Fraunhofer
FOKUS

FRAUNHOFER INSTITUTE FOR OPEN COMMUNICATION SYSTEMS FOKUS

MUSE

Contakt
Samuel Pletner
Head of System Architectures
System Quality Center – SQC
Phone +49 30 3463-7490
samuel.pletner@fokus.fraunhofer.de

Fraunhofer FOKUS
Kaiserin-Augusta-Allee 31
10589 Berlin
Germany

www.fokus.fraunhofer.de/en/sqc

Spacecraft are required to operate precisely and failsafe in docking or landing maneuvers in space. In order to attain ideal positioning, a torrent of sensor data has to be processed in real-time with a high degree of reliability in an extreme environment. The energy demand of these applications on currently available space-compliant computers is so immense that certain compromises, e.g. regarding the quality of image processing, are inevitable. The potential power consumption for board computers is limited, as well. Only further improvements in the performance of satellite computers will lead to an increase in quality. In the MUSE project (Multicore architecture for sensor-based position tracking in space), Fraunhofer FOKUS is thus researching whether multicore processors are suited for analyzing sensor data and positioning spacecraft and how an adequate computer architecture should be set up.

Multi-Core Architecture

The PowerPC multicore family "QorIQ" by Freescale was chosen as the basis for the development of such a space-compliant on-board computer. The new 8-core processor P4080 can be operated with a frequency of up to 1.5 GHz and can thus theoretically achieve a peak performance of 60 GIPS (giga instructions per second). Conventional space computers like the SCS750® provide 1,8 GIPS at 800 MHz. The P4080 is built with SOI (silicon on insulator) technology which offers particularly low power dissipation and is less sensitive to radiation than CMOS technology. In addition to its great computing power and energy efficiency, it also provides the benefits of a highly integrated embedded processor. All vital functions such as memory control with error correction and multi-gigabit communication channels are already integrated on-chip.

The eight processor cores of the P4080 are not only used to maximize computing power, but also for the realization of potent mechanisms for fault tolerance.

Fault tolerance

Particular attention is paid to the development of efficient mechanisms for fault tolerance. They have to ensure that sporadic data corruption resulting from cosmic radiation is reliably detected and corrected. The complete system hardware is designed redundantly for this reason. The redundant processing nodes operate according to the worker-monitor principle: computation is conducted by only one node – the worker. The redundant node – the monitor – controls the correct operation of the worker. Should an error be detected in the worker node that cannot be corrected, operation is automatically switched over to the monitor node which continues computation as the new worker node. The robust worker-monitor-principle guarantees a high degree of availability even in case of an error. Additionally it must be ruled out with a high degree of certainty that undetected errors lead to faulty commands causing uncontrolled movements of the spacecraft. For this reason, the eight processor cores of the P4080 are not only used to maximize computing power, but also for the realization of potent mechanisms for fault tolerance. Particularly critical calculations are conducted in parallel on different processor cores to allow for a safe comparison of the validity of the results. Hardware specialists are creating a synchronization and voting unit in a radiation-tolerant FPGA component that can compare redundant computation results on the fly. The output of erroneous commands is reliably prevented through a majority decision on the redundantly conducted computations.

Efficient algorithms for sensor data processing

In addition to the control hardware, an optical position sensor is being developed in the MUSE project which could be combined with other sensors (e.g. radar or laser-based distance measurement, LIDAR) in a spacecraft. Using the position sensor, the live picture of up to three cameras can be compared with previously stored image information of the projected landing site. In a training period, a model of the landing site will be generated using existing image data (2D and digital elevation model) and FERN classifiers. During the approach, the live camera data is compared with the landing site's model using the FAST Feature detection method and the trajectory is adjusted accordingly. The procedure is safeguarded additionally by comparing the stored camera image with the live one using optical flow procedures (alterations of features of two successive images). Beyond that, a stereo image may be generated using two cameras with which the distance to as well as the condition of the landing site's surface can be determined. All algorithms are running redundantly if needed and are parallelized in such a fashion that each of the hardware's eight cores is utilized ideally.

Technology

- 8-core processor P4080
- PowerPC multicore family "QorIQ" (Freescale)
- Frequency: up to 1.5 GHz
- Peak performance: 60 GIPS (giga instructions per second)
- SOI (silicon on insulator) technology
- Multi-gigabit communication channels (6x Gbit Ethernet, 2x PCI express, 2x Rapid I/O)
- 2x Space Wire
- Flexible interface configuration through separate I/O circuit board
- Radiation-tolerant FPGA component with triply redundant logic (TMR)
- Synchronization and voting unit (TMR)
- Fast parallel image processing algorithms

Funding

The project is funded by the space agency of the German Aerospace Center (DLR) with resources from the German Federal Ministry of Economics and Technology.

making cities smart