FPGA implementation of a video-based system for GNSS reception characterization along a railway line

Fourth International Conference on Railway Technology: Research, Development and Maintenance
3-7 September 2018 | Sitges, Barcelona, Spain
Plan

Context and Goals

Presentation of the system architecture

Presentation of the embedded algorithm

Experiments and Discussion

Conclusion and Future works
Train location is of main use in railway signaling applications. Currently, sensors are installed along the lines to detect the presence of a train. However, in order to reduce the global cost of the system relying on balises – including maintenance, the use of Global Navigation Satellite Systems (GNSS) is investigated.
=> The longer term advantages of such an evolution would be to increase the frequency of the trains and to reduce the energy consumption, thanks to adapted algorithms that optimizes the speed of circulation with respect to the profile of the lines.
The EU ERSAT GGC starting project intends to work on methodologies for the GNSS reception characterization of the lines in order to evaluate opportunities of virtual balises concept and its use efficiency.
Context and Goals

Use of sky video recording system in addition to GNSS receiver

Limit the number and time of experimentation campaigns

A single train run ➔ One video-record of the masking environment ➔ Satellite visibility & states of reception vs time
Multi-sensor fusion: use of low-cost, small size and flexible platforms which is a challenge in the next generation of navigation systems.

Contribution: develop an embedded system that combines and merges different data sets around a novel architecture based on FPGA technology.

Using FPGA-based system offer designers the maximum flexibility to customize system architecture.

Co-designing software and hardware is also an option offered for parallel computation.
1- Received GNSS and HDMI data are recovered in pipeline and independently within the FPGA circuit to be treated.
2- GNSS data extraction and decoding module.
3- Synchronize received HDMI data with respect to the pulse per second (PPS) signal and GPS time.
1- Received GNSS and HDMI data are recovered in pipeline and independently within the FPGA circuit to be treated:

- A UART receiver module is developed in VHDL. Serial coming data are collected by bytes, at 54MHz, using a FSM process.

- Video data transmission (PCLK, RGB, audio, synchronization) is performed using FPGA hardware resources. Communication channels (HPD, SDA, CEC, etc) are performed via the embedded processor of the FPGA.
1- Received GNSS and HDMI data are recovered in pipeline and independently within the FPGA circuit to be treated.

2- GNSS data extraction and decoding module: Based on the Receiver Protocol Specification that describes GNSS frames contents, a processing diagram is defined to read, identify UBX frames and extract useful data.

3- Synchronize received HDMI data with respect to the pulse per second (PPS) signal and GPS time.
1- Received GNSS and HDMI data are recovered in pipeline and independently within the FPGA circuit to be treated.

2- GNSS data extraction and decoding module.

3- Synchronize received HDMI data with respect to the GPS time. At each PPS signal, a new GPS time is acquired and saved. An image acquisition delay $\Delta T$ is calculated using the FPGA clock. When a new image frame is detected, it is time-stamped with a combination of GPS time, image acquisition delay and the clock bias.
1- Received GNSS and HDMI data are recovered in pipeline and independently within the FPGA circuit to be treated.

2- GNSS data extraction and decoding module.

3- Synchronize received HDMI data with respect to the pulse per second (PPS) signal and GPS time.
Presentation of the embedded algorithm

FPGA Design Flow Diagram

Hardware Development

VHDL Design
RTL flow verification

FPGA Design Simulation

Generate the Configuration file (.sof)

Software Development

Add Altera IP cores
Point-to-point connexion
NIOS II addressing

Generate the script file (.qsys)

Generate the system information file (.sopcinfo)

Combine .sof and .elf

Configure the FPGA

Set up the Application Project and the Board Support Package (BSP)

Build and Run

Generate the programming file (.elf)
Experiments and Discussion

- **GPS Ublox M8T**
- **RS232 output**
- **Patch Antenna**
- **GPS Supply (5V)**
- **FPGA Board Stratix IV GX**
- **Board Supply (12V)**
- **HDMI-RX and HDMI-TX interfaces**
- **RS232 communication**
- **GPS Ublox M8T RS232 output**
- **HDMI output**
- **Fish-eye camera HDMI output**
- **Alimentation caméra**
- **Black Magic Recording system HDMI input/output**
- **2 x SD card (256 GB)**
Experiments and Discussion
TIMEUTC : E2 07 07 0D 0D 39 12
Epoch Timestamp : 1531490242
Image Acquisition Delay : 5B 02
Clock Bias : 3C 06 µs

\[ \text{Hex2dec} \times \text{clock} \]

\[ \text{Delay} = \text{Hex2dec} (5B 02) \times 20 \text{ ns} = 12.06 \mu \text{s} \]

\[ \text{Clock Bias} = 1596 \mu \text{s} \]
Experiments and Discussion
Experiments and Discussion

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Place Satellites on Image

Image Classification

Enhance the precision of the train position based on LOS / NLOS signals classification

Identification LOS / NLOS
Interferences?

Masking

Reflected signals?

Optimal conditions of GNSS reception

ERSAT GGC
ERTMS on SATELLITE Galileo Game Change

Classify track areas as suitable or not for locating Virtual Balises
The prototype is almost finalized: lab tool → compact and transportable system,

First experiments have been performed on July 2018 to test the system behavior under real environmental conditions,

Methodologies of data fusion and image analysis are post-processed in order to illustrate the potential of the tool,

Amelioration of the real-time recording system: image processing algorithm will be embedded on the FPGA circuit in order to calculate the train position during its running,

The tool will be used in the ERSAT GGC project: Measures and data acquisitions are planned at the beginning of 2019 on train railway lines.
Thank you for your attention

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