The Aerospace GNC Laboratory at the University of Naples "Federico II"

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In the latest years, a laboratory of Guidance, Navigation, and Control (GNC) of aerospace vehicles has been set up at the Department of Space Science and Engineering "Luigi G. Napolitano" (DISIS) of the University of Naples "Federico II". It is intended to carry out both scientific research and educational activities. This has been achieved thanks to the financial support of the Italian Ministry of Education, University, and Research (MIUR), the Italian Space Agency (ASI), and Italian aerospace industries.

Given national and international interest in automatic control of unmanned aerospace platforms and smart integrated sensors, the guidance and navigation laboratory at DISIS is developing to fit advanced research trends. Besides the benefits for research activity, a relevant spin-off results for students who can gain direct experience of state-of-the-art aerospace applications. In particular, the most important currently running projects deal with the development of a star tracker for space platform attitude determination, and the fusion of GPS receiver and inertial sensor data in strapdown configuration for Unmanned Aerial Vehicles (UAVs) autonomous flight control.

The activities of the star tracker project have been addressed to two main fields: the sensor and the laboratory facilities for its validation. Both of them have concerned theoretical studies, design, performance analysis, numerical simulations, algorithm development, software implementation, design and assembly of hardware prototypes based on COTS components.

The prototype hardware model is composed by the image acquisition and processing sub-units. The first is based on commercial components: a CCD area sensor with its proximity electronics, and F/1.4 lens (fig. 1). The second one consists of an embedded pc-104 stack formed by a 233-MHz Pentium™ CPU, a frame grabber, a 32-MB solid state disk, and a power conditioning board (fig. 2).

Electronics was chosen accounting for temperature, vibration, vacuum, and harsh environment requirements for space applications. Algorithms and software routines for typical star tracker operating modes (autonomous initial acquisition, rotational velocity measurements in high-rate rotations, tracking) have been developed for the VxWorks real-time operating system in target-host architecture. This aims at producing an autonomous, mobile prototype for indoor and outdoor tests.

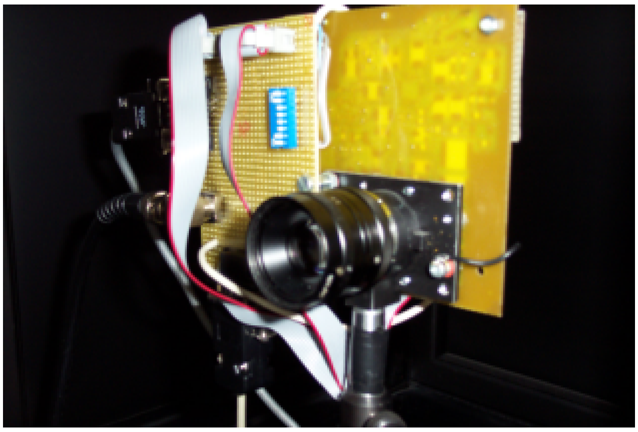


Fig. 1 - Star tracker Image Acquisition Unit

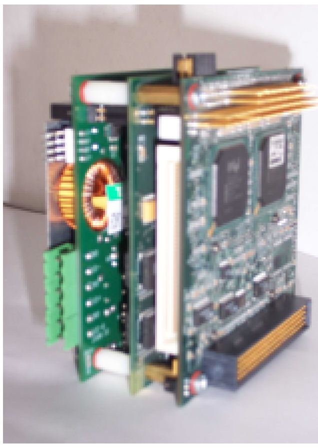
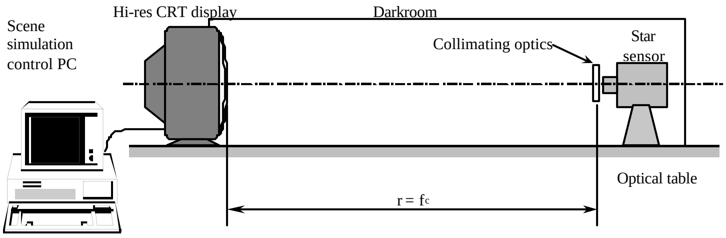


Fig. 2 - Star tracker Processing Unit

A laboratory facility for functional validation of the star tracker has been designed and set up. It is a CRT-based optical stimulator for end-to-end, full-field-of-view tests (fig. 3). The system is capable of realistic static and dynamic star field simulation, accounting for orbit and attitude of a space platform supplied as input. A considerable amount of test has been carried out, achieving validation of the instrument. In addition, it has been exploited as a case study for attitude determination educational purposes.



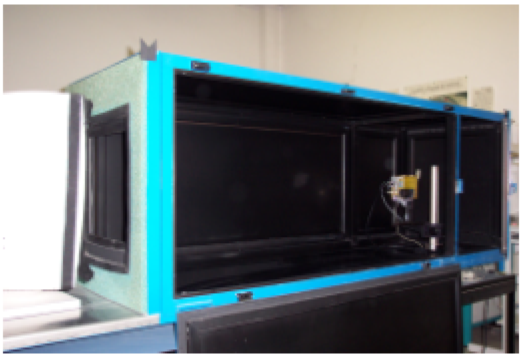


Fig. 3 – Star tracker functional validation laboratory facility

An effective tool to experiment GPS/INS strapdown integration for autonomous navigation has been realised. It is composed by an 8-channel GPS receiver and an Inertial Measurement Unit (IMU) manufactured with silicon based miniaturised sensors. They have been arranged with a mobile power unit and a notebook PC (fig. 4) for real-time testing of strapdown navigation algorithms in vehicle application (fig. 5).

Fig. 4 – GPS/INS integrated navigation tool

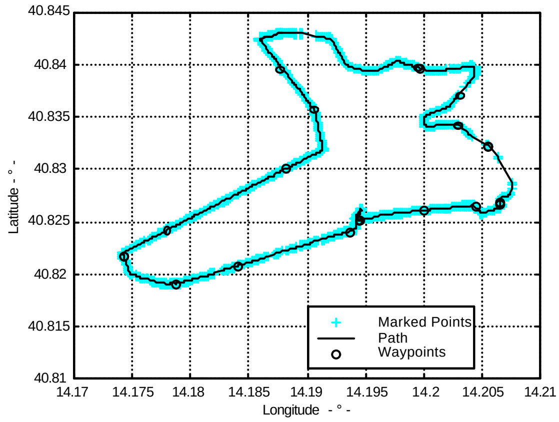


Fig. 5 – Route of an outdoor GPS navigation test

This resulted to be a valid support tool not only for research purposes, but also for demonstration to navigation course students and graduation thesis work. Presently, an aircraft model is being equipped with the system to operate flight experiments. Other devices, such as digital aerodynamic sensors, an embedded computer, a radio-modem, and a digital camera as payload, will be added to the system. The final goal is the development of a fully autonomous flight control system onboard a UAV vehicle with real-time telemetry link to ground station and remote payload operation functionality. By carrying out flight test, several educational applications will come out:

- test mission schedule planning;
- set-up and tuning of the equipment for flight test operation;
- automatic flight control logic development and implementation;
- post-flight analysis and processing of the gathered data for different applications (navigation, control, payload operation, on-board resources management).

Further developments will involve the adoption of a star tracker for INS navigation aiding. Indeed, the analysis of the best configuration of the sensor for this application is under investigation to identify modifications to the developed model for its use onboard aircraft models to support the specific INS drift compensation requirements.

The laboratory of the research team is equipped with several network-connected PCs, equipped with engineering software packages (MATLAB, AUTOCAD, LABVIEW, ORCAD circuit design and simulation tools, several programming languages compilers) and hardware devices for signal acquisition, conditioning, and analysis. In addition, the laboratory is equipped with an electromechanical bench for small components integration and testing

Several software packages have been developed by the research team for:

- simulation of satellite dynamics and control;
- simulation of airborne and spaceborne sensors functioning, in particular SAR acquisition simulation and high-accuracy radar raw data processing;
- mission simulation for Earth observation satellites (flying both microwave and electro-optical sensors);
- star tracker procedures for autonomous initial acquisition (triplet-based star catalog browsing and neural approach), tracking, angular velocity vector determination during high-rate rotations; star field scene simulation, both

static and dynamic, accounting for mission orbital and platform dynamics, to be used to test star tracker procedures.