Executive Summary

Scope and Methodology

Research Scope

The research service titled 'Developments in Sensor Fusion' focuses on advances in sensor fusion technologies and features emerging application trends. In-depth views of what drives this industry along with the impediments that need to be overcome are also assessed.

Sensor fusion is the combining of sensory data (usually from seemingly unrelated sensors) to provide/extrapolate information that is either more accurate or complete or dependable than that which would be acquired from the individual sensors. Sensor fusion can be broadly classified into data fusion, package fusion, and functional integration. Though each of the above methodologies is significantly different, they are grouped under the umbrella of sensor fusion simply because they involve multiple sensor/interface optimization in order to provide the best results for one or more applications.

The research service covers technological developments taking place around the world in academic and research institutions in the fields of automotive, defense, security, and healthcare. The research service includes an introduction to sensor fusion, its types and techniques. Next an analysis of opportunities in applications sectors is provided with information on where sensor fusion can be adopted and how its adoption is affected. The research service then analyses the technology drivers and challenges that spurn or affect adoption. Trends are also discussed in this section with roadmaps for different application sectors.

The research service also consists of a list of key industry participants as well as academic institutions along with the contact details in addition to data concerning general information on application sectors of wireless sensor networks (WSNs) from Frost & Sullivan's decision support database. A comprehensive list of patents, published as well as pending, is also contained in the research service. A technology roadmap that predicts how this technology will fare in the future has been put together based on information collated from key players in the industry.

Research Methodology

To provide a thorough analysis of each topic, *Technical Insights'* analysts perform a review of patents to become familiar with the major developers and commercial players and their processes. Building on the patent search, the analysts review abstracts to identify key scientific and technical papers that provide insights into key industry participants and the technical processes on which they work.

The analysts then create a detailed questionnaire with content created to address the research objectives of the study, which functions as a guide during the interview process. While the analysts use structured questionnaires to guarantee coverage of all the desired issues, they also conduct interviews in a conversational style. This approach results in a more thorough exchange of views with the respondents, and offers greater insight into the relevant issues than more structured interviews may provide.

The analysts conduct primary research with key industry participants and technology developers to obtain the required content. Interviews are completed with sources located throughout the world, in universities, national laboratories, governmental and regulatory bodies, trade associations, and end-user companies, among other key organizations. Our analysts contact the major commercial players to find out about the advantages and disadvantages of processes and the drivers and challenges behind technologies and applications. Our analysts talk to the principal developers, researchers, engineers, business developers, analysts, strategic planners, and marketing experts, among other professionals.

The project management and research team reviews and analyzes the research data that are gathered and adds its recommendations to the draft of the final study. Having conducted both published studies and custom proprietary research covering many types of new and emerging technology activities as well as worldwide industry analysis, the management and research team adds its perspective and experience to provide an accurate, timely analysis. The analysts then prepare written final research services for each project - featuring major innovations, key trends, and analysis on the technology sector of focus.

Research Findings

Sensor Fusion--Introduction

Sensor fusion exists in virtually all living organisms in their response and interactions with the environment. The combination of sensory inputs of sight, smell, sound, touch, and so on help achieve improved interactions. This theory of fusing information from various sources to effect action is the goal of sensor fusion. The end result is that the action or decision based on the combination of information from multiple sources is much better than if these sources where acting separately.

The Need for Sensor Fusion

A system that does not employ sensor fusion may need to manage with a lot of different sensor types. The resulting data could be both unclear and incomplete.

Physical sensor measurements can suffer from factors such as:

- **Sensor failure or loss--**The loss of a sensor can cause a misrepresentation or faulty observation of the parameter under question.

- **Restricted spatial coverage--**A single sensor is usually capable of covering only a restricted spatial area. However, when a combination of sensors is present that encompass an entire region, various parameters of the region can be detected.

- **Restricted temporal coverage--**A limitation in the frequency in obtaining measurements occurs when an independent sensor is used. However with data from multiple sensing systems, continuous measurement becomes possible.

Key Findings

The technology termed as sensor fusion refers to a combination of sensor data from different and disparate sources with the aim of providing a more meaningful and relevant set of information. Situation awareness is what sensor fusion offers. This technology has been around for a while now, with advances taking place rapidly in conjunction with the developments in the sensors industry. With new sensing capabilities being rolled out on a regular basis, the idea of combining such functionalities is on everyone's mind.

Some of the major applications of sensor fusion are:

- Aerospace and Defense

- Automotive

- Security and Identification

- Healthcare

The security related applications that implement sensor fusion techniques to develop more sophisticated and fool proof systems are currently on the rise and will continue to flourish in the future. This can be attributed to the increased urgency to have secure and reliable surveillance systems. With terrorist activities becoming more

frequent and unpredictable, the need to increase the capabilities of existing security systems will prove to be advantageous for the adoption of sensor fusion. This technology has also been implemented in designing tracking and monitoring systems such as coastal monitoring, border security, and air patrol to name a few. Integration of such techniques with biometrics to facilitate more rigid access control systems will be seen in the future. US based VIASPACE Security Inc., has developed the Area Intrusion Monitoring System (AIMS) Fast-Scan radar with port, border and base protection in mind. Along similar lines, the Swedish company Saab has developed a multi target tracking system called the Track Data Fusion Engine (TDFE) to serve both the military as well as civilian command and control centers worldwide.

Also addressing the need to beef up national security, the aerospace and defense industry is turning to data fusion techniques to enable advanced capabilities for applications such as missiles, aircraft, unmanned vehicles, and so on. Some of the key players in the aerospace and defense industry that offer sensor fusion based solutions are the American companies Boeing and Raytheon Systems Co. Recently HCL Technologies, a subsidiary of HCL Enterprise announced that it has developed a proprietary technology incorporating computer based vision and image processing solutions for the aerospace and defense industries. Some of the applications being targeted include aerial image surveillance, multi-sensor fusion, automatic fuselage vision inspection and satellite image processing. The recent air strikes performed by the Israeli Air Force on the Gaza strip employed the Lockheed Martin F-16s that were equipped with electro-optical, laser and global positioning system (GPS) guidance. Healthcare applications namely robots for hospitals, assisted living are incorporating fusion of data from multiple sources. With a probable large scale adoption taking place within the next decade, sensor fusion could be implemented in more critical applications such as medical imaging for noninvasive surgical procedures. GeckoSystems' CareBot mobile service robot is capable of functioning in crowded airports, hospitals, malls and so on for tracking applications. Intel is conducting extensive research with the aim of realizing precision contextual awareness with the help of a system that can detect a user's situation or context.

The automotive industry has been the earliest adopter of fusion and integration techniques. With certain safety norms and regulations to be adhered to, carmakers have been taking advantage of the special features of data integration to develop active and passive safety systems for the cars. Apart from features such as adaptive cruise control, advanced driver assisted systems, electronic stability control, collision detection, parking systems, and so on, sensor fusion can also be employ to accentuate comfort features in cars. This, however, is generally seen to be integrated with the high-end models of cars. Some of the examples of the adoption of sensor fusion in the automotive industry include the Universal Medium Range Radar (UMMR) platform developed by the German company Smart Microwave Sensors GmbH; the electronically scanned radar (ESR) offered by Delphi; and the forward collision warning (FCW) system developed by US based TRW Automotive and many more.

Being driven by factors such as cost, improved performance, component sharing, increased reliability, robustness, and an extension of coverage, this technology will experience a revolution in the aforementioned industries apart from making headway across different verticals as well. However, as is the case with any developing technology, certain hurdles will have to be overcome for sensor fusion to sail smoothly to different

application shores. Integration complexity and nonstandardization need to be addressed in order to take advantage of the unlimited capabilities of sensor fusion.

Sensor fusion has been widely adopted for various application verticals and will continue to be the same in the future as well. However, there will be certain factors affecting the adoption rate in the near future specially with regard to the automotive industry. With the global recession throwing the automotive industry into a complete turmoil, car makers are looking out for cost cutting measures and might start with cutting down on their research and development (R&D) expenses thereby bringing technological advances in this field to a standstill until the dark cloud of economic meltdown passes over.

DEVELOPMENTS IN SENSOR FUSION

D17C

www.frost.com

Developments in Sensor Fusion

Technical Insights
Frost & Sullivan
7550 West Interstate 10, Suite 400
San Antonio, TX 78229, USA

Tel: 210-348-1000
Fax: 210-348-1003

www.frost.com or
www.technical-insights.frost.com

CareBot Mobile Service Robot

Sensor fusion has increasingly formed an important aspect of robotics, especially in mobile service robot (MSR) applications, owing to the robots need for situational awareness. GeckoSystems that offers MSR solutions has developed a proprietary sensor fusion technology for robots that function in crowded environments such as airports, shopping malls, hospitals, and so on. The company's GeckoOrient software enables the merging of sensor inputs from odometry, a solid state compass and accelerometer-based gyroscopes (IMUs - inertial measurement unit). The data is then fused to provide an advanced level of orientation during processes such as patrolling, tracking a target, or running errands. The GeckoNav software fuses IR range finders and sonar while the GeckoTrak fuses passive IR, sonar, and machine vision.

The company recently announced a prototype called the CareBot MSR 3.8 for the assisted living sector following a decade of developments on the personal care robot. The CareBot can look after the elderly or little kids, patrol the home, and run errands for 8 to 14 hours continuously without recharging and comes integrated with features such as Web-based video conferencing. The types of sensors that contribute to the CareBot's enhanced situational awareness include 250 degree- range scanning IR sensors for frontal distances up to 5 ft., along with 8 fixed IR range finders that track within 5 ft. of a radius. The CareBot uses a 25 degree scanning IR detector to find warm bodies or people up to 15 feet. It also uses and ultrasonic range finder to measure the frontal distance from an object within 30 ft. among other sensors. The CareBot's exceptional situational awareness is brought on by the varying levels of senor fusion integrated into its architecture. This includes a combination of internal sensory data, along with information fused from the GeckoMC (Motor Controller), GeckoCSA (compounded sensor array) as well as GeckoOrient. These functionalities enable automatic navigation and maneuverability in loosely crowded areas.

While GeckoTrak helps follow a patient or elderly one room to another, GeckoChat advises the patient on the appropriate time for medications or can reminds a person on when their favorite television show go on air. This assistive technology helps caregivers teach the CareBot about what to say, and when. The system can be programmed verbally or through a desktop application and can also design a unique personality for the CareBot. The user can choose from several tones ranging from gentle to firm, from timid to teasing. On choosing specific words and phrases, the CareBot can become a personalized personal care home robot that blends into the family.

Other application of the company's mobile service robots include healthcare wherein the robot can function as a nurse's aide to assist doctors and paramedics. It can be equipped with a built in blood pressure monitor, pulse monitor, or oxygen monitor. It can also be used in hospitals, especially in the nighttime when the hospitals are understaffed to perform basic functions such as carrying supplies for intravenous therapy or blood, bandages, or defibrillators. It can also be used to run errands such as taking bed pans to a particular patient and freeing hospital staff to attend to actual emergencies. Other applications that GeckoSystems cater to include home security, professional healthcare in hospitals, nursing, assisted living and rural clinics (telemedicine), in

government systems for local, state and federal homeland security, international military and security, and mine clearing. The robots can also be used in commercial security of business property and mass transportation terminal security.