Spejbl – the Biped Walking Robot

M. Peca M. Sojka Z. Hanzálek

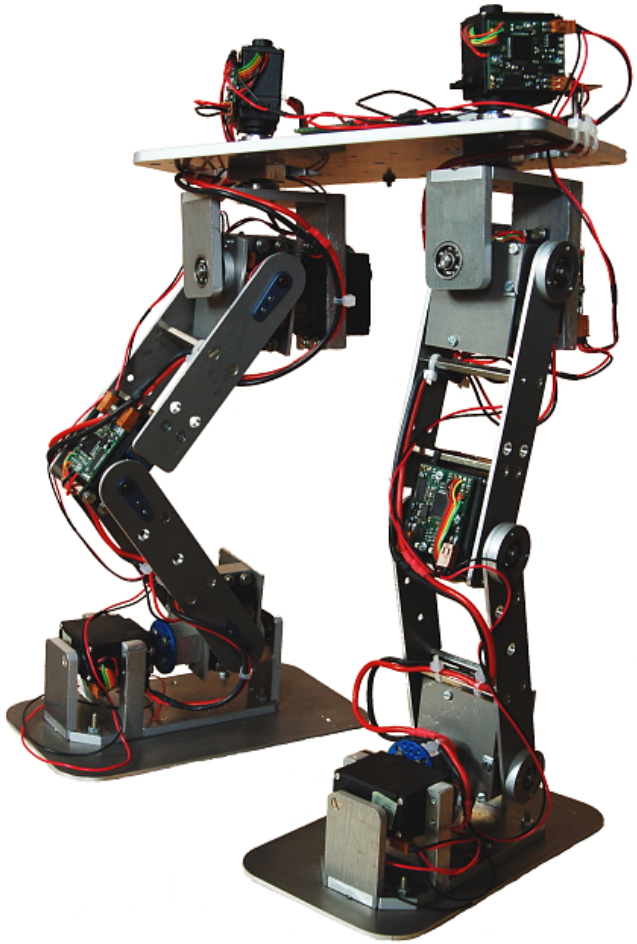
Department of Control Engineering
Faculty of Electrical Engineering
Czech Technical University in Prague

5th February 2008

Goals

- real robot, not only mathematical model
- test platform for control design
- CAN bus, GNU/Linux & real-time demonstration

- simple design
  - static walking
  - manually created trajectory
- but extendable for more advanced control (unlike commercial robot toys)



Mechanical Construction

Design idea

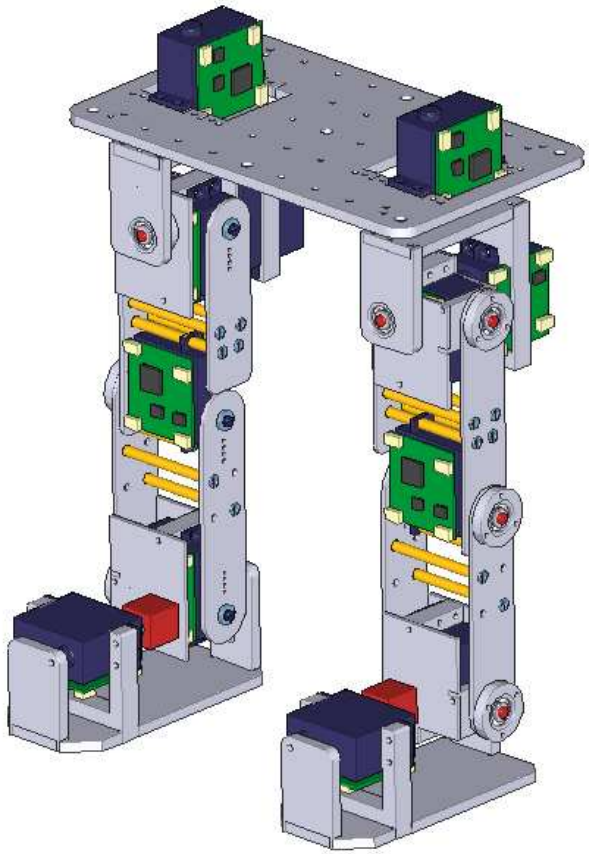
- inspired by YABiRo, Pino
  - direct shaft links (like Pino), multiaxis joints (like YABiRo)
  - only two legs, no upper body
  - 12 degrees of freedom (6 DOF per leg)
  - one type of servo motor for all axes
  - CNC laser cut duraluminium

Mechanical Construction

Computer Aided Design

CAD used to

- CNC manufacturing of frame parts
- physical modelling by polyhedral mass properties
  - static (mass, centre of gravity)
  - dynamic (+ inertia)
- visualization in software (OpenGL)



System Architecture
Actuators & sensors

Servo motors

- standard modeller geared DC motor with potentiometer position sensing
- but with our own electronics to enable
  - MIMO control
  - arbitrary control design

Sensors

- joint position sensing only (servo potentiometers)
- future addition of sensors (gravitation, feet pressure)

Power supply

- high power requirements (7 V, 10 A) $\Rightarrow$ cable power supply (no standalone operation)

System Architecture
Network

Requirements

- minimal cabling
- power electronics and measurement interference elimination
- flexibility (additional actuators, sensors)
- independent choice of control system (PC, embedded computer, FPGA)

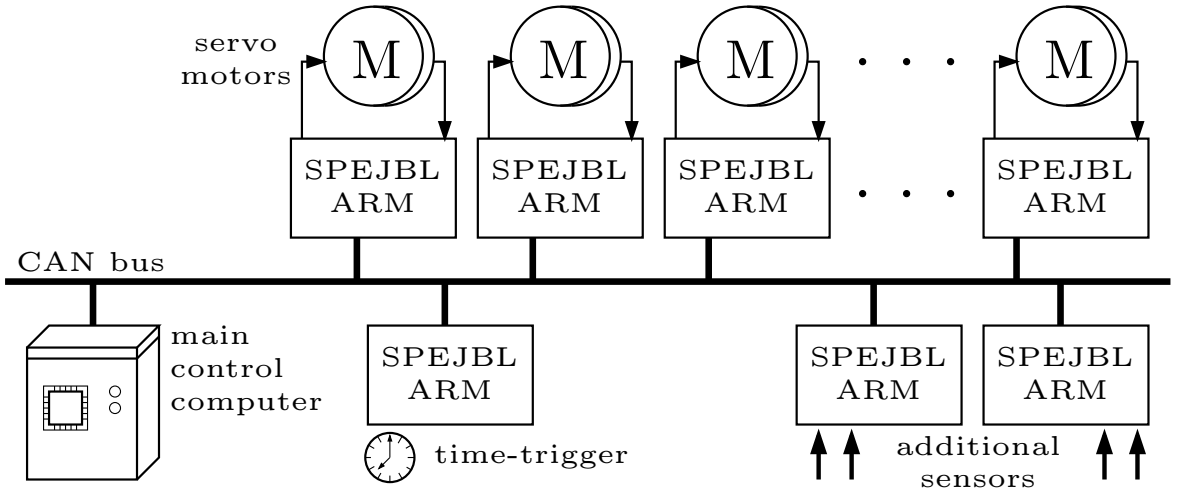
$\Longrightarrow$ CAN bus employed

- microcontroller support
- GNU/Linux support by OCERA LinCAN
- experience
- price (parts, tools)

System Architecture
Network nodes

Network nodes

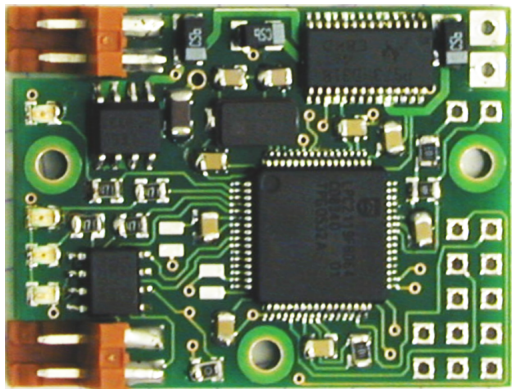
- 12 servo motors controlled by 12 “SPEJBL-ARM” computer boards
- one node as a time-trigger
- main control computer (IBM PC at present)
- additional sensors or actuators (SPEJBL-ARM or another board)



System Architecture

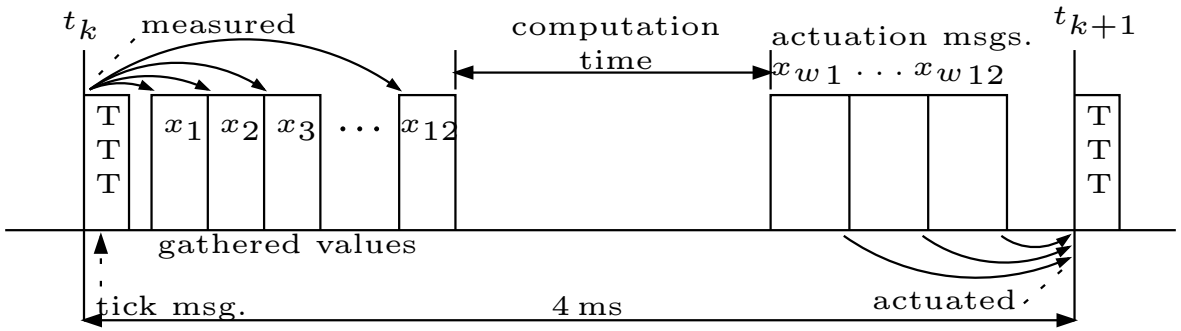
SPEJBL-ARM computer board

- designed to fit onto servo case ($37 \times 28 \times 6.5$ mm)
- 32-bit microcontroller Philips LPC2119, ARM7TDMI core at 60 MHz
  - allows fast 32-bit integer arithmetic computation at 8-bit price
- 6 PWM, 4 ADC channels for actuator/sensor connection
- software loaded on-the-fly by CAN bootloader
- running system-less, interrupt-driven



System Architecture
Network timing

- time-triggered operation
  - allows softer real-time main control computer
- servo motor control loop closed through CAN bus
  - allows controller inside of main control computer – allows MIMO control
- global control loop sampling period 250 Hz
  - sufficient for robot dynamics
  - causing up to 33.2 % CAN bus load
  - main control computer should react within 2.72 ms, ie. 66.7 % of the sampling period

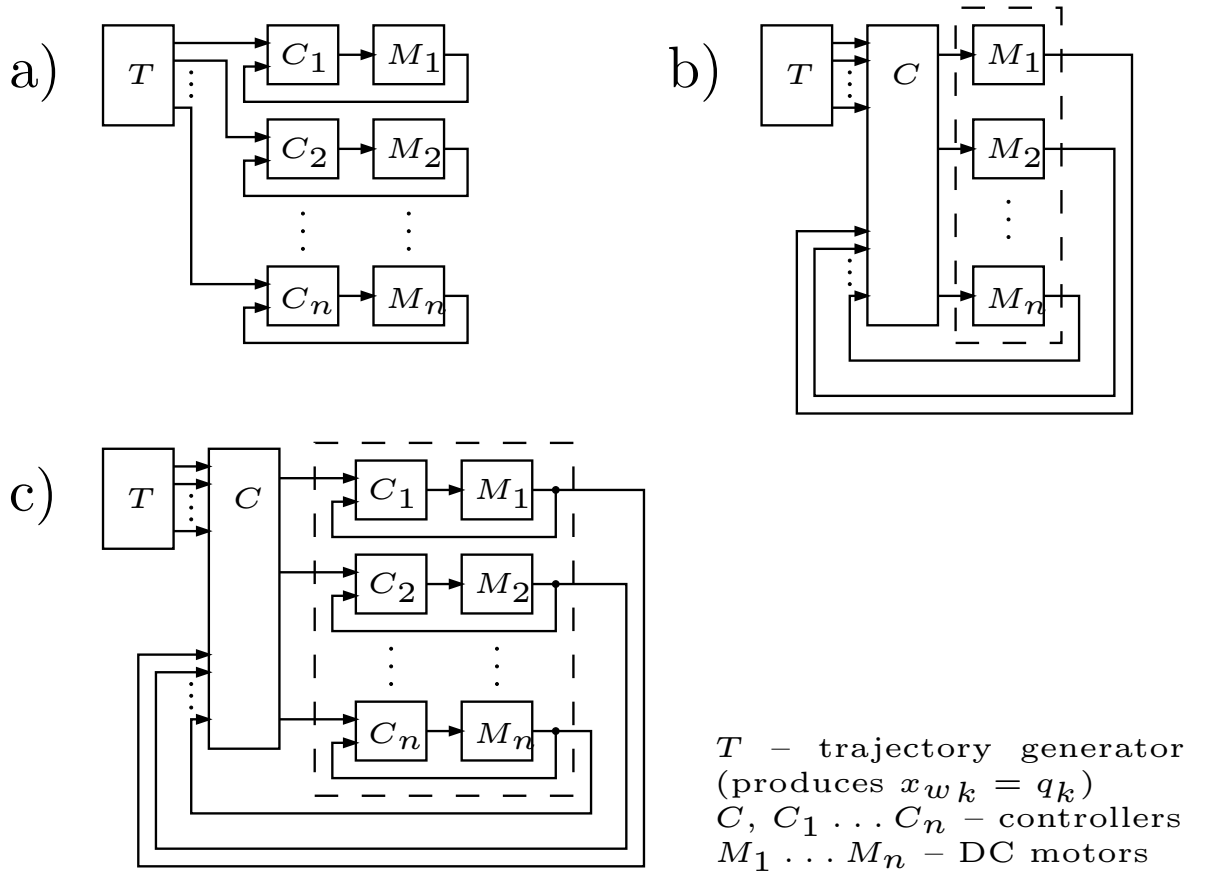


System Architecture

Network and control design

Controller topologies

- SISO
- MIMO
- MIMO-SISO cascaded

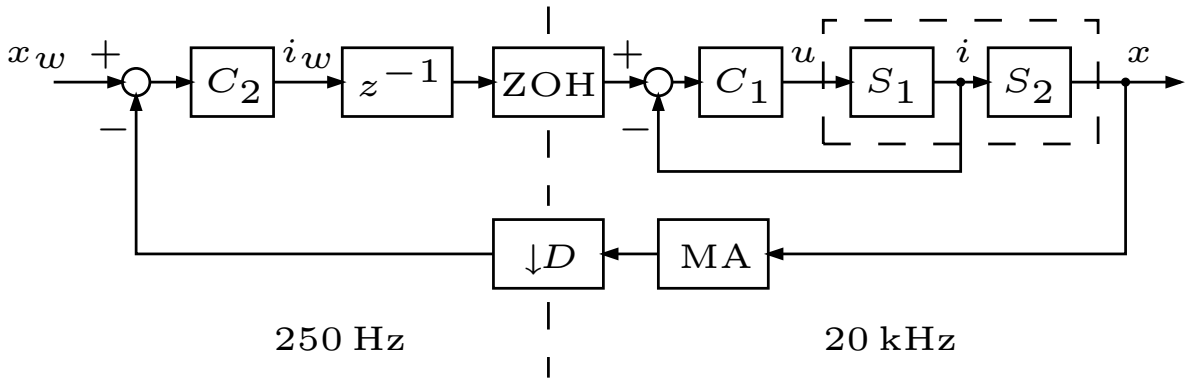


T – trajectory generator (produces $x_{w\,k} = q_k$)
C, $C_1 \ldots C_n$ – controllers
$M_1 \ldots M_n$ – DC motors

System Architecture

Network and control design

- time-triggered operation implies
  - inherent one-sample delay z^{-1} in control loop
  - but the control is deterministic, not influenced by CAN bus traffic (environment)
- fast inner control loops inside of global control loop enclosed through CAN bus $\longrightarrow$ cascaded multirate controller
  - running asynchronously – synchronization possible, but not necessary (sampling ratio 1:80)



Results

Initial version

- 12 simple SISO proportional (P-type) only controllers
- trajectory animated by hand
- worked, walking, but not robust enough
  - heavy overload caused electronics burning
  - mechanical hystheresis in hip joint disallowed correct feedback control

$\Longrightarrow$ improved version

- inner current control loops with software current limitation employed $\rightarrow$ safe operation
- hip joint redesigned
- PID controllers added to global control loop

Conclusion

- importance of robust mechanical and electronic design
- simple walking with P-type controller possible
- CAN bus with time-trigger fulfilled our expectation