ICAMechS 2012

Advanced Intelligent Control in Robotics and Mechatronics

The Navigation Mobile Robot Systems Using Bayesian Approach through the Virtual Projection Method

Tokyo, Japan, September 2012

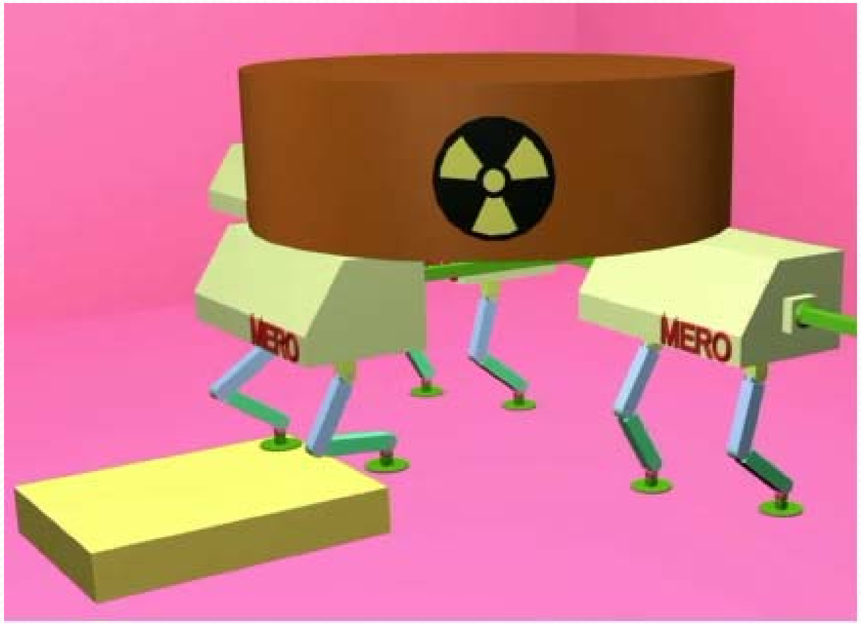
Luige VLADAREANU, Gabriela TONT, Victor VLADAREANU, Florentin SMARANDACHE and Lucian CAPITANU

Improvement of Dynamical Stability for the Real Time Walking Robot Control PERO

1. Introduction
2. Dynamic Stability Control
3. Simultaneous Localization and Maping
4. A Petri Net and Markov Chains Approach
5. Robot simulation through Petri Nets
6. Virtual projection architecture for robot experimental control
7. Results and Conclusions

1. Introduction

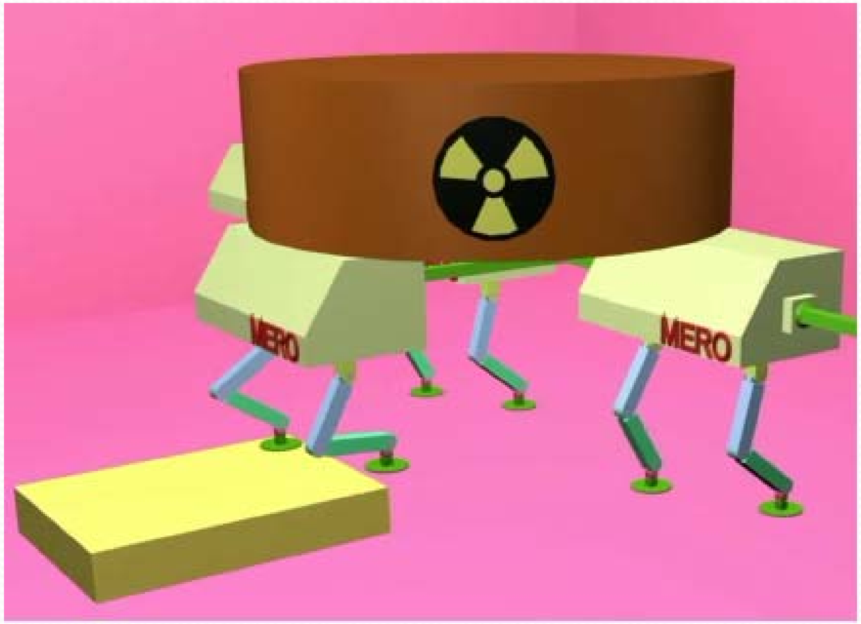
The Navigation and Stability of the Mobile Robot Systems



- The approach of the localization and navigation problems of a mobile robot which uses a WSN which comprises of a large number of distributed nodes with cameras as main sensor
- Hybrid force-position control through operational space method
- The Zero Movement Point (ZMP) method by processing inertial information of force torque and tilting and by implementing intelligent high level algorithms

1. Introduction

The Navigation and Stability of the Mobile Robot Systems

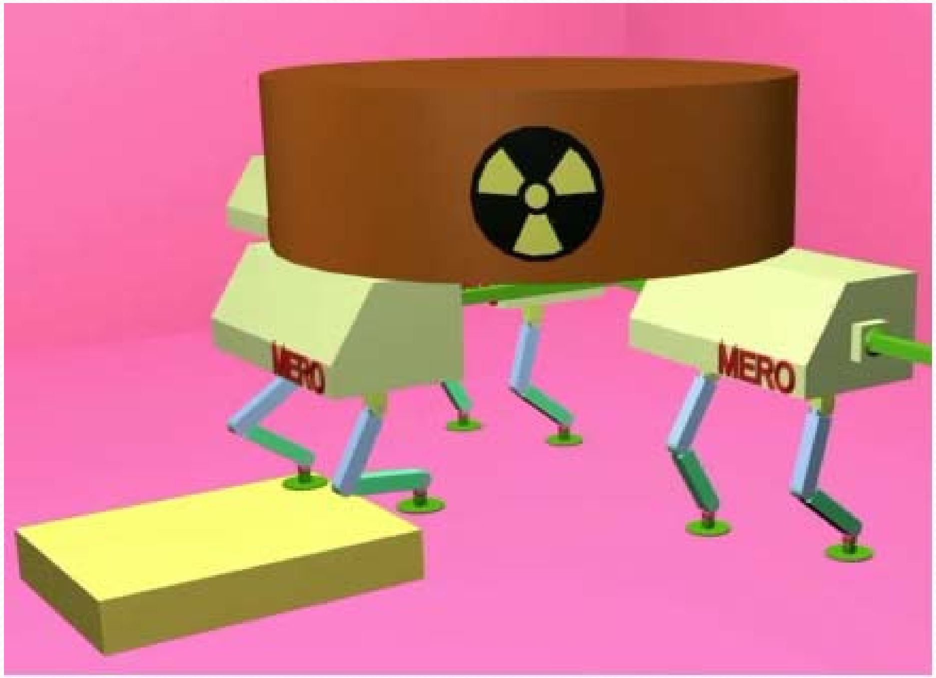


Walking robot control strategy is based on three approaches:

- real-time balance control
- walking pattern control
- predictable motion control
- in correlation with a stochastic model of assessing system probability of unidirectional or bidirectional transition states

1. Introduction

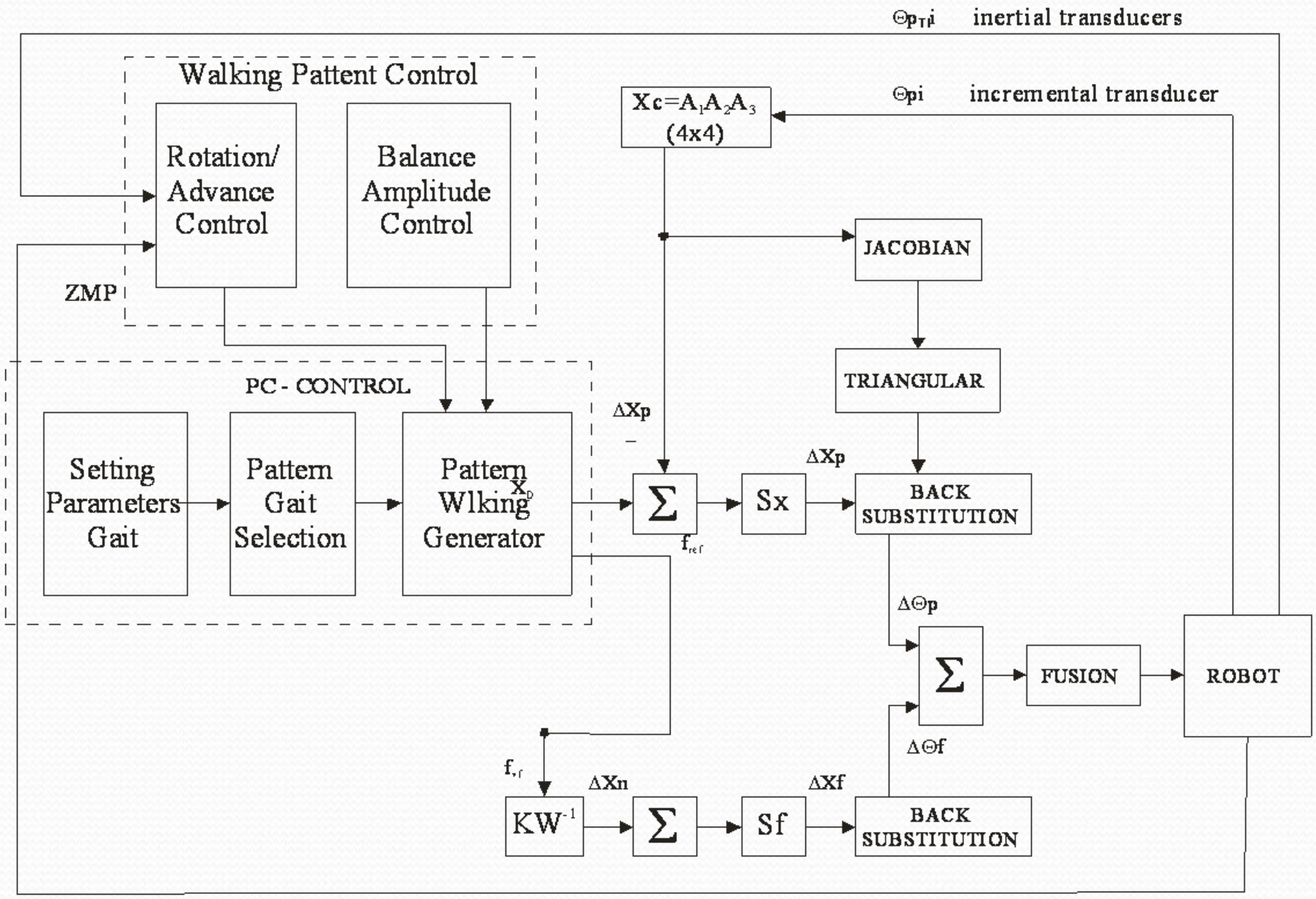
The Navigation and Stability of the Mobile Robot Systems



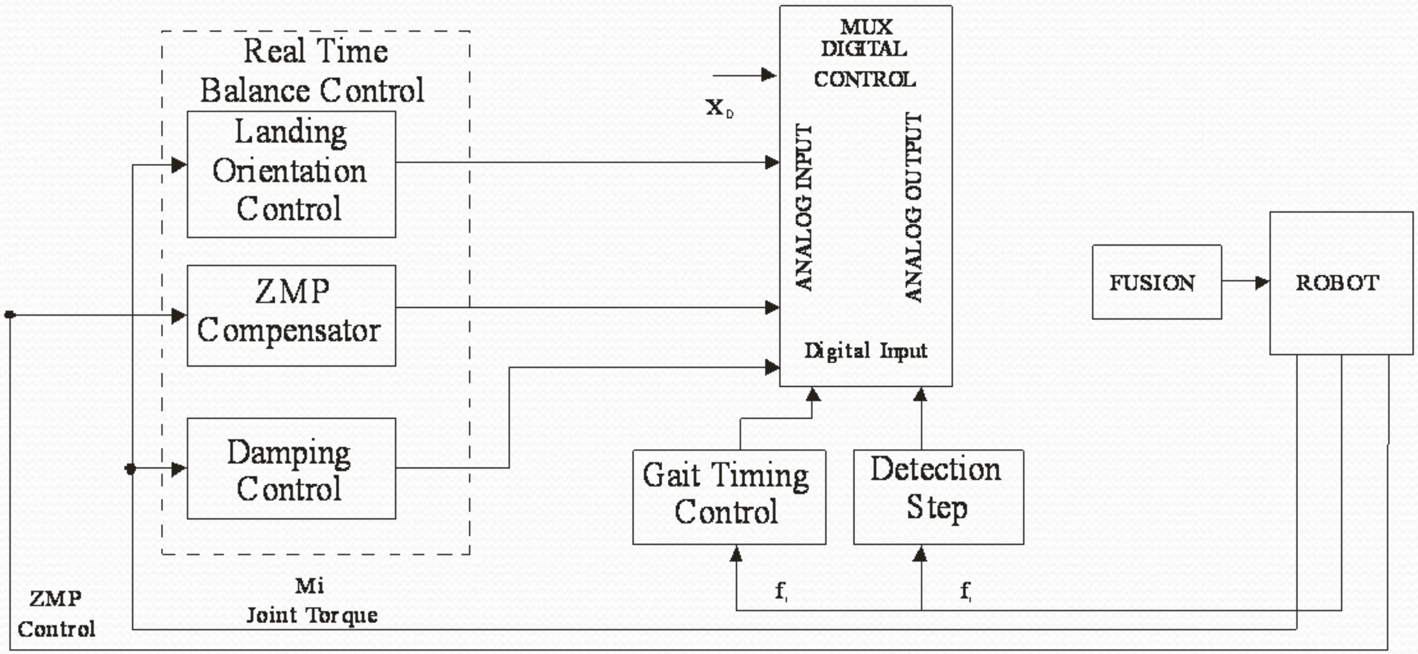
- the system architecture control was completed for HFPC walking robots (hybrid force-position control) with two other control functions
- Online controllers were designed for the objectives of the control schemes and planned in the early stages of walking.
- Was obtained the walking control algorithm with online simulations obtained experimentally through the virtual projection method.

2. Dynamic Stability Control

Dynamic control of the walking robots motion

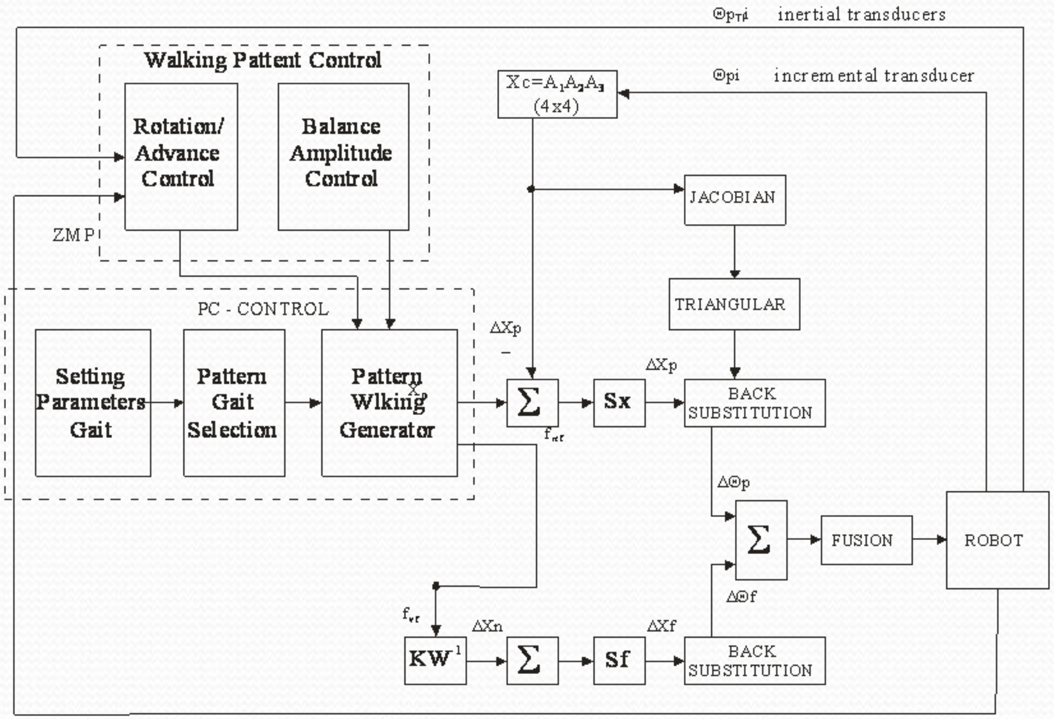


2. Dynamic Stability Control



- **Real time balance control of the robot** using sensorial feedback, has 3 online types of control loops:
  - **Damping control strategy** aims to eliminate the oscillations that occur in the single support phase.
  - **ZMP compensation control strategy**. Control strategy consists in mathematical modeling of ZMP compensator through the springloaded inverted pendulums.
  - **Gait timing control strategy**. Generates a signal to block the walking diagram if the foot doesn't touch the ground at the end of phase 2 and 4.

2. Dynamic Stability Control

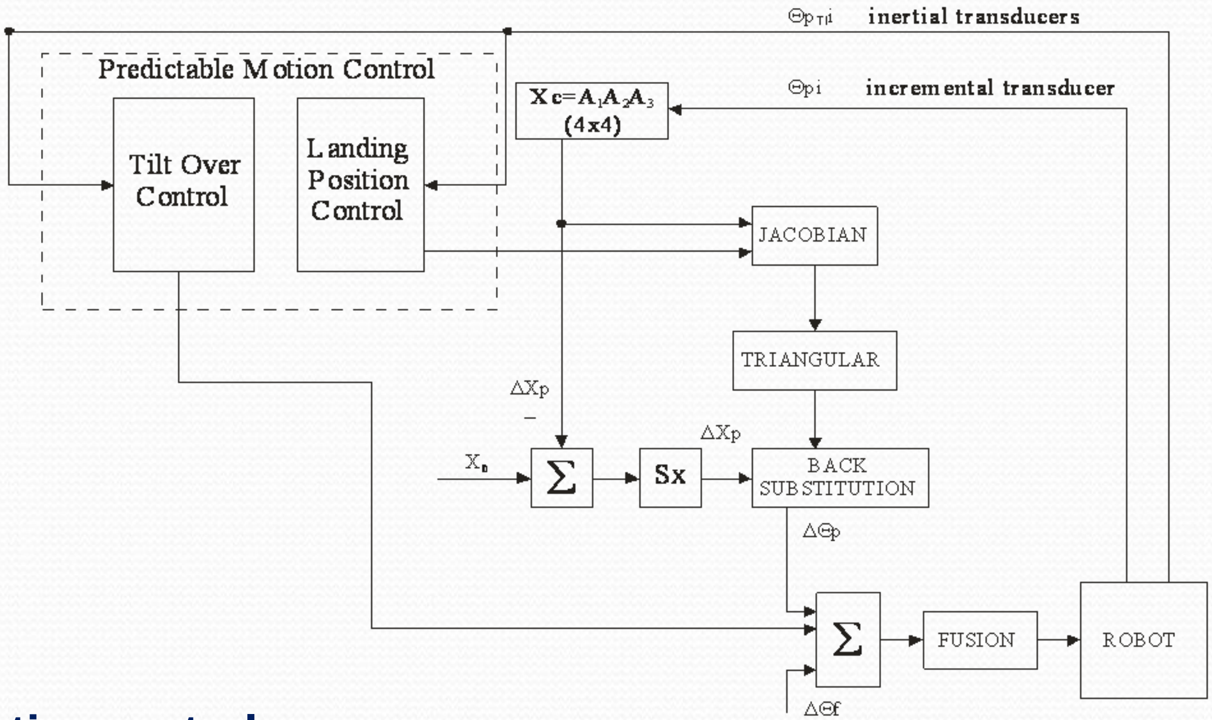


The walking pattern control, may be changed periodically according to the information received from an inertia transducer during each walking cycle.

Modeling of platform balance. In terms of control strategy, periodically adjust the lateral balance amplitude of the platform in order to move ZMP, corrected by measuring ZMP during each walking cycle.

Rotation/advance platform control strategy, allows the central position of the platform to move in the opposite direction to the inclined transverse plane so that the swinging movement can be well balanced.

2. Dynamic Stability Control



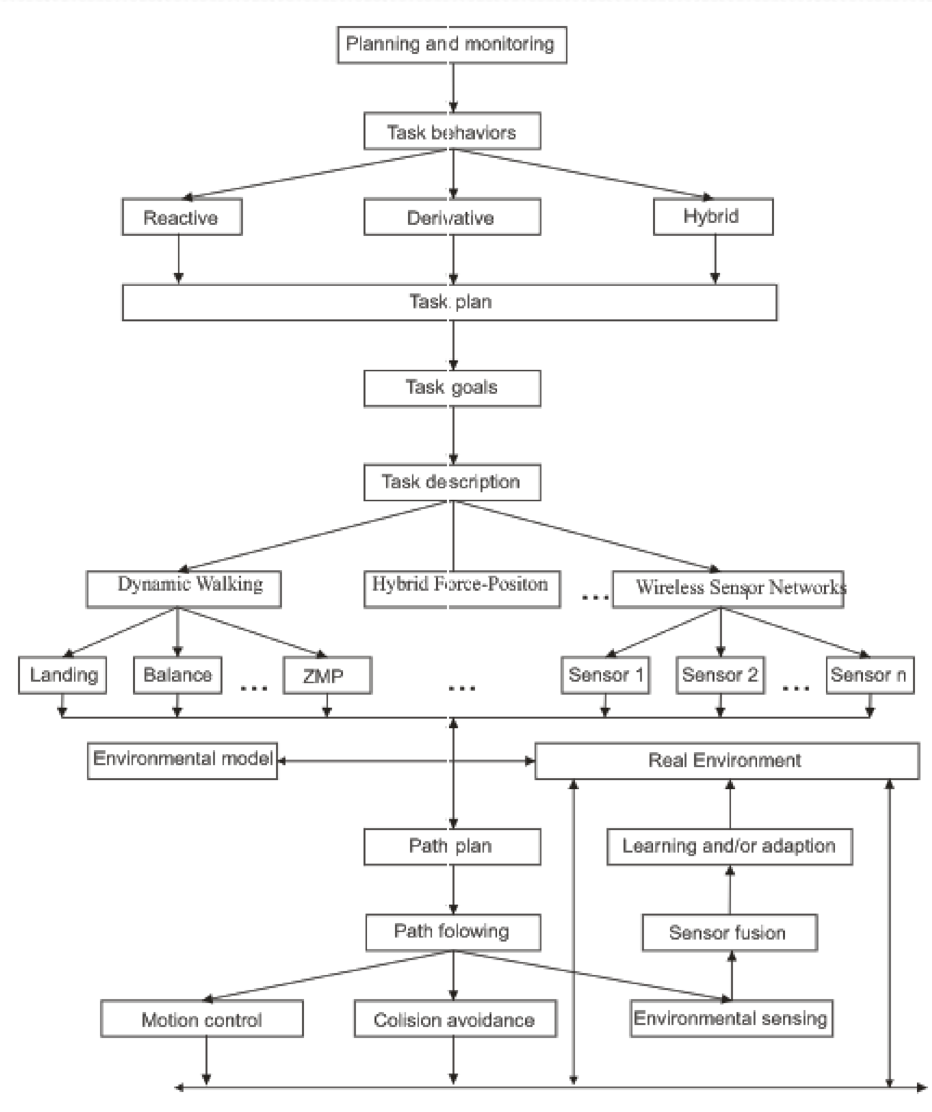
Predictable motion control.

Is based on generating probable robot movements achieved by processing earlier movements, in order to avoid overthrowing the walking robot.

Control of landing position, is for to compensate foot landing position on ground, in order to walk towards the direction of the fall, by a twisting movement of the platform.

Control of tilt over the side of safety of the robot. The tilt control loop prevents the fall of the walking robot in lateral directions, in case of moving on a bumpy field or external forces.

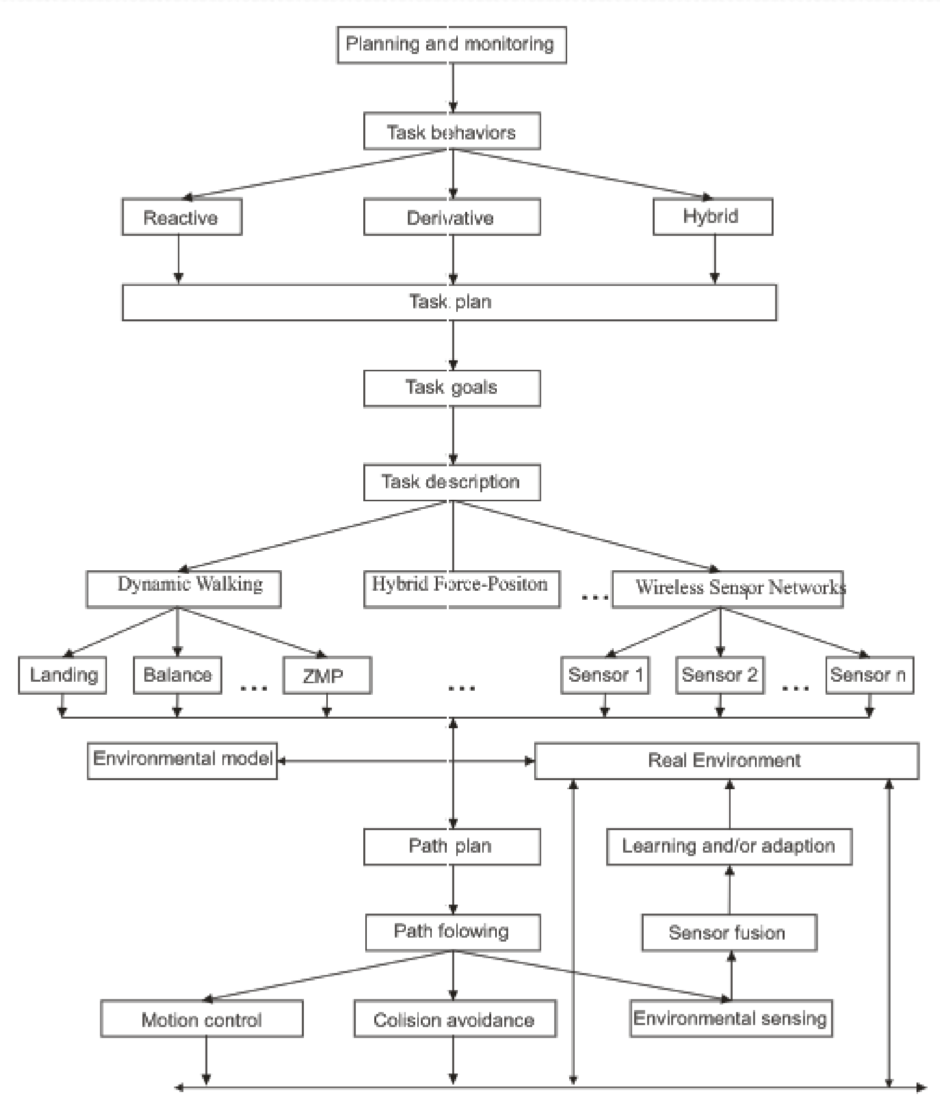
3. Simultaneous Localization and Maping



- Autonomous mobile robots systems that can perceive their environments, react to unforeseen circumstances, and plan dynamically in order to achieve their mission have the objective of the motion planning and control problem.

- The relationship between the subtasks mapping and modeling of the environment; path planning and selection; path traversal and collision avoidance into which the navigation problem is decomposed, is shown in diagram.

3. Simultaneous Localization and Maping



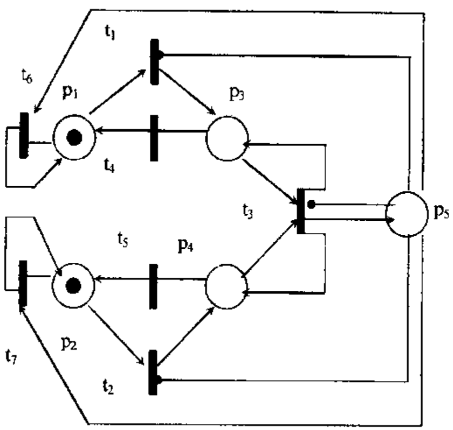
• Motion planning of mobile walking robots in uncertain dynamic environments based on the behavior dynamics of collision-avoidance is transformed into an optimization problem. Applying constraints based on control of the behavior dynamics, the decision-making space of this optimization.

• In this sense, a new control algorithm has been studied and analyzed for dynamic walking of robots based on sensory tools such as force / torque and inertial sensors. Distributed control system architecture was integrated into the HFPC architecture so that it can be controlled with high efficiency and high performance.

4. A Petri Net and Markov Chains Approach

Petri Nets

The interest in modeling by means of PN came from the following reasons:



⇒ More detailed causal modeling considering the two main aspects;

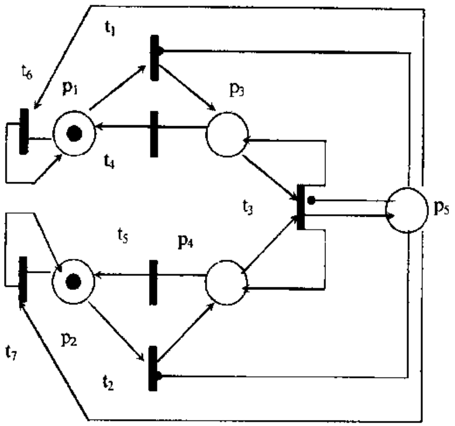
⇒ information flow within the system takes the form of process and task and control sequences, may satisfy the Markovian property [10, 17];

⇒ allow to build dynamic models which incorporate time information of the process development ;

⇒ sequencing and planning actions can be checked and monitored throughout system states that can be related to insecurity conditions.

4. A Petri Net and Markov Chains Approach

Petri Nets



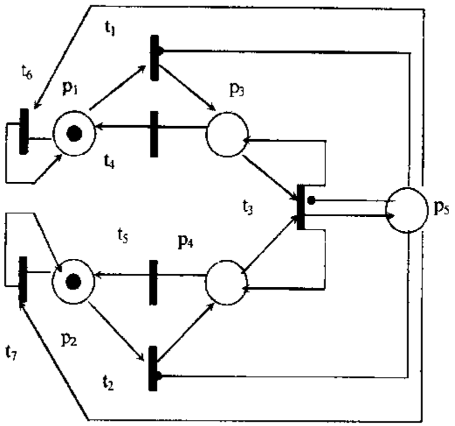
Petri nets share many common properties with other formalisms. Petri nets can normally be converted to time Petri nets for simulation and performance modeling.

■ Petri nets have a dual identity. They can be represented graphically and non graphically;

■ Compared with other formalisms Petri nets are preferable for visualization and comprehension by different stakeholders.

4. A Petri Net and Markov Chains Approach

Petri Nets



Petri nets have been used to model:

i) hardware;

ii) software systems;

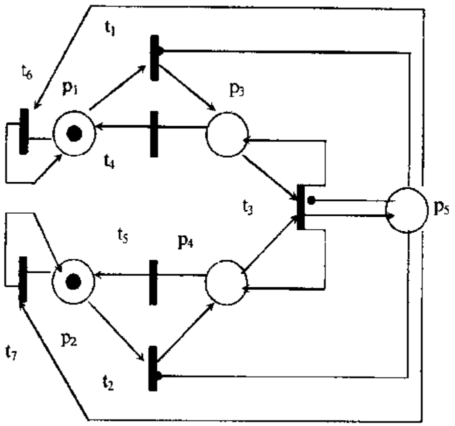
iii) communication systems;

iv) manufacturing

v) software modeling.

4. A Petri Net and Markov Chains Approach

Petri Nets



In order to perform the evaluation Petri net, it is necessary to quantifying the probabilities of states using Markov chains, assuming following hypothesis:

i) stability and instability of the component is random, the currently state depends only on the immediately preceding state;

ii) the instability intensity, and stability intensity are time constant.

4. A Petri Net and Markov Chains Approach

Petri Nets

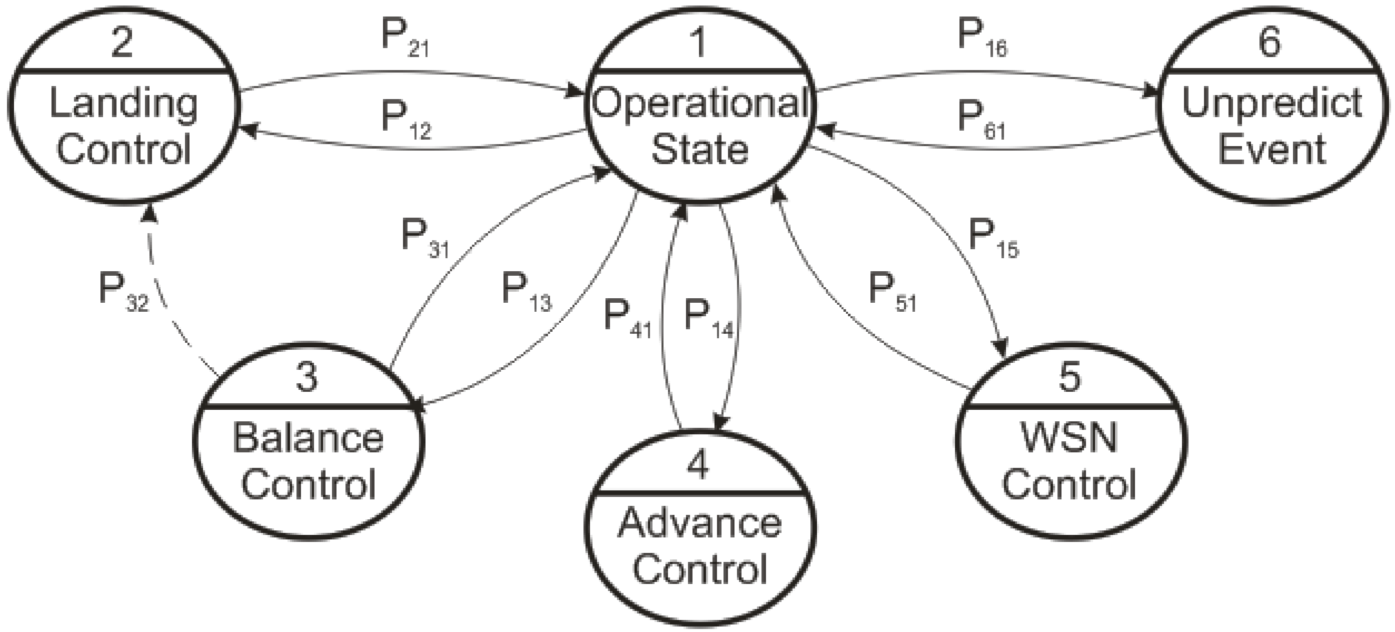
$$[P'(t)] = [a_{ij}] \cdot [P(t)] \quad (1)$$

$$\begin{cases} \sum_{j=1}^{n} a_{ij} = 0, (\forall) i = \overline{1,n} \\ a_{ij} \geq 0, (\forall) i = \overline{1,n}, i \neq j \\ a_{ij} \leq 0, (\forall) i = \overline{1,n}, \end{cases}$$

Assimilating development over time of system through the various states that may occur as a result of fail and restore of elements with a continuous time Markov process, solving is done by the system of differential equations, written under generalized form as the matrix

4. A Petri Net and Markov Chains Approach

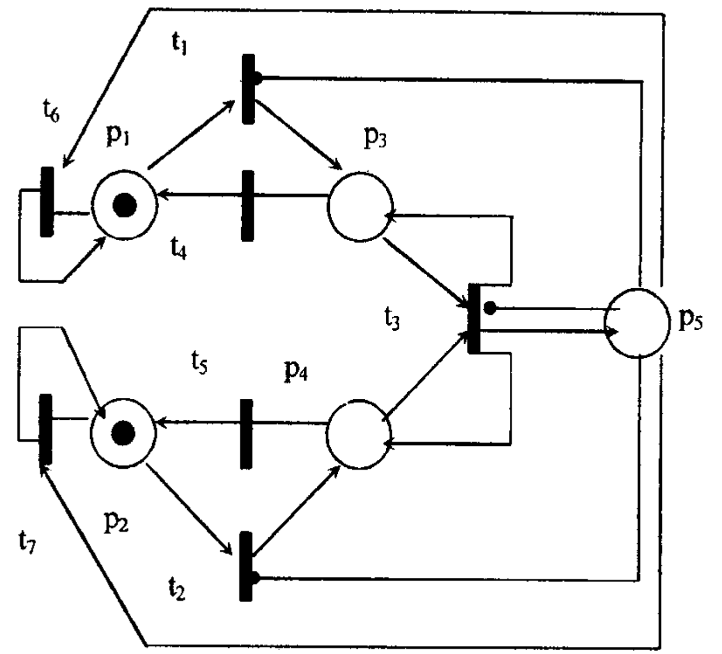
Petri Nets



Modeling the states with possible transitions for robot

4. A Petri Net and Markov Chains Approach

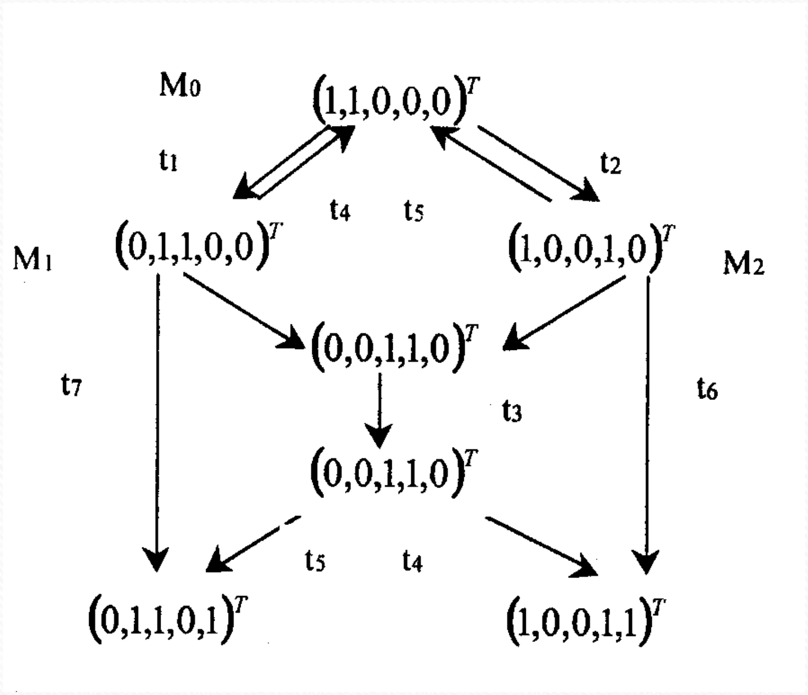
Petri Nets



System Petri Net Representation

4. A Petri Net and Markov Chains Approach

Petri Nets



Associated Markov graph of the system modeled by means of Petri nets

4. A Petri Net and Markov Chains Approach

Petri Nets

$$P(t)=[P_1(t), P_2(t), P_3(t), P_4(t)]$$

$$C(t)=\begin{bmatrix} -\lambda_1(t)-\lambda_2(t) & \lambda_1(t) & \lambda_2(t) & 0 \\ \mu_1(t) & -\lambda_2(t)-\mu_1(t) & 0 & \lambda_2(t) \\ 0 & 0 & -\lambda_1(t)-\mu_2(t) & \lambda_1(t) \\ 0 & \mu_2(t) & \mu_1(t) & -\mu_1(t)-\mu_2(t) \end{bmatrix}$$

State probability vector P (t) system and matrix of transition rates C (t)

4. A Petri Net and Markov Chains Approach

Petri Nets

$$\begin{cases} P_1^{/}(t) = -P_1(t)\left[\lambda_1(t) + \lambda_2(t)\right] + P_2(t)\mu_1(t) + P_3(t)\mu_2(t) \\ P_2^{/}(t) = P_1(t)\lambda_1(t) - P_2(t)\left[\lambda_2(t) + \mu_1(t)\right] + P_4(t)\mu_2(t) \\ P_3^{/}(t) = P_1(t)\lambda_2(t) - P_3(t)\left[\lambda_1(t) + \mu_2(t)\right] + P_4(t)\mu_1(t) \\ P_4^{/}(t) = P_2(t)\lambda_2(t) + P_3(t)\lambda_1(t) - P_4(t)\left[\mu_1(t) + \mu_2(t)\right] \end{cases}$$

The state equations of the system

4. A Petri Net and Markov Chains Approach

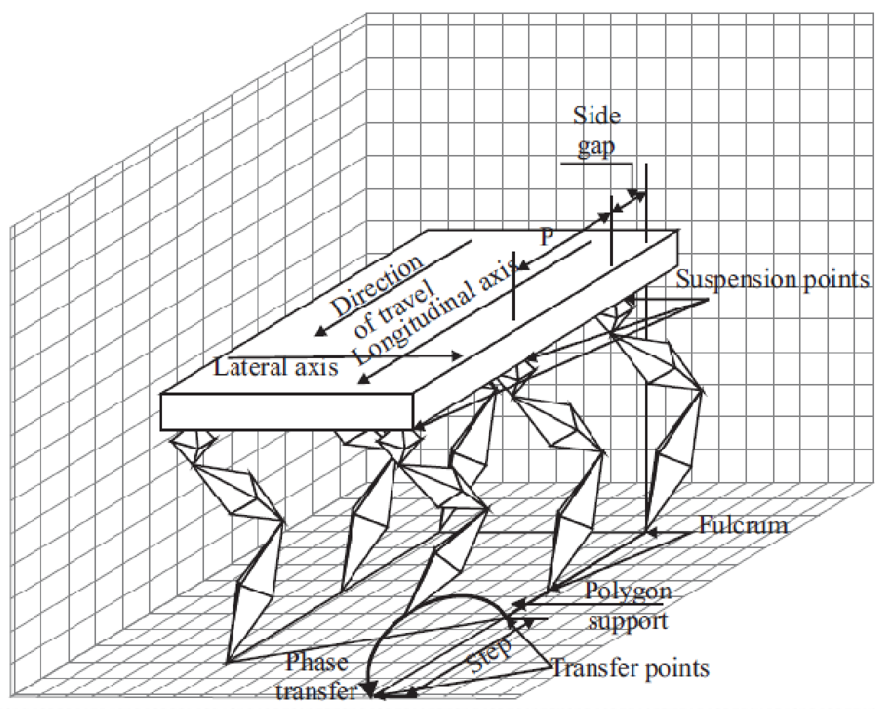
Petri Nets

$$\mathbf{Fu(T)} = \sum_k \mathbf{P}_K(\mathbf{T}) = [R(t_0), R(t_1), \ldots, R(t_q)] = \left[\sum_k P_k(t_0), \sum_k P_k(t_1), \ldots, \sum_k P_k(t_q)\right]$$

$$\mathbf{A}(\mathbf{T}) = \sum_k \mathbf{P}_1(\mathbf{T}) = [A(t_0), A(t_1), \ldots, A(t_q)] = \left[\sum_l P_l(t_0), \sum_l P_l(t_1), \ldots, \sum_l P_l(t_q)\right]$$

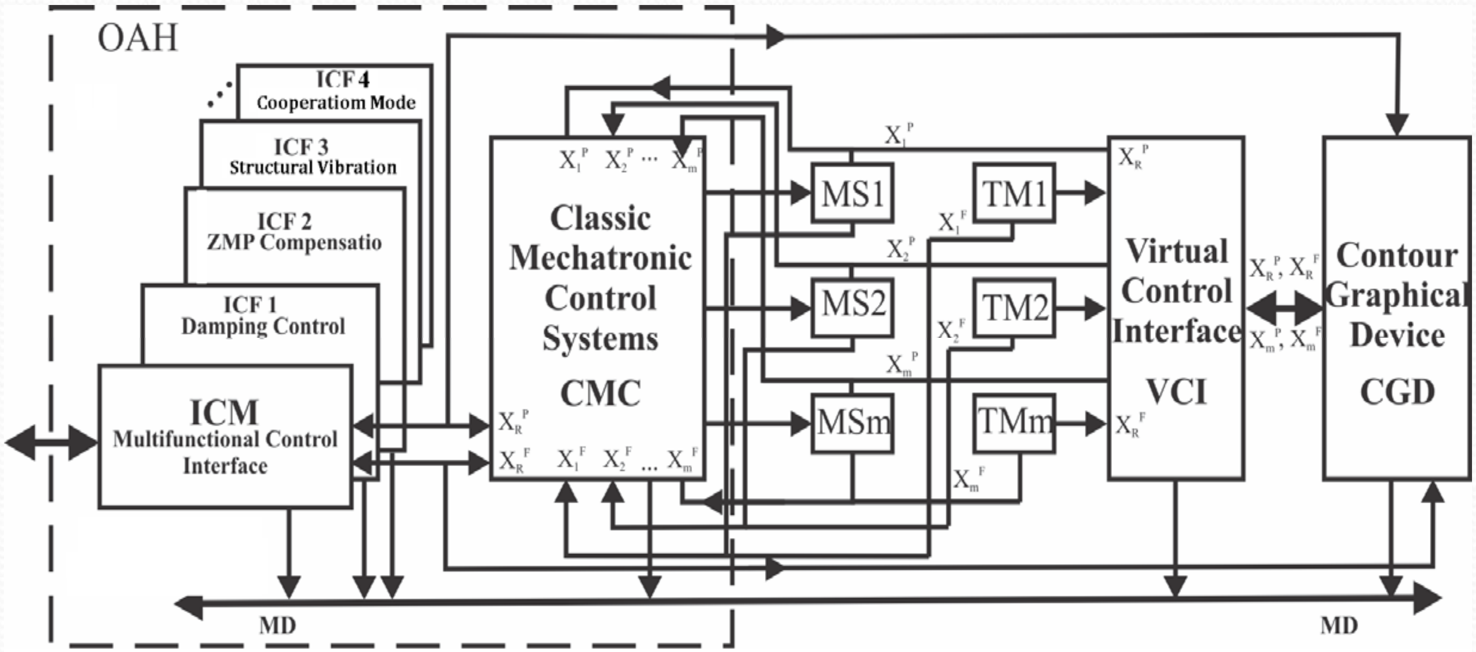
The functionality functions Fu (t) and instantaneous availability A (t) vectors

5. Virtual Projection Architecture



- In order to verify the force-position dynamic control performance of walking robots, in addition to integrating the dynamic control loops through the ZMP method, the virtual projection system architecture allows new control functions
- simultaneous localization and mapping (SLAM) interface
- structural vibration control functions of the operating mechanism interface
- cooperation functions for obstacles avoidance interfece

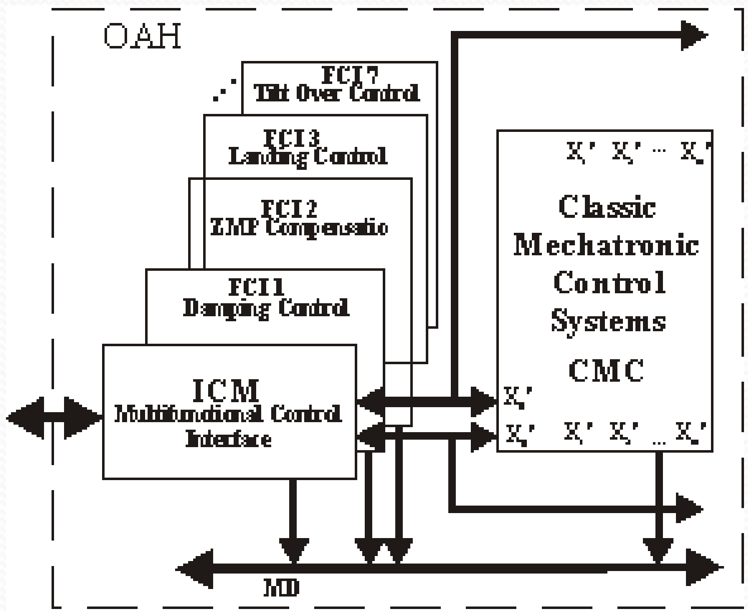
5. Virtual Projection Architecture



- The virtual projection method realizes the dynamic force-position control performance testing by integrating the fuzzy multi-stage method with resolved acceleration in controlling the dynamic force-position control loops through ZMP method and another two control loops.
- Method is patented by the authors

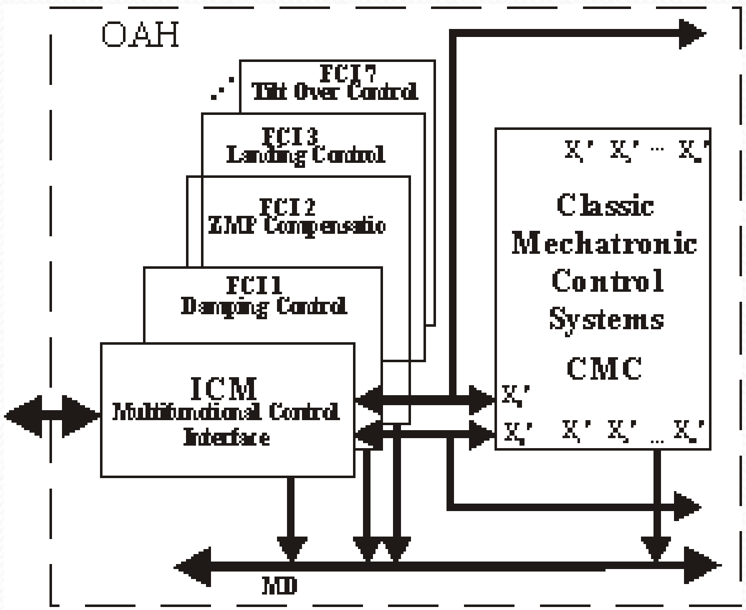
5. Virtual Projection Architecture

- A number of n functions of the control interfaces ICF1-ICFn ensure the development of open architecture control system by integrating a number of n control functions



- Additional functions provided by the mechatronic control : trajectory tracking, walking control scheme for tripod robots, center of gravity control, and orientation control by image processing

5. Virtual Projection Architecture

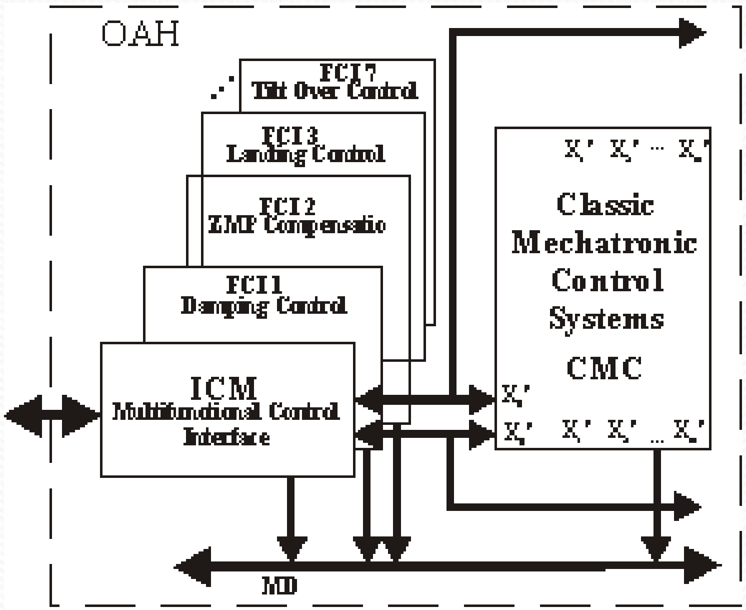


The HFPC system was designed with an open architecture (OAH) in a distributed and decentralized structure to enable easy development of new applications or adding new hardware modules or software for new control functions.

As basic functions there are:

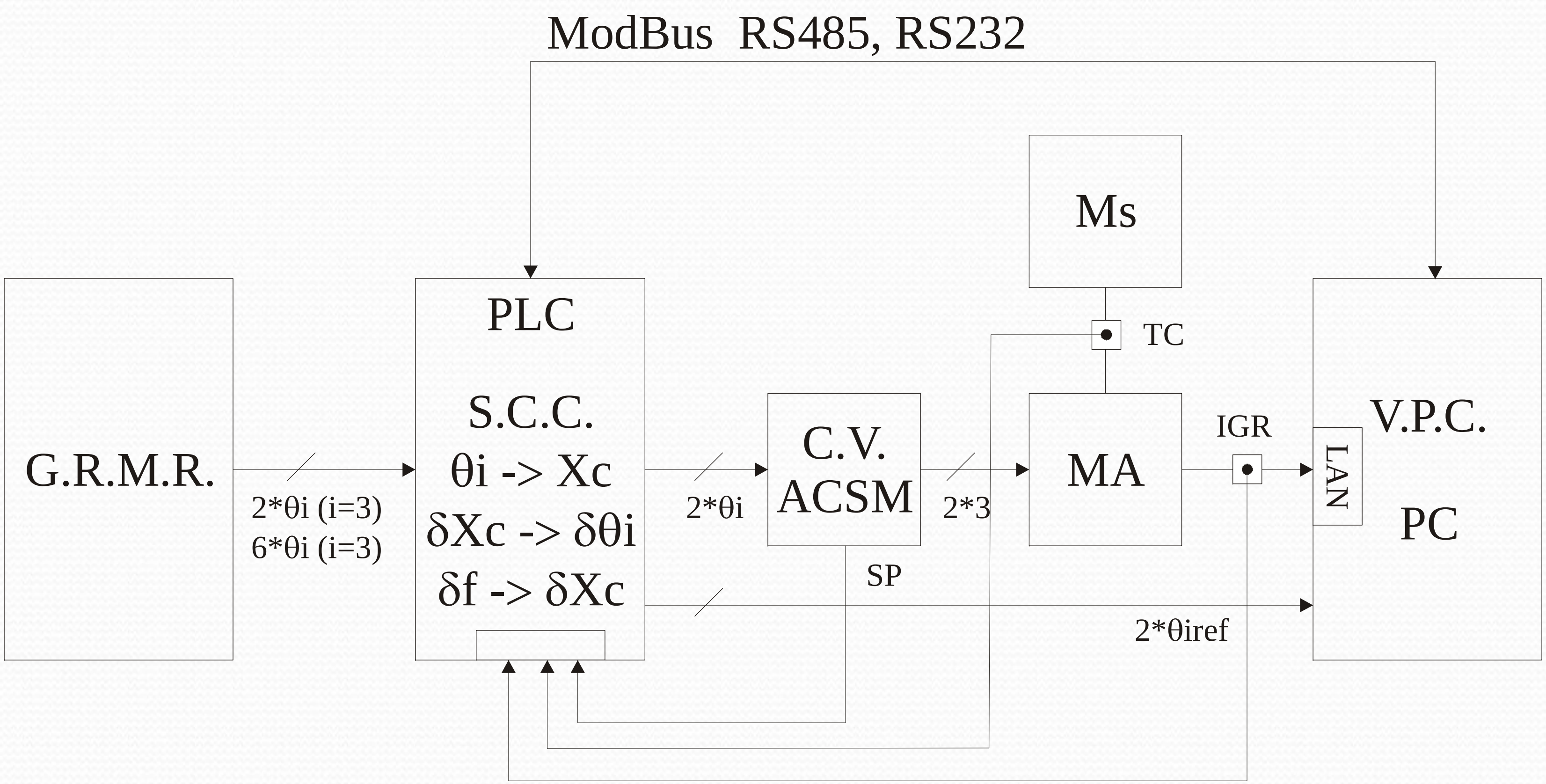
- Hybrid force-position control through operational space method
- Compliant control through multi-stage fuzzy method
- Damping control strategy
- ZMP compensation control strategy
- Simultaneous Localization and Mapping strategy

5. Virtual Projection Architecture



- **Hybrid force-position control using operational space method,** allow dividing a vector with the transformation matrix A in two perpendicular components through a set of associated projection matrices.
- **Compliant control through multi-stage fuzzy method** allows, by using resolved acceleration control, getting a control system in which dynamic and kinematic stability are simultaneously achieved in rigid environments.

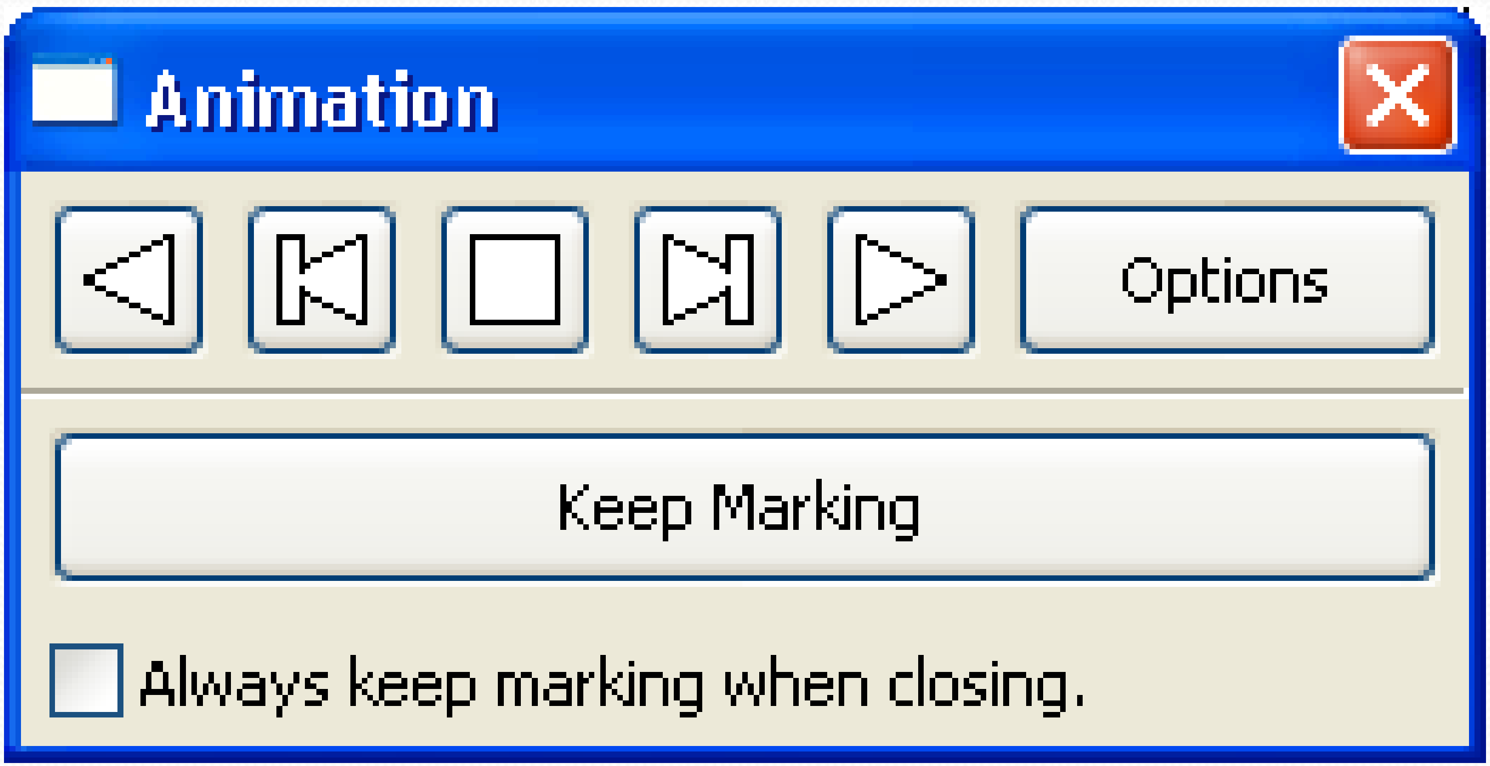
5. Virtual Projection Architecture



Simulation through virtual projection

6. Robot simulation through Petri Nets

Petri Nets



6. Robot simulation through Petri Nets

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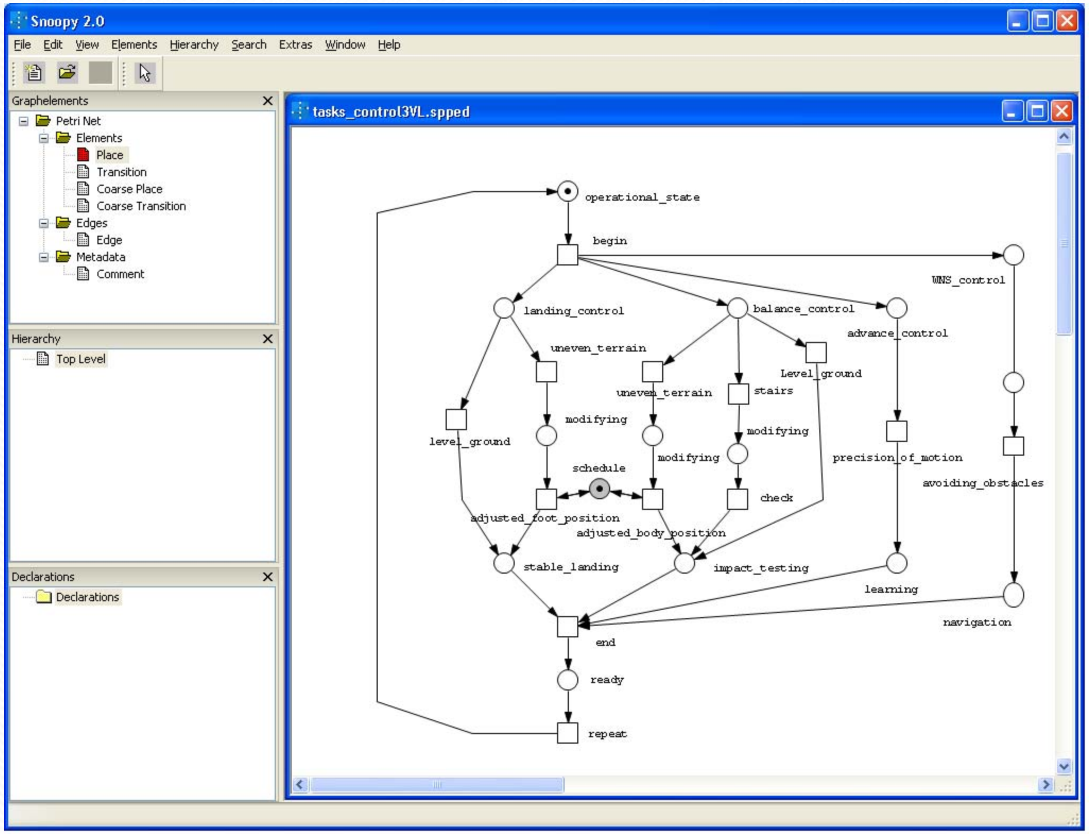
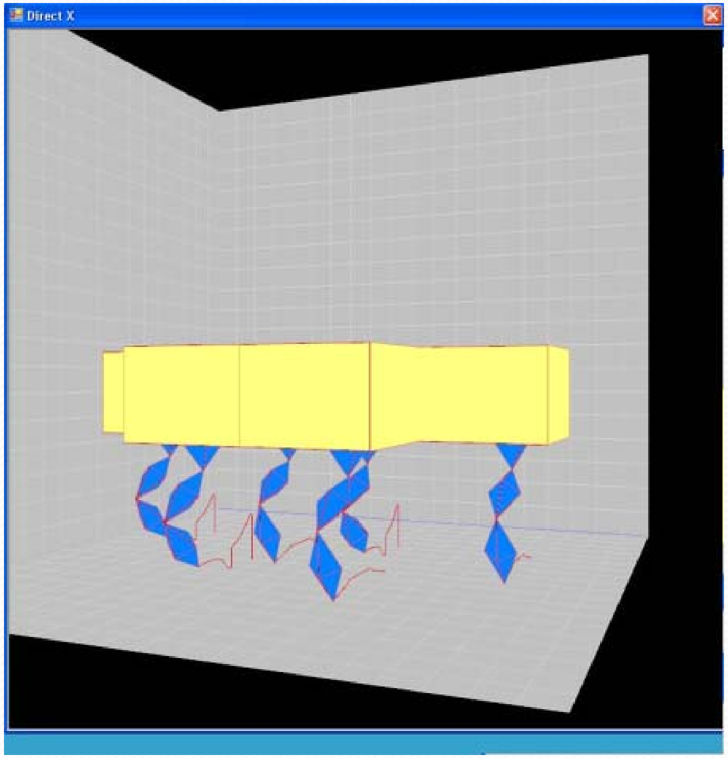


7. Results and Conclusion

View from the right side camera movement

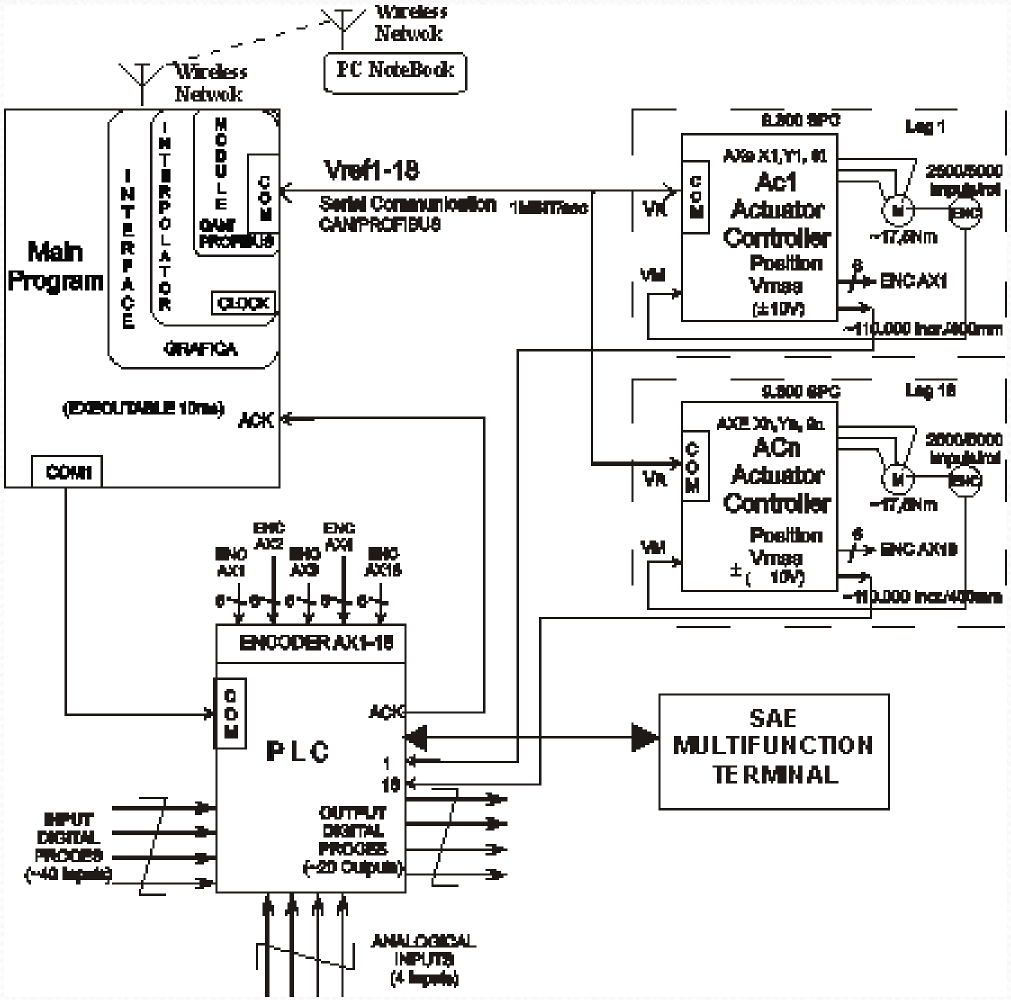


- Petri nets provide a promising solution towards the development quantitative approach of dynamic discreet / stochastic event systems of task planning for mobile robots .

- For a deeper insight into control and communication governing task assignment of the robot, the entire discrete-event dynamic evolution of task sequential process have to be linguistically described in terms of representations.

- A comprehensive inference framework is required in analyzing the database of rules of expert systems, Petri nets using a large amount of details for building analysis, even for small systems, which lead to high costs.

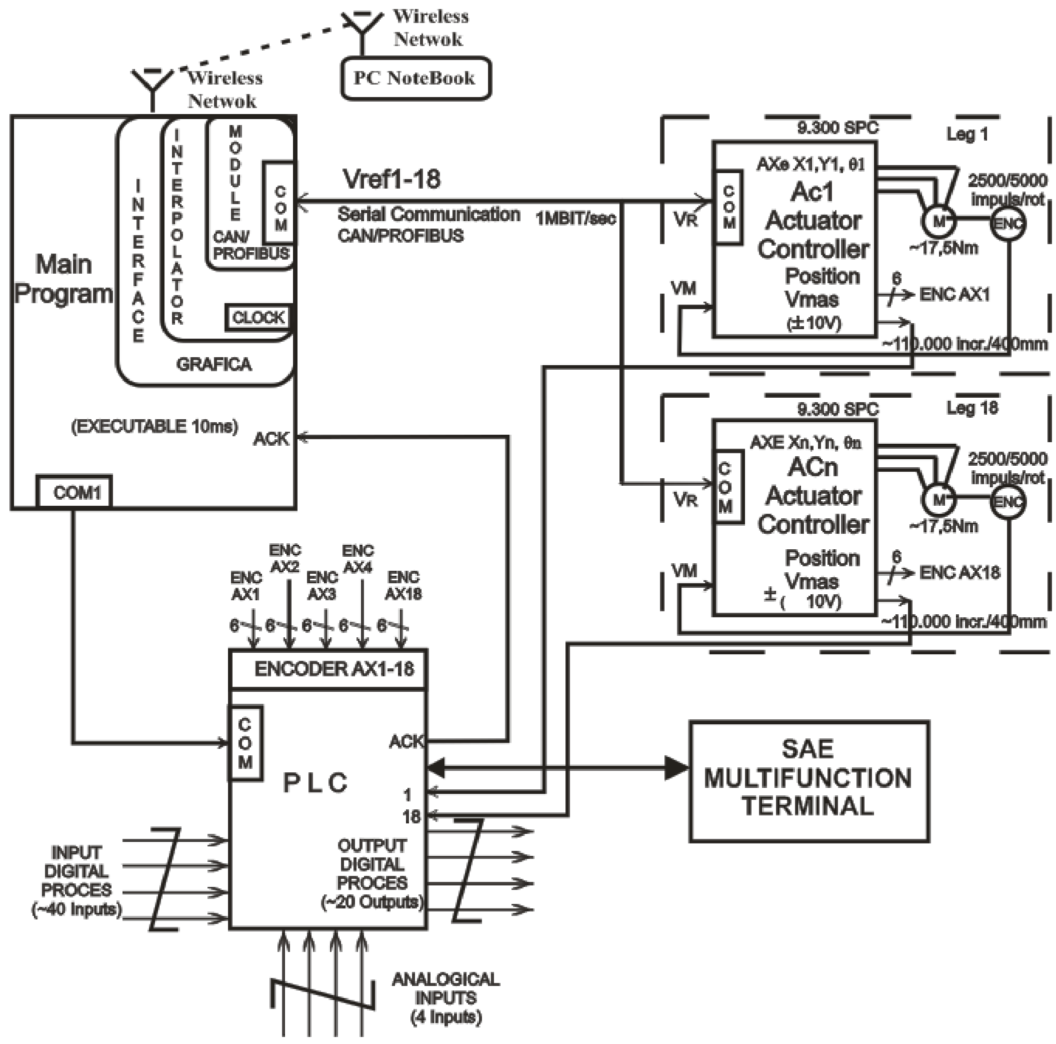
7. Results and Conclusion



Results and conclusions.

- The research evidences that stable gaits can be achieved by employing simple control approaches which take advantage of the dynamics of compliant legs.
- The compliant control system architecture was completed with tracking functions for HFPC walking robots through the implementation of many control loops in different phase of the walking robot, led to adapt the robot walking on sloping land, with obstacles and bumps.

7. Results and Conclusion

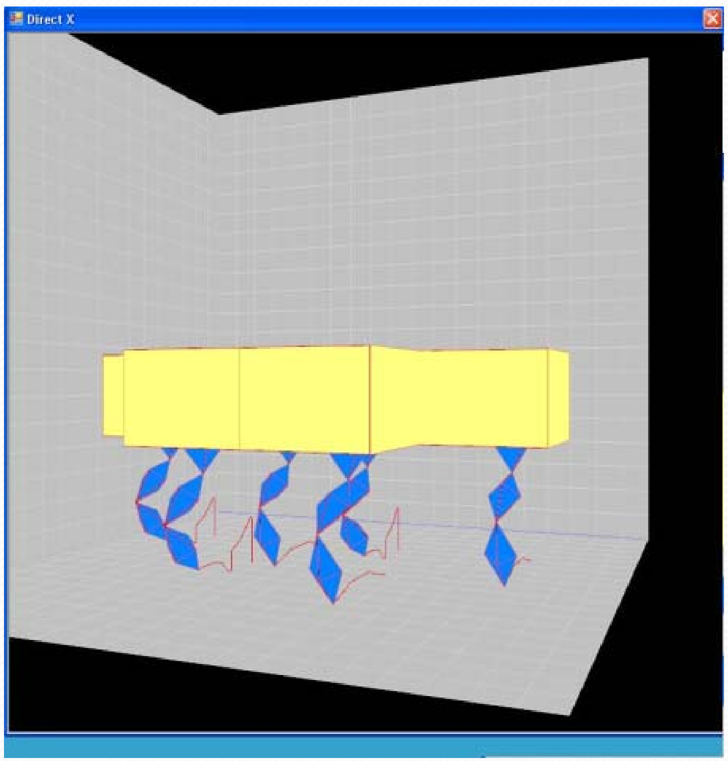


Results and conclusions.

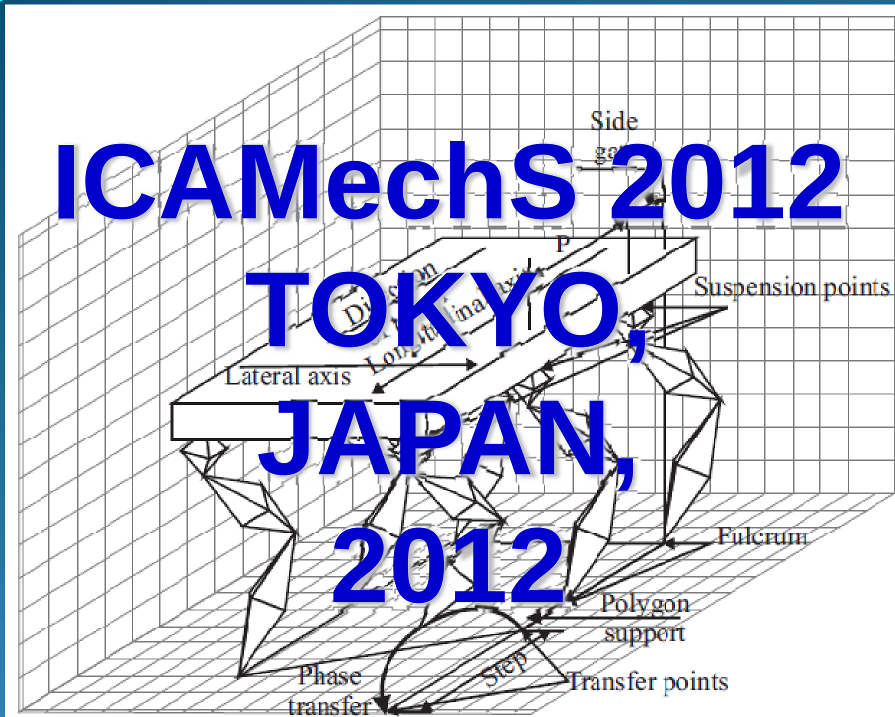
- The control system is distributive with multi-processor devices for joint control, data reception from transducers mounted on the robot, peripheral devices connected through a wireless LAN for off-line communications and CAN fast communication network for real time control.
- Distributed control system architecture was integrated into the HFPC architecture so that it can be controlled with high efficiency and high performance.

7. Results and Conclusion

View from the right side camera movement



The results obtained through simulation and experiments show an increase in mobility, stability in real conditions and obtaining of high performances related to the possibility of moving walking robots on terrains with a configuration as close as possible to real situations, respectively developing new technological capabilities of the walking modular robot control systems for slope movement and walking by overtaking or going around obstacles.



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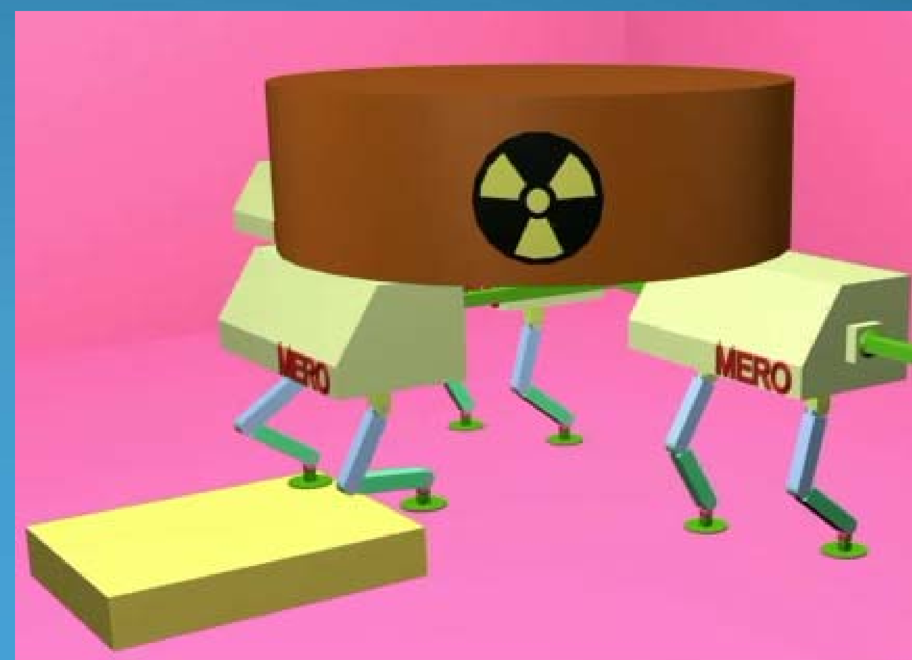
HFPC Walking Robots



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Thank you for your attention

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