Two-Dimensional Communication Technology Inspired by Robot Skin

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Abstract

A Two-dimensional communication device proposed in a recent paper is a device in which signals travel freely between arbitrary points in flexible two-dimensional space using two-dimensionally-spread electromagnetic field. The new form of communication solves the wiring problems in various situations. It also has advantages over wireless communication. It consumes less energy for signal transmission, it can provide energy for the connected elements, and the communication capacity is larger because multiple 1D signal chains transmit signals simultaneously. In this paper, we demonstrate examples of high speed signal transmission through flexible 2D layers with proximity interfaces.

Keywords; two-dimensional communication, sensor network, ubiquitous computing, wearable, robot skin, micromachine, distributed computing, LAN, wireless

1. Introduction

A concept of two-dimensional communication has been proposed in [1]. A series of challenges to realize stretchable skin containing a large number of tactile elements inspired the new field of technology. The forms of communication in today's available technologies are categorized into the one or three dimensional. One dimensional communication is based on signal transmission using electro-magnetic energy confined in one dimensional medium of a wire and optical fiber. The problem of it is the labor of wiring a large number of elements. Wireless signal transmission based on electromagnetic wave can be classified into three-dimensional communication, as the electromagnetic field is released in 3D space. Wireless communication had been considered to be an alternative to solve the wiring problem. The problem of it is that the electromagnetic field propagates beyond the target, which makes energy transmission difficult, and causes interference among multiple elements.

The two-dimensional communication medium, in which signals travel freely between arbitrary points in flexible two-dimensional space, has an intermediate property between the one and three dimensional communication, and is an appropriate form to solve a wide range of problems related to wiring labor in system design. The application area ranges from robotics to communication infrastructure in buildings, communication tools on the desk, sensor networks, wearable computing, and circuit boards without individual wires for general purposes. In this paper, we demonstrate examples of high speed signal transmission through flexible 2D layers with proximity interfaces.

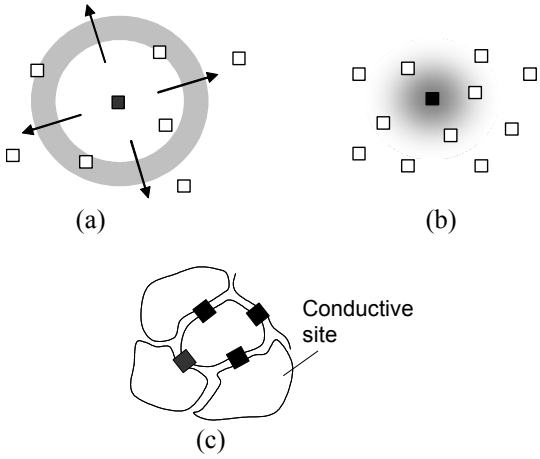

Fig. 1: Basic strategies of the physical layer of 2D communication. Signal transmission by 2D isotropic electromagnetic wave (a), local diffusion using signal layer resistance (b), and 2D linkage of conductive areas (c).

2. Key concepts of the device

In this research, we fabricated multipurpose 2D communication chips and proposed the 2D communication device using the chips. The key concepts of them are summarized as follows.

A. Easiness of mounting communication chips

The terminals of the communication chip are typically two. The minimum number of terminal allows us to mount them on elastic conductive material like rubber or cloth, and various shapes of object surface printed with conductive paint.

B. Allowing communication chips located at a high density

The low cost communication chips with small number of terminals can be located with high density at low cost. The packets are relayed among the communication chips. The chained signal path is a virtual wire that is created dynamically. The energy consumption is propor-

tional to the volume of the 1D chain. The high density of communication chips realizes a large communication capacity with multiple signal paths.

C. Proximity connection

The two-dimensionally-spread electric field can be monitored by capacitive coupling on the signal layer. The two-dimensional communication sheet provides a surface on which apparatuses with the 2D communication interface at its bottom can have proximity connection to the communication world.

3. Basic strategies of signal transmission

The first method of signal transmission is radiating electro-magnetic wave between conductive layers as shown in Fig. 1 (a). In this method, the signal transmission distance is controllable by the resistance layer located between the conductive signal layers. The second method uses voltage diffusion localized by the signal layer resistance [1] as shown in Fig. 1 (b). The third one is to link multiple conductive layers by communication chips as shown in Fig. 1 (c). The third method provides the easiest connection of multiple conductive sites into a network. A suitable form is selected by the application.

4. Applications

Above mentioned 2D communication device with large throughput is useful in various aspects and scenes as follows.

A. Excluding complicated wires from robot system

If we cover a robot with this 2D communication layer, elements of the robot such as computers, actuators, and sensors can be connected to the device at arbitrary positions to communicate each other. In addition to the information exchange, they obtain energy by simply being connected to the signal layers. The complicated wires combining those elements are removed.

B. A vast amount of elements can be connected

A large number of elements including sensors, actuators, and other functional parts can be connected and communicate at fast speed. An elastic tactile sensing device is one of suitable applications. A floor equipped with contact sensors provides a high security room. The floor is also useful for merchandize monitoring.

C. Activating micromachines and small tags

A small tag put on the 2D device can connect to the network receiving energy through non-contact proximity connection. Two dimensional communication is a suitable form for micromachines to communicate each other.

D. Wearable computing

One conductive string lacks reliability for stable communication. A two dimensional fabric provides a sufficient reliability in signal transmission between neighboring chips. It has been confirmed that signals at 30 Mbps (100 MHz operation) can be transmitted in the flexible clothes.

E. Wireless connection without electromagnetic radiation

The communication sheet provides a desk or a floor on which devices including computers and peripherals can have proximity connection to the network. That is also a “wireless communication” without electromagnetic radiation. The signal cannot be intercepted outside of the room, and it does not interfere with other wireless apparatuses. Connected apparatus can receive the power. If our feet have the interfaces, we can connect to the network through the feet as freely as the traditional wireless communication. The communication capacity offered by a 2D communication floor in which the signal paths are one-dimensional chains is larger than that of 3-D communication with a single 3-D space shared by all communication elements.

References

[1] Hiroyuki Shinoda, Naoya Asamura, Mitsuhiro Hakozaki, and Xinyu Wang, “Two-Dimensional Signal Transmission Technology for Robotics,” Proc. 2003 IEEE Int. Conf. on Robotics & Automation, pp.3207-3212, 2003.

Table 1: Comparison with other forms of communication.

Comparison with 1D communication (Cables and wires)	Comparison with 3D communication (Wireless)
No laborious wiring -- Communication without individual physical wire. -- Easy connection of a large number of elements. -- Circuit design without complex consideration on wiring. Robust Virtual wires are dynamically created. The partly broken wires can be reproduced. Mountable on elastic and free-shaped surfaces Elements can be mounted on surfaces of various materials.	Lower energy consumption Electromagnetic energy is localized around the 1D virtual wires. Larger communication capacity Multiple signal paths can be generated simultaneously. Throughput of each path is determined by the operating speed of the communication chip. Providing electrical power Apparatuses connected to the signal layer can get energy supply. No radiation of electromagnetic wave Harmless to other apparatuses. Healthy environment. Advantageous in information security.