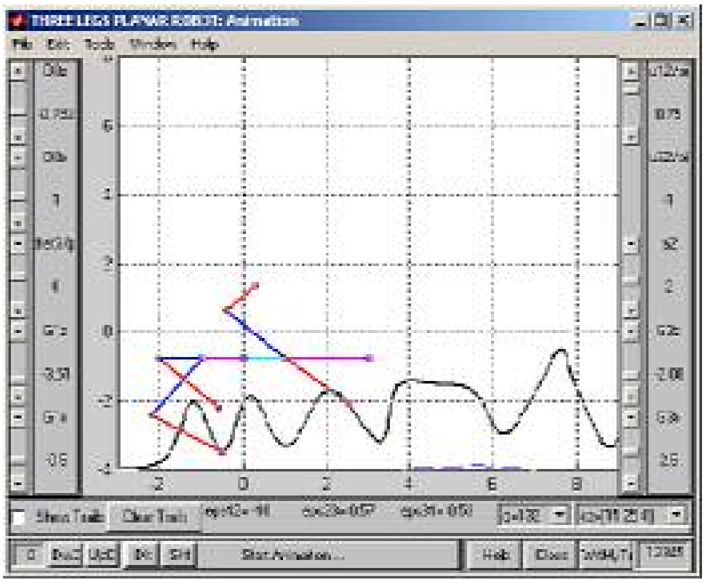
UNIVERSITY OF CRAIOVA
Faculty of Automation Computers & Electronics

Eng. Anca PETRIŞOR

ALGORITHMS FOR WALKING ROBOTS CONTROL UNDER THE EXISTENCE OF UNCERTAIN DYNAMIC MODELS

Summery of PhD thesis



Scientific coordinator
Univ. prof. dr. eng. Mircea IVĂNESCU

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KEY WORDS: mathematical model, walking robots, control algorithms, causality ordering, mobile robots, suboptimal trajectories, fuzzy control algorithms.

Chapter 1

GENERAL APPROACHES OF ROBOTS MOTION PLANNING

1.1. Up-to-date knoledgement on walking robots evolution

It is presented an analysis of the achievements in walking robots field and are specified the mains research directions in this field.

1.2. Fuzzy logic approach of motion planning and control

It is approached the robots motion planning problem witch evolves in uncertain environments. Are presented some notions, definitions and theorems existing in the speciallity literature regarding the problem of the planning and control robots motion in uncertain environments, to accomplish some goals, using fuzzy logic.

Starting from the researches concerning of using fuzzy logic in mobile robots control complex process, it is interpreted this control philosophical from a systemic point of view.

1.3. Algorithm for mobile robot control in uncertain environments

All the theoretical aspects presented in §1.1. are developed, in the following, in two stages. In the first stage is determined the crisp mathematical model and then it is combined with the environment uncertain where it evolves. In the second stage the mathematical model of the mobile robot is incorporated in local and recent geometry determined by environment evolution.

In this context it is proposed a mobile robot control algorithm in uncertain environments and a method to establish the trajectory of evolution.

1.4. The mobile state representation in local and recent space by circular scanning

Using circular scanning of the evolution space, by some Matlab programs are determined the signature in local and recently geometry. Signature which specifies the mobile robot position in local and recent geometry is represented in this paper by four figure types, both in cartesian and polar coordinates.

Based on this signature are established the landmarks followed by the robot during it's evolution between the obstacles.

In the paper is illustrated the proposed algorithm considering an evolution trajectory formed by nine linear segments.

It was also conceive the animation program by which it is possible to visualize the evolution trajectory of the mobile robot, from the initial point to the target point, in accordance with the previous proposed and implemented algorithm.

It is accomplished the proposed objective for this chapter, that is to present a possibility to determine the trajectories of robot evolution which must accomplish an elementary goal.

In the next chapter it is developed fuzzy logic algorithm of the mobile robot which efectively follows a trajectory obtained in this planning stage.

Chapter 2

FUZZY SYSTEMS FOR ROBOTS MOTION CONTROL

2.1. Fuzzy systems equivalent representations for robots control

In this part, considered as first part of this chapter, are presented some fundamentals elements of fuzzy logic controller (FLC), specially insisting on the inference aspects.

2.2. Fuzzy motion robot control in uncertain environments

In the second part of this chapter is developed fuzzy control algorithm of the mobile robot on the desired trajectory. It is considered the desired trajectory as suboptimal one regarding the shortest way. Some trajectories sections are approximated by polynomial witch parameters are determined for ensure the evolution continuity and for avoiding the obstacles.

In this context is established the mathematical model of the mobile robot with four wheels, interpreted as variable causality system, for both causality ordering with back motion wheels and with front motion wheels.

Also, are established the evolution equations of the robot, from an initial state to a final one and the algorithm which ensure the robot direction of evolution on the optimal desired trajectory.

Following, to achieve a fuzzy control algorithm of the mobile robot, is proposed an adaptive fuzzy control structure. The base of rules contains 20 fuzzy rules. Its size depends of a new input variable in fuzzy logic controller (sense variable) and also of the calculus time.

Finally, using Matlab environment are presented and analyzed two types of examples regarding the way in which the mobile robot found and followed the desired trajectory. First, the trajectory consisted a second degree curve and in the second way it is formed by a lot of linear segments.

The originality of this chapter consists of the interpretation of the mobile robot and of the trajectory as variable causality dynamic systems. Because of this last interpretation, the mobile robot identifies the initial disturbed state and also the nearest segment of the trajectory, then follows the other segments of the trajectory without losing its control, in accordance with the equation state evolution on the trajectory.

Chapter 3

GAITS OF A HEXAPOD ROBOT FOR IRREGULAR TERRAIN

3.1. Geometry of four standard obstacles for an irregular terrain

In Chapter 3, gaits over three dimensional irregular terrain are studied. Since the variety of irregular terrain is unlimited, it is difficult to cover all the different cases of the walking over irregular terrain.

In order to study this problem the real terrain features are simplified into geometrical features. The geometrical feature types chosen for study are: a gradient, a ditch, a vertical step and an isolated wall**.**

3.2. Geometrical parameters of the hexapod robot

As a general walking robot model is chosen a hexapod structure.

3.3. Gaits for walking on a gradient

For this obstacle, gait stability for walking on a gradient and strategies to improve the stability are studied. The maximum gradient which can be traversed in different methods are also calculated.

The two strategies can be used to improve stability when walking on a gradient are: walking on a gradient by adjusting the walking height and/or body attitude and walking on a gradient with adjustment of the beginning and the end of the stroke.

3.4. Ditch crossing

An idealized ditch it is complety described by one parameter which is the width of the ditch.

There are two methods for a walking robot to cross the ditch. If the ditch is relatively narrow, a walking robot can step across it in a periodic gait. If the ditch is wider than can be handled using a periodic gait, a large obstacle gait should be used. A general approach to the formulation of a large obstacle gait is also discussed.

3.5. Vertical step crossing

In this section, vertical step crossing of a hexapod with a large obstacle gait is studied.

A vertical step it is fully defined by one parameter which is the step height. Crossing a vertical step is more complicated than crossing a ditch. The foot ranges in the vertical direction, which are called the vertical ranges, are first studied in the three phases. The motion between the corresponding foot conditions is then studied. The case of descending are included.

3.6. Isolated wall crossing

An isolated wall is defined by two parameters: the thickness and the vertical heigh. In general, an isolated wall crossing is a combination of a step ascent and descent. If the thickness is sufficient for two pairs of feet to be supported on the top simultaneously, the wall crossing is exactly the same as step ascent followed by descent. If the thickness is smaller, a special method is needed for the crossing.

This chapter makes the connection with the following chapter in which are proposed and analyzed a new approach of the walking robot control, in environments with this obstacle types.

Chapter 4

LOCOMOTION ALGORITHMS

This chapter is representative, entirely original, well structured and justified.

In this chapter it is proposed and analyzed a new approach of the walking robot control in uncertain environments, called Stable State Transition Approach (SSTA) by which both the type and the steps sequence and the evolution in each step are determined by the environment evolution and by the objective proposed in evolution. This original approach is dominated by the robots representation as dynamic systems with variable causality (VCDS-Variable Causality Dynamic Systems).

First, it is considered a walking robot structure having three normal legs and a vertical plane evolution. Then, all the results obtained for this particular case is extended to the three-dimensional space evolution.

4.1. WALKING ROBOT CONTROL IN UNCERTAIN ENVIROMENTS USING STABLE STATE TRANSITION APPROACH (SSTA)

It is considered a walking robot structure having three normal legs and a head equivalent to another leg containing the robot centre of gravity placed in its foot. The robot body is characterized by two position vectors and the leg joining points denoted. It is considered the vertical evolution. All the points in the xz-plane are considered as being complex numbers.

The robot position in the vertical plane is defined by the pair of the position vectors, O^0, O^1 where $|O^1 - O^0| = 1$, or by the vector O^0 and the scalar θ, the angular direction of the robot body.

Each of the four robot legs is characterized by a so-called Existence Relation depending on specific variables. The mathematical model of this object is a Variable Causality Dynamic Systems (VCDS) and it is analyzed from this point of view.

The walking robot evolution is depended by the so-called active legs which achieve the movement and condition the system stability. For a robot plane evolution there is only one active pair of legs and for a three-dimension robot evolution is only a tuple of active legs.

A pair of legs $\{L_i, L_j\}$ constitutes the so called Active Pair of Legs (APL) if the robot body position is the same irrespective of the feet position of all the other legs different of L_i and L_{j}.. A label is assigned to each possible APL. The APL label is expressed by a variable q called Index of Activity (IA), which can take N_a values, numbers or strings of characters. All the other legs that at a time instant do not belong to APL are called Passive Legs (PL). The leg in APL, having a free joining point (FJP) is called slave leg, the opposite of the motor (or master) leg whose both joining points are external controlled (EC).

In the paper it it performed a detalied analysis for the VCDS systemic representation of a robot leg which is a Two Joint Arms kinematics structure.

A very difficult problem, connected with the kinematics restrictions existence can be solved by VCDS representation.

Starting from the VCDS representation of a robot leg, it is determined the mathematical VCDS model of the walking robot and it is analyzed the relationships between the terminal variables of one pair of legs for different types of causality orderings: causality ordering of one rigid active pair of legs , causality ordering of one active pair of legs with one free joint, causality ordering of one active pair of legs with three free joint and causality ordering of one active pair of legs with four free joint.

The results obtained in the walking robot VCDS modeling are used for its control algorithms development. Control system of the walking robot has a specify character established by two aspects: the mathematical model of the walking robot and the type of specifies walking robots movements.

A different problem solved in the paper is that of the controlability domains.

For the SSTA control algorithm are necessary sections in the controlability domains. It is then presented the implementation algorithm for the SSTA strategy.

All the controls, both the steps sequence and the step evolution are determined by the control process objective and by the environment evolution, without having pre-established structures.

The mathematical model on VCDS allows the best implementation of the robot behavior. Based on relations obtained it was conceived and implemented computers programs for simulation and control.

4.2. TRIDIMENSIONAL SPACE WALKING ROBOTS CONTROL, WHEN EXISTING SOME UNCERTAIN ENVIRONMENTS

All these results, obtained for this particular case, are extended in this second part of this chapter for the evolution in {x,y,z} three-dimensional space, considering that the environment evolution is characterized by the same z height whatever y coordinate be.

Chapter 5

SIMULATIONS AND RESULTS

In this chapter, entirely original, is analyzed a study of the walking robot evolution presented in §4.1, using MATLAB programs. It is conceived a graphical interface under MATLAB environment, for modeling and simulation walking robots, which allows easily pick out of different types of dependencies for visualization.

The theoretical results concordancecoincide with those obtained by simulation and confirm the considered calculus ipothesis and the conclusions.

The paper is finalized with a conclusions and contributions chapter.

CURRICULUM VITAE

Name: *PETRIŞOR*
Surname: *ANCA*
Birthday: *25-th of may 1963*
Address: *Romania, Craiova city, Vrancei street No. 22*
Civil status: *married, one daughter*
Nationality: *Romanian*
Job: *University of Craiova, Faculty of Electromechanics, Department of Electromechanics*
Occupation: *Diplomat Engineer*
Telephone *+(40) 51 411039 (home). +(40) 51 435255 (job)*
Fax: *+(40) 51 435255*
E-mail: *apetrisor@em.ucv.ro*

Basic education:

" Nicolae Bălcescu"- Craiova, secondary school

University of Craiova, Faculty of Electrotechnics, Department of Automation and Computers, class 1988;

PhD Study

PhD student engineer, "Automation" specialty, Faculty of Automation Computers & Electronics - Craiova, PhD scientific coordinator: univ. prof. dr. eng. Mircea Ivănescu.

PhD thesis name: "Algorithms for walking robots control under the existence of uncertain dynamic models".

Exams of training period: Robotics, Linear systems theory, Nonlinear systems theory.

Essays of training period: Cinematics models of the robots, Algorithm and control systems, Control algorithms for uncertain models.

The date of the PhD thesis presentation in Mecatronics department: 19-th of July 2004.

The date of the PhD thesis public presentation : 3-rd of December 2004.

Scientific title:

Engineer, University of Craiova, Faculty of Electromechanics, Department of Electromechanics.

Membership of scientific and proffesional associations :

- Romanian Society of Automation & Technical Information *SRAIT ;*
- Romanian Society of Robotics *SRR.*

Profesional experience :

- *Project engineer, M.E.R. department, I.C.M.E.T., Craiova, 1988-1992 ;*
- *Engineer, University of Craiova, Faculty Electromechanics, Department of Electromechanics from 1992.*

Scientific experience*:*

- 14 scientific papers published at internationals conferences;
- *5* scientific papers published at nationals conferences;
- 4 scientific papers published in profile magazines;
- 8 scientific research contracts ;

- *Didactics:*
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  3. ***Anca Petrişor**, G. Militaru –Grafică asistată prin AutoCAD, Îndrumar de laborator, Reprografia Universitatii din Craiova, 1994.*
- *Course notes:*
  1. *Grafică asistată prin AutoCAD*

Scientific skills*:*

- Computers
- Robotics
- Fuzzy control systems.