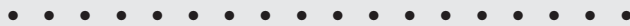


## Editorial: Integration of Visual and Inertial Sensors



This two-part special issue of the *Journal of Robotic Systems* is devoted to the topic of "Integration of Visual and Inertial Sensors" which was the title and topic of a workshop—called in short "InerVis 2003"—preceding the International Conference on Advanced Robotics (ICAR) in Coimbra, Portugal, on 29 June 2003. The topic highlighted by this workshop has received increased recognition and importance recently due to its natural connection to real life robotic systems. Ten reviewed and well-selected papers were invited to and presented at this workshop. From these, nine papers—after some reworking—constitute the content of this special issue.

The topic of this special issue in robotics has strong biological motivation. We know that the inner ear vestibular system in humans and animals provides inertial information for a number of motion connected activities like orientation, navigation, control of body posture, and equilibrium. Moreover, the vestibular sensor system is also essential for many visual tasks and head stabilization, and supports the execution of visual movements like gaze holding and tracking. Neural interactions of human vision and vestibular system appear at an early processing stage, as pointed out in the first paper entitled "Inertial Sensed Ego-motion for 3D Vision." This paper offers a framework for the combination of visual and inertial sensing modalities, and also underlines the fact that modern micromechatronics produced single chip inertial systems, enabling the practical integration of video cameras and inertial sensors leading to a wide range of application developments. The paper shows and discusses results of stereo depth map alignment using the vertical reference from inertial sensors.

The second paper, "Principles of Fusion of Inertial Navigation and Dynamic Vision," is first focused

at the validation of separate estimates obtained from inertial and vision sensor modalities before their use in combined algorithm. This is followed by a detailed discussion of principles of data fusion and by an evaluation of the obtainable results for indoor and outdoor navigation problems, illustrated by a simulation. The third paper, "Fusing Visual and Inertial Sensing to Recover Robot Ego-Motion," presents a new approach to enrich visual tracking of active contours with information from inertial sensors by modifying tracking strategy to include inertial data. Contour search in the new image frame becomes more robust by taking account of the contour's position in the previous frame, which then permits video data tracking at higher velocities. A framework is also presented for extending the method to track multiple contours, allowing a way to estimate the 3D pose from several tracked contours.

The fourth and final paper in Part 1 (issue 21.1), "Omnidirectional Vision and Inertial Clues for Robot Navigation," presents the combination of visual clues with inertial sensor information for reliable detection of navigation direction for a mobile robot and the independent motion which may be present in the visual scene. The paper discusses the intrinsic features of the omnidirectional motion fields for motion detection, and introduces methods for ego- and independent motion detection using the omnidirectional optical flow fields and gyroscope, and gives examples. The issue continues with the fifth paper in Part Two (issue 21.2), "An Inertial and Visual Sensing System for a Small Helicopter," which presents the design and architecture of a low-cost and light-weight vision and inertial sensing system which is used for real-time control of a small helicopter. The paper discusses the resolution and dynamic range of the motion sensing system and the sensitivity of measured optical flow to

motion of the various vehicle d.o.f., and concludes that a loose coupling of the inertial and visual motion subsystems provides a robust solution to the “camera motion problem” compared to the use of vision alone.

The sixth paper, “A Flexible Software Architecture for Hybrid Tracking,” discusses a scalable class software structure for any combination of vision and inertial sensors, permitting software reusability for different tracking applications. The presented architecture strictly separates the tracking process from the context-dependent model feature selection, and inherently supports multi-sensor fusion and does not restrict the fusion algorithm to be of any distinct type. The seventh paper, “Navigation Aided Image Processing in UAV Surveillance—Preliminary Results and Design of Airborne Experimental System,” presents an image processing oriented sensor management architecture for UAV IR/EO-surveillance, and describes preliminary results of navigation aided image processing in UAV applications. The presented system consists of a gyro-stabilized gimbal with IR and CCD sensors and an integrated high-performance navigation system which combines dGPS real-time kinematics data with data from an inertial measurement unit mounted with reference to the optical sensors.

The eighth paper, “Fusion of Vision and Inertial Data for Motion and Structure Estimation,” presents a method for fusing measurements obtained from a rigid sensor rig which consists of a stereo vision system and a set of 6-d.o.f. inertial sensors to estimate ego-motion and external structures. The fusion of these two sensor signals enables more robust and stable estimates than with only one sensor. The basic idea of the presented method is to use a common state vector and a common dynamic description stored together with the time instant of estimation. For estimation extended Kalman filter equations are used which are derived together with considerations of the tuning. Simulations with real sensor data are presented. The ninth paper, “Vision Based Intelligent Wheel Chair Control; The Role of Vision and Inertial Sensing in Topological Navigation,” investigates ways to improve the performance of vision based mo-

bile robot navigation for wheel chairs by incorporating the use of inertial sensors for several reasons. First, inertial sensors can work on high frequencies compared to the slow process of image acquisition and processing. Second, in region tracking, inertial sensor information provides very good estimation of the position of the region in the next image frame. Third, position measurements from inertial sensors render the calculation of the magnitude of relative translation in visual servoing more accurate.

In summary, integration of visual and inertial sensing modalities offer advantages in two major and important application directions in robotics. First, it can lead to robust solutions for image segmentation and 3D structure recovery from images. Second, it can improve estimation of ego-motion of an autonomous system in several important cases like navigation, surveillance, and 3D human-computer interaction. The advantages of integrating the two sensing modalities in robotic applications are based on the complementary characteristics of TV camera and inertial sensors. Inertial sensors have large measurement uncertainty at slow velocities and low relative uncertainty at high velocities, while TV cameras can track features very accurately at low velocities, but with increased velocity tracking becomes less accurate because resolution must be reduced to have a larger tracking window with same pixel size, that is, to have higher tracking velocity.

Many thanks to all authors of the workshop papers for their cooperation in the preparation of this special issue. Also, sincere gratitude to the JRS journal editors for publishing the InerVis 2003 workshop papers to make the novelties and progress in the selected topics available to a broad class of readers interested in the scientific and technical aspects of robotics.

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