Title: SENSITIVE SKIN

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Abstract: **Sensitive skin is a large-area, flexible array of sensors with data processing capabilities, which can be used to cover the entire surface of a machine or even a part of a human body. Depending on the skin electronics, it endows its carrier with an ability to sense its surroundings via the skin's proximity, touch, pressure, temperature, chemical/biological, or other sensors. Sensitive skin devices will make possible the use of unsupervised machines operating in unstructured, unpredictable surroundings—among people, among many obstacles, outdoors on a crowded street, undersea, or on faraway planets. Sensitive skin will make machines "cautious" and thus friendly to their environment. This will allow us to build machine helpers for the disabled and elderly, bring sensing to human prosthetics, and widen the scale of machines' use in service industry. With their ability to produce and process massive data flow, sensitive skin devices will make yet another advance in the information revolution.**

Keywords: **-**Automation, electronics, large area sensor arrays, material science, robotics, sensing, sensitive skin

I. INTRODUCTION

Several novel technologies can be used in order to fabricate sensitive skin, and many novel ideas have already emerged. They will allow us to fulfill our dream for machines sensitive to their surroundings and operating in unstructured environment. Flexible semiconductor films and flexible metal interconnects that will result from this work will allow us to develop new inexpensive consumer electronics products, new types of displays, printers, new ways to store and share information (like electronic paper and "upgradeable" books and maps). New device concepts suitable for large area flexible semiconductor films will lead to new sensors that will find applications in space exploration and defence, specifically in mine detection and active camouflage. An ability of parallel processing of massive amounts of data from millions of sensors will find applications in environmental control and power industry. These areas will be further developed because of the highly interdisciplinary nature of the work on sensitive skin. One of the most powerful abilities of the sensitive skin as applied to motion control is demonstrated in Fig. 1. Here a skin-equipped robot arm manipulator dances with a ballerina. She does not hesitate to turn her back to the "partner," fully expecting a "human" reaction

Fig.1 Ballerina dancing with a robot manipulator.

II.SYSTEM CONCEPT

The system consists of a number of distributed sensor, actuator and intelligence units , which are connected by some network of interconnects.

Intercoonects are necessary for providing power to the system as wll as for communication. The sensors/actuators may have intelligence associated with them but there are other higher levels of intelligence to which they are connected

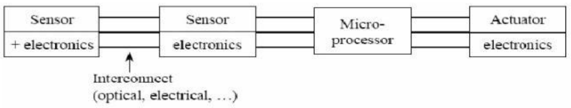

Fig. 2. Sketch of interconnects between sensors, intelligence, and actuators

III. REQUIREMENTS TO SENSITIVE SKIN DEVICES

The following are the requirements to sensitive skin device:**A. Skin Materials**

Sensitive skin material (substrate) holds embedded sensors and related signal processing hardware. It needs to be flexible enough for attaching it to the outer surfaces of machines with moving parts and flexible joints. The skin must stretch, and desirably shrink and wrinkle the way human skin does, or to have other compensating features.Wiring must keep its integrity when sensitive skin is stretched or wrinkled. This requirement calls for novel wire materials, e.g., conductive elastomers or vessels carrying conductive liquid, or novel ways of wire design with traditional materials, such as helical, stretchable wires.Still another possibility is semiconducting textiles, a technology that will find applications in wearable computing and wearable electronics. The efforts in developing such materials are now under way at several universities and several companies, including NCSU, IBM, Phillips, BIT's, Inc., and Printed Transistors, Inc.

B. Sensing Devices

Sensitive skin components have to be deployed in two-dimensional (2-D) or even quasi-three-dimensional (3-D), layered) arrays of sufficiently high density. A representative model would be a piece of skin of 1×1 m^2, with sensors spread uniformly at a pitch of 1×1 mm, with the total of 1 million sensors. This model immediately points to the need to mass-produce sensitive skins as large-area integrated circuits. Smaller arrays may be of use as well: the key feature is that the skin should allow, by itself or with appropriate data processing, to identify with reasonable accuracy the points of the machine's body where the corresponding sensor readings take place.

Ideally, sensors and their signal processing hardware should be spread within the array so as to allow cutting it to any shape (disc, rectangle, an arbitrary figure) without losing the entire sensing and control functionality. This suggests interesting studies in hardware architecture. Any sensing modalities, including proximity or tactile, discrete or continuous, are acceptable. Sensor arrays with special or unique properties are of much interest, for example a cleanable and washable skin for “dirty” tasks in nuclear/chemical waste site applications; radiation-hardened skin for nuclear reactor and space applications; and skins that can smell, taste, or react to ambient light. The ability to measure distance to objects would be a great advantage for enabling dexterous motion of the machine equipped with the skin.

For self-diagnosis and reliability, “self-sensing” ability of the skin is highly desirable; this may include sensing of contamination, dust, chemical substances, temperature, radiation on its surface, as also detection of failure of individual skin sensors and an ability to work around failed areas.

C. Signal/Data Processing

To produce continuous motion, the sampling rates of today's typical computer-controlled moving machines should be in the range of 30–50 Hz. Taking 50 Hz as an example, within the available 20 ms sampling period all skin sensors must be polled, information from those sensors that sense objects passed to the machine control and analysed, and motion commands for the next step sent to the drive motors and executed. With possibly millions of sensors per 1 m^2 of the machine's surface, this requires a very high data bandwidth and sophisticated data processing algorithms.

Large numbers of discrete sensors on the sensitive skin make it advantageous to use lower level data processing locally at each sensor. This can include analog-to-digital processing, sensor calibration, individual sensor based distance measurements, etc., and calls for highly parallel processing and efficient software architectures.

IV. APPLICATIONS

1) **Use of Sensitive Skin in Bioengineering**

There is an intriguing possibility of combining this artificial skin and natural living skin, to help people with lacking or diminished sensing abilities, or in prosthetic devices, or in augmenting human sensing via wearable clothing, such as for military personnel.

2)**Man–Machine Systems**

Human and machine intelligence could be merged in real-time motion planning. Envision, for example, a pilot trying to keep his helicopter hovering low above the ground to collect samples from the rain forest without colliding with the underbrush. Besides informing the pilot of any undesirable contacts with plants below, data from the sensitive skin-covered helicopter underbody can be directly used for automatic control of the hovering height to avoid collision.

3) **Environmental Sensitive Skin**

Machines that by virtue of their size, power, and operation of their moving parts can present danger to the surrounding objects or be damaged by them will be able to operate safely in their environment when equipped with the sensitive skin. For example, with the help of the sensitive skin covering its body, a semi-autonomous machine helper in a senior citizen's house or a robot probe in a deep space experiment will be carrying out its function without jeopardizing its own safety and that of the surrounding objects.

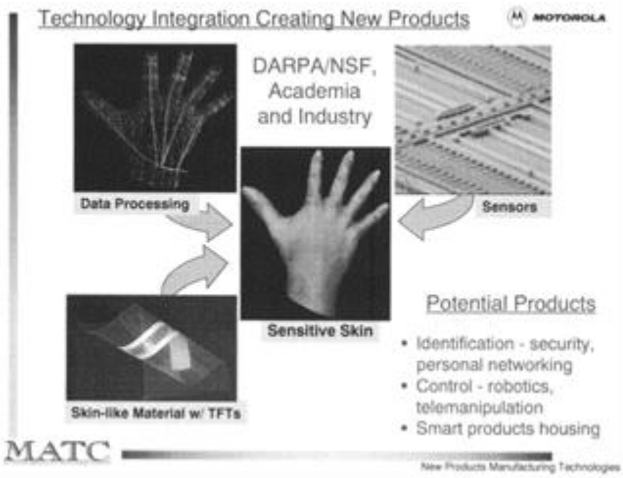

Fig.3 Potential applications of sensitive skin

V. REMARKS

A. Advantages

1) wIt can work in an unstructured environment.
2) RReduction in weight and thickness of equipments.
3) It can be conformed to arbitrary shapes. Can be rolled, bent , stretched.
4) Environment friendly technology sensitive skin will contribute in a dramatic way to the reversal of the

well-known negative impact of machines on our environment.

B. Disadvantages

1) IProperties of fusion may vary when components fail or are repaired.
2) Difficulty of acceptance. We are psychologically unprepared for automatic moving machines operating in our midst.

Fig.4 Sensitive skin module: 8x8 = 64 infrared sensor pairs (LED's and detectors); the distance between neighbouring pairs is 25 mm

VI. CONCLUSION

Sensitive skin is a large array of sensors embedded in a flexible, stretchable, and/or foldable substrate that might cover the surface of a moving machine. By endowing these machines with an ability to sense their surroundings, sensitive skin will make it possible to have unsupervised machinery in unstructured, unpredictable surroundings. Sensitive skin will make the machines "cautious" and thus friendly to their environment. With these properties, sensitive skin will revolutionize important areas of service industry, make crucial contributions to human prosthetics, and augment human sensing when fashioned into clothing. Being transducers that produce and process information, sensitive skin devices will be generating and processing data flows in real time on a massive scale, which will lead to yet another leap in the information revolution. Sensitive skin presents a new paradigm in sensing and control. It is an enabling technology with far reaching applications, from medicine and biology to industry and defence

VII. REFRENCES

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