Reconfigurable Industrial Process Monitoring using the CHROMOSOME Middleware

Stephan Sommer, Alois Knoll (Technische Universität München, Germany)
Michael Geisinger, Christian Buckl (fortiss GmbH, München, Germany)
Gerd Bauer (efm systems GmbH, Stuttgart, Germany)
Outline

1. Motivation and Idea
2. CHROMOSOME Middleware
   - Introduction
   - Architecture
   - Components
3. Multifunk Application Scenario
4. MST2012 Sensor System
5. Summary and Contribution
Project Overview

Goals of Project “Multifunk”:

- Wireless sensor network-based monitoring of industrial production processes for quality assessment
- Model-driven design tools
- Code generation
- Network self-organization

Showcases:

- Development of redundant sensor system “MST2012” for monitoring of temperature and pressure data
- Development of a generic automation line monitoring sensor network
Motivating Application Example

Tire Production:
- Certain temperature and pressure profiles have to be asserted during vulcanization
- Rough environment, industrial sensors

Goals:
- Acquisition of temperature and pressure data for later reference and quality assurance
- Optimization of heating and hence energy consumption
- Acquisition of quality assurance data should be isolated from physical process
Idea

Observation:

- Process monitoring for quality assurance...
  - Is often added or extended after installation of the automation system
  - Needs to be easy to set up and reconfigurable
  - Needs to be adaptable during runtime
  - Needs to be isolated from the production process

Idea:

- Introduce a flexible sensor network that is based on a middleware with dynamic reconfiguration during runtime
- Reliability aspects such as health monitoring need to be considered

→ CHROMOSOME Middleware
The CHROMOSOME Platform

- **Adaptive Runtime System:**
  - Execution
  - Plug & Play

- **Communication:**
  - Middleware
  - Real-time capability

- **Multi-domain and Multi-platform:**
  - Support “from 8 bit controllers to the cloud”
CHROMOSOME Architecture

Scalable Middleware Architecture:

- On resource constrained systems, the middleware is configured statically and only contains core functions
  → Suitable for small embedded controllers

- On more elaborate systems, aspects like PnP allow dynamic reconfiguration at runtime
  → Flexibility

Model-driven Tooling:

- Allows to select the appropriate implementation variant and to configure the middleware
Middleware Components

Basic Structure of a single Node:

- **Advancement components**
- **Optional core components**
- **Mandatory core components**
- **Primitive components**
- **HAL components**
- **Hardware periphery**
- **Data centric communication**
- **Function call**
- **Execution Manager**
- **Node Manager**
- **Health Monitor**
- **Advanced Components**
- **Broker**
- **Routing Table**
- **Interface Manager**
  - **UDP Plug-in**
  - **TCP Plug-in**
- **Primitive Components**
- **Resource Manager**
- **Hardware Abstraction Layer (HAL)**
  - **Communication Library**
  - **GPIO, ADC, … Drivers**
  - **Resource Abstraction**
- **Operating System / Board Support Package**
  - **Ethernet Periphery**
  - **GPIO, ADC, … Periphery**
  - **Interrupts**
Data Centric Communication

Goal:
- Make all data available to all processing units

Rationale:
- Avoid costs by unneeded redundancy

Realization:
- Decoupling of sender and receiver → Data centric communication
- Route resolution during runtime is performed by Directory, which updates local and remote Routing Tables accordingly

Concepts:
- **Topic**: Data type with assigned semantics and fixed structure (e.g., temperature, pressure)
- **Publication**: Intent to send data of a given topic
- **Subscription**: Request to receive data of a given topic
Health Monitoring

Goal:
- Increase reliability by detecting hardware and software faults as well as the absence of a node

Realization:
- Health Monitor component on every node
- Suite of hardware and software tests on every node
- Health Manager component on a dedicated node (collects information)

Concepts:
- **Periodic hardware tests:** Hardware tests that are performed at a specific interval
- **Periodic software tests:** Algorithmic tests that are performed at a specific interval
- **Node-level proof of life:** Monitor data exchange and force explicit signaling between nodes where no data is exchanged at a regular basis
Multifunk Application Scenario

Purpose:
- Experimental setup with temperature and pressure sensors before implementing the concept in the plant

Functionality:
- Logging and fusion of industrial sensor data (e.g., temperature) for product quality assessment
- Sensor life cycle management

Target Platform:
- PC with Windows, ARM

Middleware Configuration:
- Dynamic login and logoff of sensors
- *Topics*: Temperature, pressure, error, fusion data, ...
MST2012 Sensor System

Purpose:
- Industry compliant sensor system implementing the stated requirements

Basic Concept:
- Dual-channel: process control channel (industry compliant Modbus/RS485) and quality assessment channel (CHROMOSOME communication protocol)
- Health cross-check and health monitoring

Realization:
- ARM-Cortex M3 controller
- Ethernet (Modbus/TCP)

Benefits:
- Data pre-processing
- In-system drift detection of sensor and ADC
Summary and Contribution

Industrial Application Scenario:
- Thermal processes: temperature and pressure
- Redundant data acquisition for quality assurance

CHROMOSOME Middleware:
- Open source
- Data centric communication
- Portability

Redundant Sensor System:
- Small size
- Connectivity
- Simple deployment
Thank you for your attention!

Questions?

Contact:
Stephan Sommer
Robotics and Embedded Systems
Technische Universität München, Germany
sommerst@in.tum.de