IPS - an autonomous navigation system for future planetary exploration missions

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Traditional landing sites for planetary rovers were characterized by relatively benign terrain characteristics (e.g., slopes, roughness), but these sites are not necessarily the most scientifically attractive places. Next generations of planetary exploration missions will feature advanced mobility concepts that focus on close-up or in situ investigations of more challenging regions, e.g., canyons, caves and other sites with difficult topography. Scientific questions linked to such sites rose already from different disciplines, be it astrobiology, geology or geochemistry. As an example, caves on Mars are thought to be unique environments that may enable analyzing habitable conditions, yet their exploration is impossible with current rover designs. Another example are compositionally interesting outcrops high on steep slopes, for example in the Valles Marineris on Mars, which cannot be accessed by wheeled vehicles. In order to explore such spots, innovative mobile robotic systems such as rovers, crawlers, copters, and planes have to be involved. Such robots will need a high degree of autonomy, since they have to move with restricted interaction with any ground station. These robotic systems will have to determine and decide on their own, where they are, where they want to go and which way they will select. This will be a revolutionary step enabling an unprecedented look at the objects of interest.

This paper introduces a sensor system for enabling robots to navigate autonomously called IPS (integrated positioning system). It is based on a multi-sensor approach, including a stereo camera and an inertial measurement unit emulating the main sensors for localization and guidance of human beings. The vision sensor detects and tracks natural features and applies a pose estimation with imaging frequency. The inertial measurement unit gathers data about angular velocities and accelerations. By integrating these values, information about rotation and translation can be estimated. Both input data are coupled closely within an error filter and result in a 6 degrees of freedom state estimation without any external reference, e.g. GNSS, pseudolites). Due to the stereo approach, depth maps can be created in real time. Based on these, risk assessment and route planning can be performed. The image data themselves can be used for additional tasks, e.g., detection, monitoring.

The navigation system IPS was developed for terrestrial applications and reached a high technology readiness level already. Dozens of measurement campaigns in different environments were performed. An indoor setup was used as test bed for validation. By now, IPS reaches a positioning accuracy of 2m/sqrt(hr).

In an outlook, the authors will describe possible mission scenarios for applying IPS as a support system for mobile robots of future planetary exploration missions.