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Overview Of Sensors For Robotics

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Abstract*The article presents a survey of sensors relevant for robot and their sensing principles. One of the features of robot intelligence is to deal robustly with uncertainties. This is only possible when the robot is equipped with sensors; e.g., contact sensors, force sensors, distance sensors, cameras, encoders, gyroscopes. There are many applications, from different sectors that could profit from this type of technology: autonomous mobile platforms for materials handling in industry, warehouses, hospitals, etc.; forestry cutting and undergrowth management equipment; autonomous fire-fighting machines; mining machinery; advanced electrical wheel chairs; autonomous cleaning machines; security and surveillance robots. Advanced sensor systems which are now emerging in different activities from the health care services to the transportation sector and domestic services, will significantly increase the capabilities of autonomous vehicles and will enlarge their application potential.*

1. Introduction

An android or a humanoid is a robot that looks and behaves like a human, and many of us think of robots in that way.However, a typical robot does not look human like and completes its tasks by following a set of specific instructions that tell it what and how the job is to be done.Robots range from simple industrial robots that perform a single task, such as spot welding on an assembly line, to complex machinery capable of making many decisions and carrying out a range of tasks including driving trains.

Humans are systems that work within narrow ranges of temperature and pressure and need constant supplies of energy and raw materials to function.For example,the robot temperature system, according to the setting of temperature sensors, is able to work within a much larger range of temperature and pressure[1]. It also needs constant supplies of energy.In the robot system, the data will need to be converted from analogue to digital data and back to analogue data as it is processed and output.

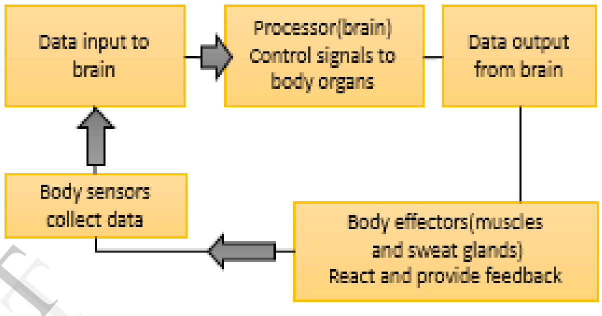

Fig1: Similarities between human and robot system

Sensor constitute robot's window to the environment. A robot needs to sense to be an active participant in the environment. Each sensor is based on a transduction principle conversion of energy from one form to another. Sensors measure a physical quantity, they do not provide state.

2. Classification of sensors

a) Proprioceptive ("sense of self", internal state):-Measures values internally to the system (robot), e.g. battery level, wheel position, joint angle, etc.

b) Exteroceptive (external state): Observations of robot environment, objects in it.

c) Passive sensors
Energy coming for the environment.

d) Active sensors
- Emit their proper energy and measure the reaction
- Better performance, but some influence on environmentsince the "action" capability is physically interacting with the environment, two

types of sensors have to be used in any robotic system

- "proprioceptors" for the measurement of the robot's (internal) parameters;
- "Exteroceptors" for the measurement of its environmental (external, from the robot point of view) parameters[3][1].

a) Proprioceptors

Proprioceptors are sensors measuring both kinematic and dynamicparameters of the robot. Based on these measurements the control systemactivates the actuators to exert torques so that the articulated mechanicalstructure performs the desired motion.The usual kinematics parameters are the joint positions, velocities, andaccelerations. Dynamic parameters as forces, torques and inertia are alsoimportant to monitor for the proper control of the robotic manipulators.

The most common joint (rotary) position transducers are: potentiometers,synchros and resolvers, encoders, RVDT (rotary variable differential transformer)and INDUCTOSYN. The most accurate transducers are INDUCTOSYNs (+ 1 arcsecond), followed by synchros and resolvers and encoders, with potentiometers as the least accurate.

When mounteddirectly on the joint, position sensors allow feedback to the controller with thejoint backlash and drive train compliance parameters.Angular velocity is measured (when not calculated by differentiating jointpositions) by tachometer transducers. Strain gages mounted on the manipulator's links are sometimes used to estimatethe flexibility of the robot's mechanical structure. Strain gages mounted onspecially profiled (square, cruciform beam or radial beam) shafts are also used tomeasure the joint shaft torques [12].

b) Exteroceptors

Exteroceptors are sensors that measure the positional or force-type interaction ofthe robot with its environment.

Exteroceptors can be classified according to their range as follows:

- contact sensors
- Proximity ("near to") sensors
- "far away" sensors

1. Contact Sensors

Contact sensors are used to detect the positive contact between two matingparts and/or to measure the interaction forces and torques which appear whilethe robot manipulator conducts part mating operations. Another type of contactsensors are the tactile sensors which measure a multitude of parameters of the touched object surface[13].

Force/Torque Sensors

The interaction forces and torques which appear, during mechanical assemblyoperations, at the robot hand level can be measured by sensors mounted on thejoints or on the manipulator wrist. A wrist force/torque has a radial three or four beam mechanical structure. Twostrain gages are mounted on each deflection beam. Using a differential wiring ofthe strain gages, the four -beam sensor produces eight signals proportional withthe force components normal to the gage planes. Using a 6-by-8 "resolved forcematrix", the eight measured signals are converted to a 6-axis force/torque vector.

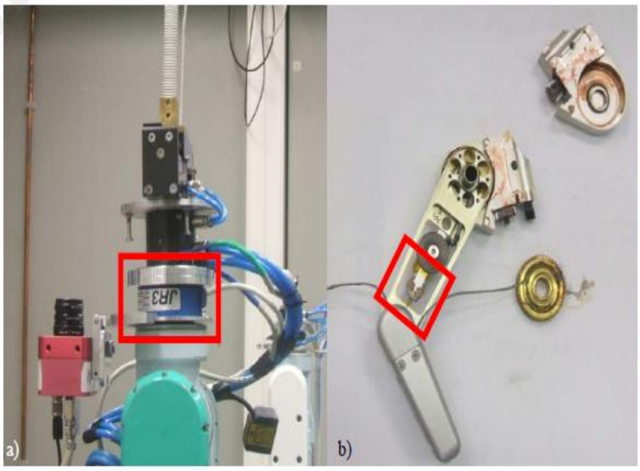

Fig.2 :(a) six axis force/torque sensor placed at the robot wrist. (b) Built-in strain gauge in a Barrett hand finger.

Tactile Sensing

Tactile sensing is defined as the continuous sensing of variable contact forcesover an area within which there is a spatial resolution. Tactile sensing is morecomplex than touch sensing which usually is a simple vectorial force/torquemeasurement at a single point. Tactile sensors mounted on the fingers of thehand allow the robot to measure contact force profile and slippage, or to grope and identify object shape [7].Table 1 gives us the general classification of tactile sensors.

Sensor Types	Technologies	Physical Properties	Robot Configuration
Pressure sensing arrays	-capacitive -Piezoresistive -Optical	Static (normal pressure)	Extrinsic
Skin deflection sensors	-Conductive -Piezoresistive strain gauges -optical	Static (deformation)	
Dynamic tactile sensors	-Piezoresistive transduces accelerometers -Piezoresistive strain gauges	Dynamic (vibration stress)	
Fingertip Force/torque sensors	- Piezoresistive strain gauges	Static (force/torque)	Intrinsic

Table 1: Classification of Tactile sensors

2. Proximity Sensors

Proximity sensors detect objects which are near but without touching them [6].These sensors are used for near-field (object approaching or avoidance) roboticoperations. Proximity sensors are classified according to their operatingprinciple; inductive, hall effect, capacitive, ultrasonic and optical.

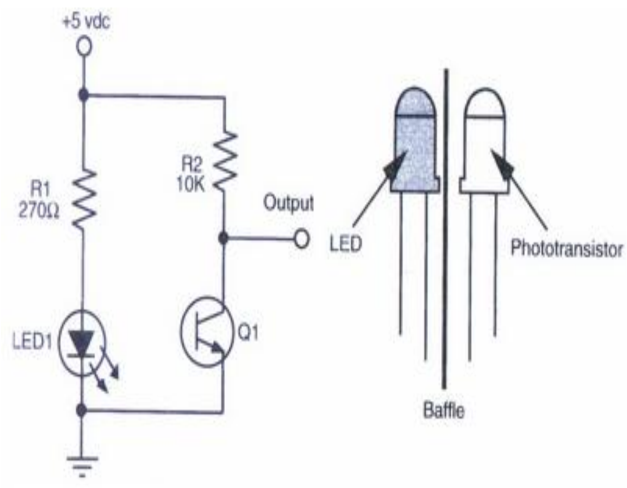

Fig.3: Proximity sensors

3. "Far Away" Sensing

Two types of "far away" sensors are used in robotics: range sensors and vision.

Range Sensing

Range sensors measure the distance to objects in their operation area. They areused for robot navigation, obstacle avoidance or to recover the third dimension for monocular vision [8]. Range sensors are based on one of the two principles:Time-of-flight and triangulation.

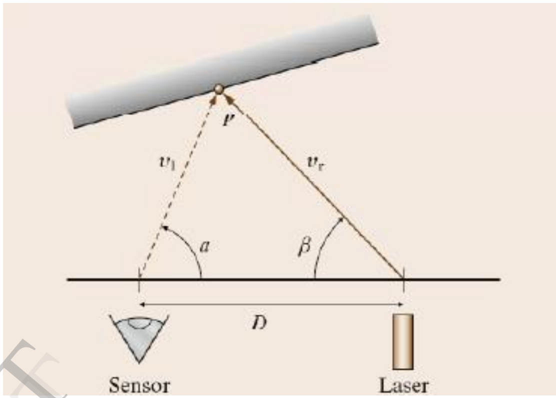

Fig.4: Triangulation sensors

Vision

Robot vision is a complex sensing process. It involves extracting, characterizingand interpreting information from images in order to identify or describe objects in environment [9]. A vision sensor (camera) converts the visual information to electrical signalswhich are then sampled and quantized by a special computer interface electronics yielding a digital image [2] [5].

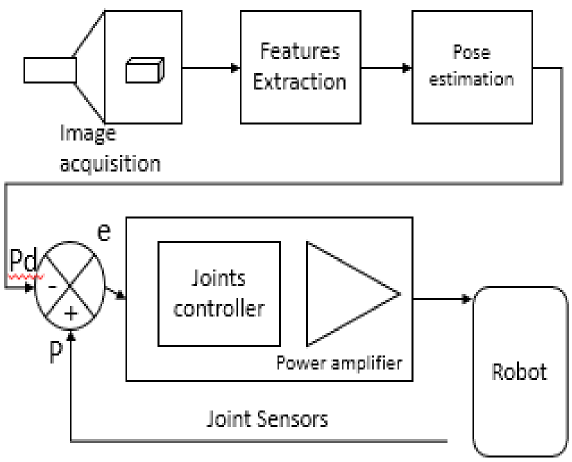

Fig .5: Visual sensing in Robotics

Thepotential range of robotic applications requires different types of sensors to perform different kinds ofsensingtasks. Specialized devices have been developed to meet various sensing needs such as orientation,displacement, velocity, acceleration and force. Robots must also sense the characteristics of the tools andmaterials they work with. Though currently available sensors rely on different physical properties for theiroperation, they may be classified into two general types: contacting and non-contacting [4] [10].

Contact, or Tactile, Sensors

- Touch and ForceSensing
- Proximity or Displacement Sensing
- Slip Sensing

Noncontact Sensors

- Visual and Optical Sensors
- Magnetic and Inductive Sensors
- Capacitive Sensors
- Resistive Sensing
- Ultrasound and Sonar Sensors
- Air pressure Sensors

3. Technology trends in sensors

Depending on applications, sensors are used to satisfy four main functions within a system:

- monitoring &control: in order to increase the performances and regulate the system
- Security&warning: in order to increase the safety of the system and anticipate default
- Diagnosis&analysis: in order to understand the system and improve
- Interface&navigation: in order to operate the system and increase functionalities

The dynamic development of thin film integration technologies (ICs, MEMS, etc.) is supporting this trend by allowing new integrated solutions along with sharp potential price decrease[11]

- It is in a position to modify profoundly the technological landscape of the sensor industry, still dominated by mature solutions
- And introduce new products segments (e.g. bio-sensors, spectrometers)

There are 212 sensors manufacturers have been integrated into the panel analysis during the course of the survey

• European companies represent 78% of the panel
• Out of the 212 sensors manufacturers, 183 have a local office in France
• Out of the 183, 113 either have a production or development site in France
• In comparison, the German sensor industry is composed of 420 members (including 70 R&D institutes)

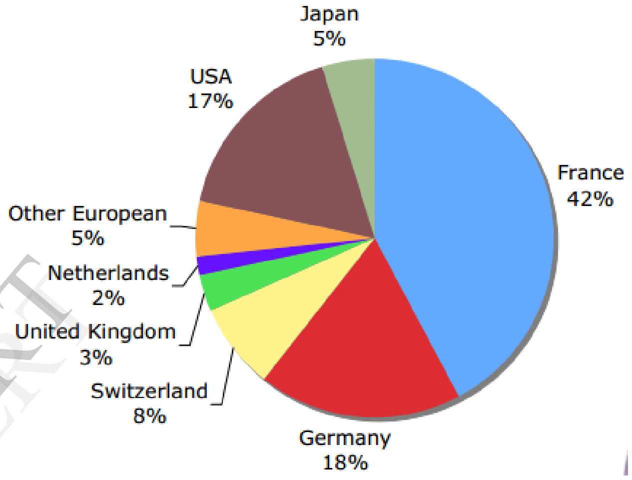

Fig.6:Worldwide sensor manufacures

6. Conclusions

Recent developments in sensor systems are providing the availability of devices with increasing performances, lower cost and smaller size. Micro-sensor technology, implemented in silicon has the ultimate potential to achieve integrated sensor systems combining absolute sensing with high dynamic performance in a miniature package, at a moderate cost.

The robotic controllers which process and analyze this sensory information are usually based on three types of sensors (visual, force/torque and tactile) which identify the most widespread robotic control strategies: visual servoing control, force control and tactile control.

This paper presents a detailed review on the control strategies developed by researchers which are used to control the movements of robotic systems depending on the information

registered by sensors. As vision, force and tactile sensors are the most commonly used sensors to analyze how robots interact with the environment.
This in-depth study permit us to develop an analysis of current research on robotic sensory control and an estimation of future research lines which will be based on it.

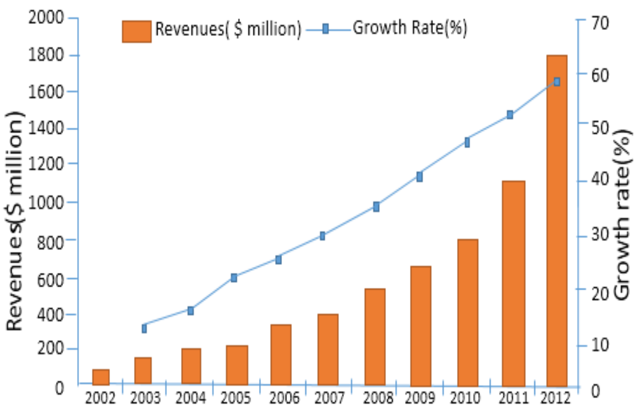

Fig.7: Sensors Revenue forecast (world2002- 2012)

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