

Smart Textiles: Self-organizing and Fault-tolerant Integration of Microelectronics

Many promising technologies are emerging in the area of intelligent textile materials like electrically conductive yarns or pressure sensitive fabrics. State of the art feature sizes of integrated circuits allow for powerful and yet small and cost-efficient microelectronic devices. Many interesting applications in the field of technical textiles arise by merging micro-systems and textile fabric structures:

Pressure sensors in floor coverings for alarm plants or motion detection (person tracking), indicator lamps in floor or wall coverings for guidance systems in public buildings, distributed sensor networks for detection of defects in textile concrete constructions, and many more.

Recently, we presented results of a robust interconnect and packaging technology for connecting microelectronic circuits to conductive fibers within textiles, making the complete system washable for its application in wearable electronics [1]. Figures 1a-1b show a connect between copper wires interwoven within a Polyester fabric and a microelectronics module. The encapsulation insulates the module electrically and protects it in a robust and waterproof way.

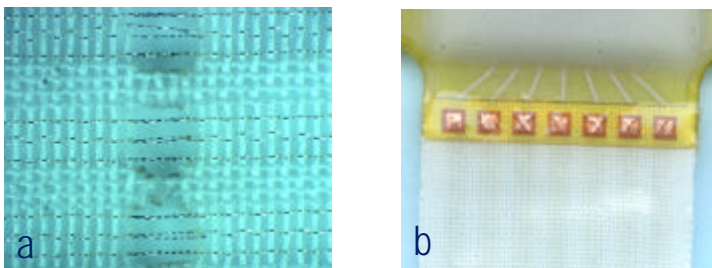


Figure 1 Interconnect of electronics and interwoven copper wires

- Removal of wire isolation by laser treatment
- Contacts by soldering on flexible board and encapsulation of module and contact area

A very similar technology enables the integration of sensor elements, light emitting diodes and microprocessors in large-scale textiles that contain a regular grid of conductive weft and warp threads. Figure 2 illustrates the idea of microelectronics integration within a coarsely meshed fabric. This fabric could be a basic or

intermediate layer of floor or wall coverings or any other kind of technical textiles.

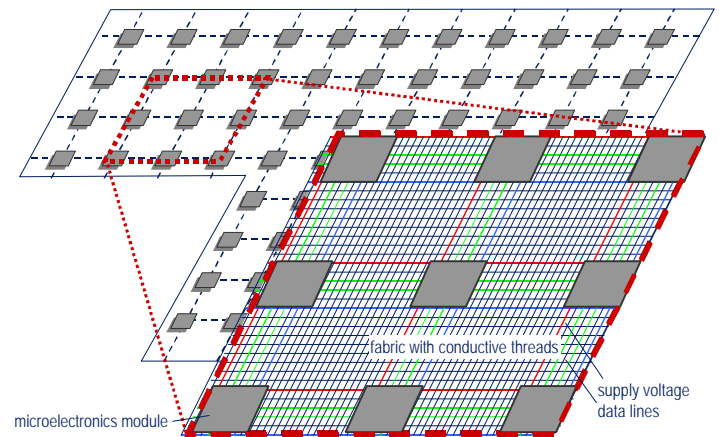


Figure 2 Schematic of an embedded network of processing element in a textile fabric

Figure 3 shows a concept study of a smart carpet. Red and blue threads indicate the supply wires, the green threads mark data lines. A small microelectronics module is connected at the cross-over points of the wires. In this way, each module is connected at each of its four edges to both supply and data lines. After encapsulation, a smart fabric is realized featuring a regular grid of integrated microelectronics modules.

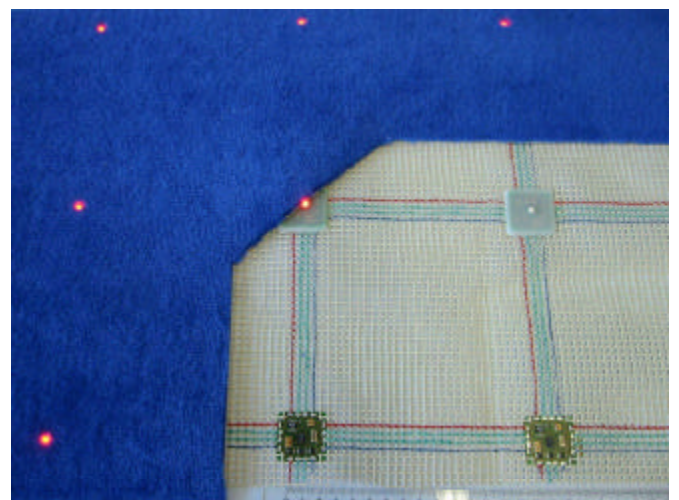


Figure 3 Photograph of a concept study of a 'smart carpet': microelectronics modules with integrated red light emitting diodes connected to a coarsely meshed fabric, with interwoven conductive wires, before and after encapsulation (background); a blue carpet forms the top layer.

For a practical realization the following questions arise: how can we exploit the functionality of the integrated microprocessors, sensors and light emitting diodes? What happens if the smart fabric is cut to fit as a functional floor covering of an arbitrarily shaped room? Will a single destroyed or defective module or wire lead to a complete failure of the smart textile system?

To solve these problems, we introduced a self-organizing technique based on newly-invented algorithms [2]. During a initialization phase the embedded network of processing and sensor elements starts the self-organization according to simple local rules (Figure 4a). The elements learn their coordinates and their position in the network grid (Figure 4b) and channels for data flow are established, automatically routing around defective regions (Figure 4c).

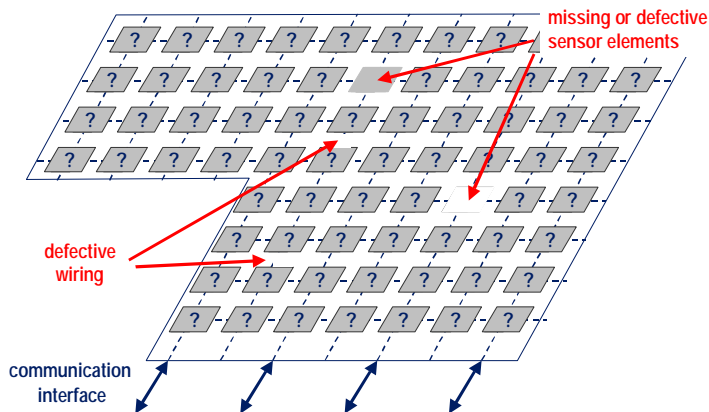


Figure 4a Before initialization: the sensor and processing elements carry no information about their position in the network grid

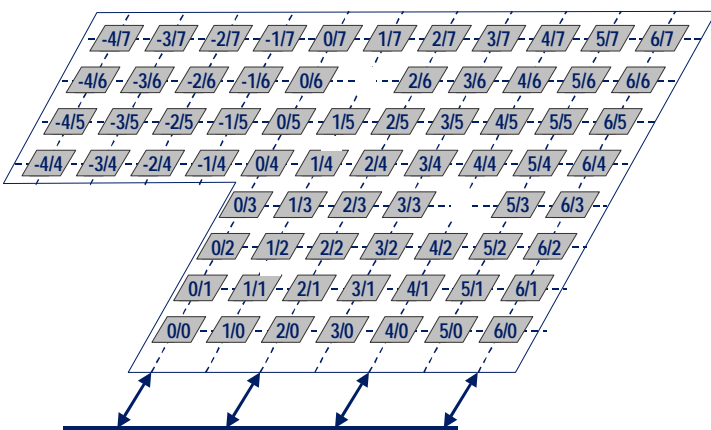


Figure 4b During self-organization: the elements learn their coordinates according to local rules

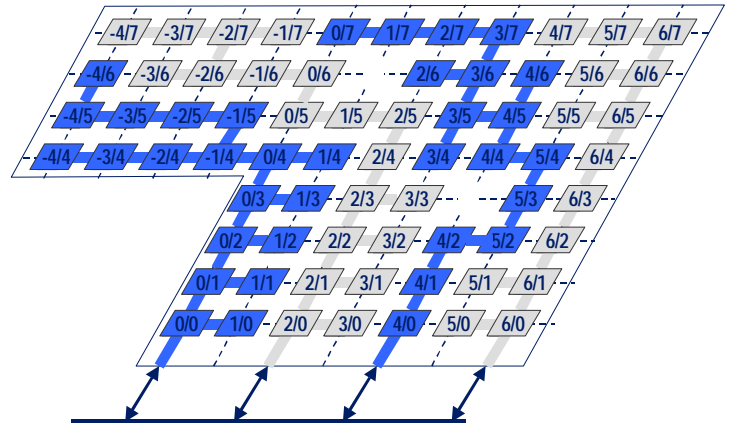


Figure 4c Final status: the channels for data flow are established, automatically routing around defective regions

The unique feature of the proposed integration concept is its fault-tolerance: by means of a self-organization technique, the fabric network automatically recognizes defective regions. It therefore remains operational if a microdevice fails or conductive threads are damaged. The fabric even remains functional when cut to arbitrary shapes to fit to a given room floor. Moreover, due to the self-organization, there is no need for a manual installation of the grid microelectronics. This fact largely facilitates installation of the carpet.

"Fault-tolerant Integration Concept of Microelectronics in Smart Textiles" by Christl Lauterbach, Stefan Jung, Thomas Sturm, Rupert Glaser, and Werner Weber, Infineon Technologies AG, Corporate Research, Munich, Germany, received the TechTextil Innovation award 2003 in the category "Integration of new technologies".

References

- [1] S. Jung, C. Lauterbach, M. Strasser, W. Weber, "Enabling Technologies for Disappearing Electronics in Smart Textiles", International Solid-State Circuits Conference, ISSCC 2003, San Francisco, CA, 9.-13.02.03
- [2] T. F. Sturm, S. Jung, G. Stromberg and A. Stöhr, "A Novel Fault-Tolerant Architecture for Self-Organizing Display and Sensor Arrays", In Jay Morreale, editor, 2002 SID Symposium Digest of Technical Papers, Volume XXXIII, Number II, pages 1316-1319, San Jose, California, May 2002. Society for Information Display

Infineon Technologies AG
 Corporate Research, Laboratory for Emerging Technologies
 e-mail: emerging.technologies@infineon.com