Storage and Visualization On-The-Ground and in Near Real-Time of the Data Measured by the Optical Sensors Connected to a Flying Test Bench

Storage and visualization on-the-ground and in near real-time of the data measured by the optical sensors connected to a flying test bench

Antonio Costantino Marceddu[1,a,*], Bartolomeo Montrucchio[1,b]

[1]Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, ITALY

[a]antonio.marceddu@polito.it, [b]bartolomeo.montrucchio@polito.it

Keywords: Computer Graphics, Data Visualization, Databases, Graphical User Interfaces, Middleware, Optical Fiber Sensors, Remotely Piloted Aircraft, Wireless Communication

Abstract. Nowadays, sensors are massively used for different types of applications, ranging from the control of production processes to the continuous monitoring of systems of various kinds. Often, due to the large amount of data collected, it can be difficult to fully understand them or extract their inherent value. For this reason, the main research objective discussed in this paper regards the creation of intuitive tools for the visualization of sensor data in a human-readable way so as to facilitate their deep analysis. One of the main cases of study is linked to the PhotoNext Interdepartmental Center and regards the intuitive visualization of near real-time data coming from a flying test bench.

Introduction

The *sensor* is a device that, based on the value assumed by a given input quantity, returns an output signal dependent on it. The term *transducer* is often used interchangeably as it is frequently based on the same working principle, but they differ in their function. The sensor is normally used to control or regulate the system in which it is immersed through the measurement of a certain variable of interest, while the transducer is normally employed for direct use, the recording or measurement of the conversion made on the variation of a physical quantity into a corresponding variation of an alternative physical quantity [1].

The sensors can be differentiated according to the type of:

- Input signals, such as temperature, light, and speed.
- Output signals such as acoustic, optical, and electrical.

They are adopted in various contexts, such as saving electricity through the automatic heating and switching on of the lights based on the presence of people in a room, for emergency situations such as the actuation of automatic braking of vehicles based on the detection of obstacles, or even the control of air quality and the presence of toxic gases [2].

Throughout their entire lifetime, sensors can produce a wide amount of data. Measured variables can sometimes contain more information than is visible directly from the collected data. This information can be brought to light through special tools, which often make use of an intuitive visualization carried out through the use of graphs, tables, or others. The purpose of this paper is therefore to create useful tools for the analysis and visualization of data coming from different types of sensors.

Materials Research Proceedings 33 (2023) 277-280 https://doi.org/10.21741/9781644902677-40

Figure 1 - Logo of the PhotoNext Interdepartmental Center. Taken from [1].

Since then, the authors's attention has been posted to the following kind of sensors:

- Fiber Bragg Gratings (FBG) sensors, which are optical sensors fabricated within the core of a single-mode optical fiber through the use of patterns of intense UV laser light that can vary spatially [3].
- Camera sensors, which are commonly used to digitize images for processing, analysis, or recording purposes in cameras, camcorders, scanners, etc. [1].
- Photodiode sensors, which are used to obtain electrical energy by converting light energy [4].

Data from SCADA systems (an acronym for Supervisory Control And Data Acquisition) are also being analyzed. They are systems composed of software and hardware part for monitoring, analyzing, and controlling industrial processes and devices [5].

Research Project on Fiber Bragg Gratings Sensors

Concerning the FBG sensors, the inherent research presented in this paper is carried out in collaboration with the Interdepartmental Center of the Politecnico di Torino dedicated to the study of photonic technologies, called *PhotoNext* [6]. Fig. 1 shows the logo of the PhotoNext Interdepartmental Center. It brings together the work of five different departments:

- Department of Electronics and Telecommunications (DET).
- Department of Mechanical and Aerospace Engineering (DIMEAS).
- Department of Applied Science and Technology (DISAT).
- Department of Environment, Land and Infrastructure Engineering (DIATI).
- Department of Control and Computer Engineering (DAUIN).

Its work combines pure research with applied experimentation activities and mainly focuses on:

- Optical components and sensors for industrial applications.
- High-speed optical fiber communication systems.

The research presented in this paper and located inside the PhotoNext Interdepartmental Center is the result of a collaboration between the DIMEAS and the DAUIN. It concerns the recording and visualization in near real-time and on-the-ground of temperature and strain data coming from a flying test bench [7]. This flying test bench is composed of two interconnected parts, defined *physical system* and *software applications*. The *physical system* encompasses the device to be measured, which is the model aircraft called *Anubi* created by the Icarus student team of the Politecnico di Torino [8], and the FBG sensors needed to perform temperature and strain measurements. It also includes the *SmartScan interrogator* [9], which is the device currently used for reading the values coming from the FBG sensors, a *Raspberry Pi™ 3 Model B+* System-On-Chip (SOC) connected both to the interrogator through an Ethernet connection and to the Internet via a 4G USB dongle, and the batteries needed to power both. Fig. 2 shows the complete physical system.

Materials Research Proceedings 33 (2023) 277-280
https://doi.org/10.21741/9781644902677-40

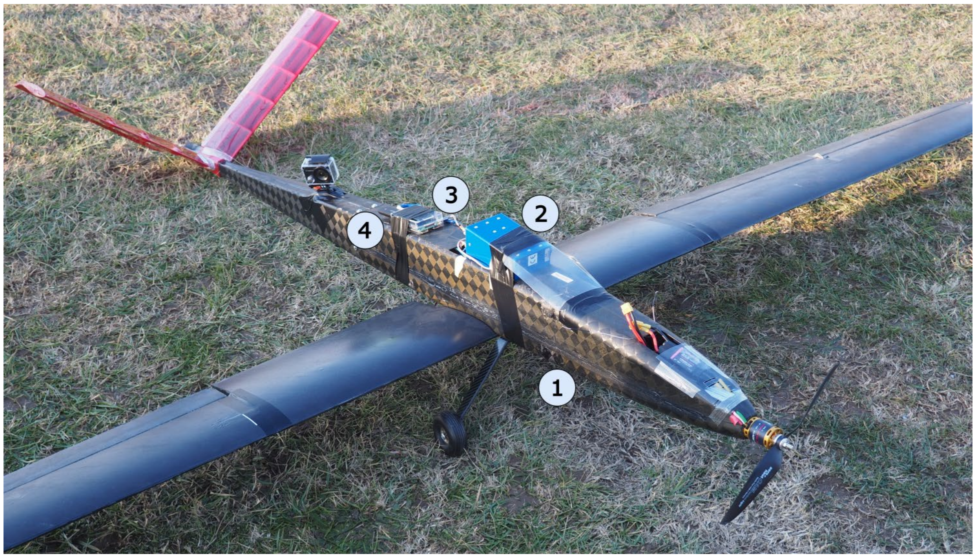

Figure 2 - The complete physical system that makes up the flying test bench. In order: (1) Anubi model aircraft made by the Icarus Student Team, (2) interrogator, (3) Raspberry Pi^{TM}, (4) 4G Internet Dongle.

The software applications oversee reading, transmitting, storing, and displaying data to the end user. Their description will follow the same order as the data flow. The first application that will be discussed is therefore the *Middleware*, an application written in C and C++ that runs on the Raspberry Pi^{TM} to get sensor data from the interrogator and send them to the *Cloud Database*. The *Cloud Database* is based on *MongoDB®* and stores sensor data and forwards them to any listening *3D Viewer* applications. Finally, the *3D Viewer* application allows the almost real-time visualization of the deformation and temperature data measured during the flight through the use of:

- A *graph visualization*, capable of providing information related to the variation of the value of the sensor with respect to their base value (delta).

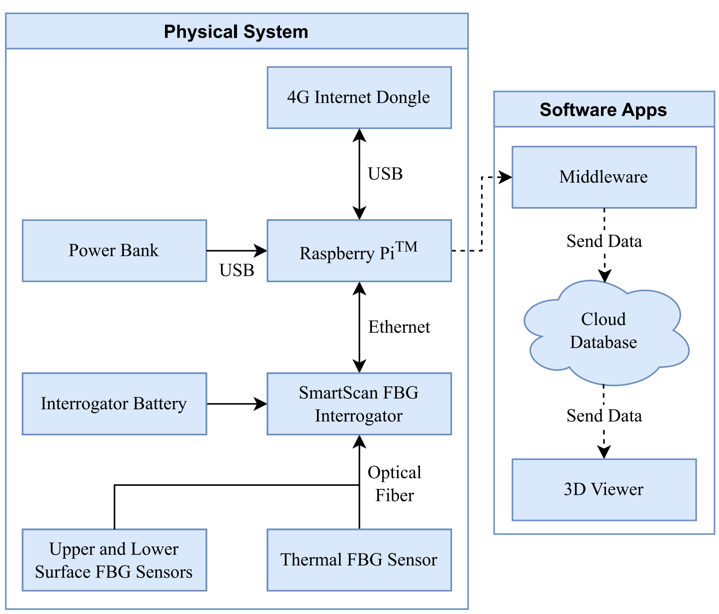

Figure 3 - A block diagram representing the flying test bench in its entirety.

- A *3D heat map visualization*, capable of providing more qualitative information than that provided by the graphic visualization since it varies the color gradation of the area in which a particular sensor is positioned based on its current value. However, an indication of the approximate physical location of the sensors in the system is also provided. This is especially useful for monitoring areas of the system under stress.

A block diagram showing the full system is represented in Fig. 2.

To validate the entire system, several tests were carried out at the Tetti Neirotti runway, located near Turin. For the interested reader, please refer to the information contained in [7].

Conclusions

This paper concerns the intuitive visualization of data measured by sensors of different types. In particular, it regards the implementation of a complete flying test bench capable of reading, transmitting, storing, and displaying the data measured in near real-time to the user on the ground. The authors of this paper are currently working on a more complete version of the Desktop version of the *3D Viewer* together with a new Augmented Reality (AR) version. They are also working on adding new sensors to enrich the measurements currently made by the flying test bench.

Funding

This work was carried out under the PhotoNext initiative at Politecnico di Torino (http://www.photonext.polito.it/).

References

[1] Treccani S.p.A., Sensore. Link: https://www.treccani.it/vocabolario/sensore/

[2] Mohd Javaid, Abid Haleem, Shanay Rab, Ravi Pratap Singh, Rajiv Suman, Sensors for daily life: A review, Sensors International, vol. 2, 2021, 100121, ISSN 2666-3511. https://doi.org/10.1016/j.sintl.2021.100121

[3] Smart Fibres Ltd., Our Technology. Link: https://www.smartfibres.com/technology

[4] Ravi Teja, What is a Photodiode? Working, V-I Characteristics, Applications, May 15, 2021. Link: https://www.electronicshub.org/photodiode-working-characteristics-applications/

[5] Scada International A/S, What is SCADA?. Link: https://scada-international.com/what-is-scada/

[6] PhotoNext, PhotoNext Official Site. Link: https://www.photonext.polito.it/it/

[7] A. C. Marceddu et al., Air-to-Ground Transmission and Near Real-Time Visualization of FBG Sensor Data via Cloud Database, IEEE Sensors Journal, vol. 23, no. 2, pp. 1613-1622, Jan. 15, 2023. https://dx.doi.org/10.1109/JSEN.2022.3227463

[8] Icarus Student Team, Icarus Student Team Official Site. Link: https://icarus.polito.it/

[9] Smart Fibres Ltd., SmartScan interrogator. Link: https://www.smartfibres.com/products/smartscan