Tactile Sensing And Analogic Algorithms
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Forces and torques on the fingertips

In this dissertation, a bio-inspired, proactive-adaptive tactile system and analogical algorithms were presented. The sensing, processing, actuating systems are strongly coupled, and they work together in order to realize an intelligent, closed-loop control of the autonomous robotic arm. I propose an efficient and fast method to detect and identify the slipping and twisting motion of the touching objects. This kind of action cannot be detected with sensors sensing only the normal (perpendicular) component of the forces acting between the surfaces. In this experimental setup the signal processing unit is a 64*64 CNN-UM analog VLSI chip; the sensing elements are Si-based tactile sensors with 500x500 μm2 taxel size. The size of the array is 2*2 taxels. Each taxel is of four piezorezisitive elements. The sensing elements are mounted on a two-fingered robot hand. Multiple 2*2 sensor elements are connected to the system. The actuator is controlled in closed loop. An integrated sensing-processing-actuating system has been developed. The analogic algorithm detects the typical events.

My work was motivated by the perception how important it is to comprehend and know the rising forces between contacting surfaces. In different areas of science (in geology for earthquake prediction, in robotics, automation etc.) and industry (motor-car-, aeronautical-, construction industry), it is essential to be able to read and process the above 3D pressure fields.

As a practical example, a method to detect the optimal grasping force has been presented. The method has proved to be robust in practice. The maximum readout speed is 10 ms for the 32 channels, this means 100 frames/sec for the two 2*2 arrays. The running time of the analogic algorithm is 7-8 ms.

A method to detect and identify the slipping and twisting forces acting on the contacting surfaces of large objects is presented as well. The overall pressure map is decomposed in three orthogonal pressure maps, all of them being processed by the topographic processing unit.

Textile quality control

The main interest is the problem of product inspection after fabric manufacturing, before final assembly.

A method to detect faults on textile has been presented. It is used as a part of a whole inspection system for quality control in textile industry. The method has proved to be robust in practice, working perfectly when applied to textiles with different patterns, complexities and colors. The real-time requirements of the task have been adequately met. The operations carried out here are very fast, of the order of a 10 to 20 processed frames per second. It is important to mention that during a cycle there is only one download and one upload between the ACE4K and DSP. All the morphologic operations are done on the CNN chip. The post processing steps, like pixel counting and logical decision are done on the DSP.

The average running time of the analogic algorithm is 2-3ms. The largest tactile sensor array is 50mm*50mm. The width of the sensor multiplied by the running time will result the average speed of the fabric: up to 5 m per second. The sensory array inspects the adjoining images sequentially if the width of inspected surface is larger than the width of the sensor array. The average speed is decreasing proportionally with the ratio of the inspected area and sensory array.

Increasing the area of the sensor array the number of the sensor points will increase quadratic, but the running time of the algorithm will increase only linearly.

	Bump	Hole	Break
D (%)	93	85	91
M (%)	7	15	9
FA (%)	5	8	3

Table 1 The algorithm' overall detection (D), misdetection (M) and false alarm (FA) rates