing non-Smart furniture.

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