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Generalized model of cyclic dispatching discipline in mobile robots based on swarm systems

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Abstract

The problem of dispatching discipline choice when managing programs are linked into unified multi-loop computer control system is considered. It is shown that a problem of control of such a system may be reduced to the problem of evaluation of states both robot and controller. In multi-circuit computer control systems time intervals of residence of robot in any state depends on both time complexity of control algorithm and dispatching discipline. Two simplest disciplines of most common use are investigated: the cyclic dispatching and foreground (quasi-stochastic) one. With use the formalism of semi-Markov process models of functioning of control programs under investigated dispatching disciplines are worked out. Mathematical relationships for time of return to any state of semi-Markov process and time between switches are obtained. The parameters obtained are essential for choice the efficient regimes of data processing when control of robots.

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1. Introduction

Main feature of computer control system of robots is their multi-functionality. When multi-circuit object is under digital control emerges the task of evaluation of system states in every current time. As a rule, in real single-processor control systems operation of managing software modules resides under control of the dispatching program, which defines, what module must be executed the next [1,2,3].

Organization of priorities of programs execution is defined by discipline of dispatching. Due to the features of robot (constrained number of modules, rigid limits for time complexity, etc.) discipline of dispatching must be extremely simple [4,5].

One of the features of operation of onboard computer, which control a functioning equipment of robots, is a steady data stream between them, sensors and servos. In the case it is expedient to apply the cyclic scheduling disciplines. In such routines no task has advantages over the other. Program launching is implemented on timer (synchronous disciplines) or on signals of feedback, after completion of previous program (asynchronous disciplines).

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Priority scheduling disciplines also are applied for operation with steady data streams, but the programs are executed in routine, defined with predetermined priorities. First of all are processed data with highest priority, and then - with lower. Data processing lasts until the list of tusks in queue complete, or finish time of cycle. For steady functioning of digital control circuits both programs of processing of signal with wider spectrum (consequently with higher sampling frequency) and programs with lower computational complexity would have higher level of priority. Despite of rigid content of dispatching algorithms for external observer sequence of execution of programs in onboard computer is unpredictable. This fact permits to call this scheduling discipline the quasi-stochastic one.

Exactly because the simplicity of their realization and stability of operation, cyclic and quasi-stochastic scheduling disciplines are rather of widely used in a control systems of robots. When soft of robots is designed, functioning of dispatching programs is planned in advance: demands to sampling frequency and semantic of signals processing is defined, and schedule prepared with taking into account time characteristics of system and applied software. So for proper planning of computational process time coordination of functioning of control circuits is necessary, and evaluation of time factor of soft is quite actual task. When evaluation of time factor it is necessary to divide functioning of robot onto the states and to define both the residence of robot in its states and switching the states of robot.

It is possible to evaluate the system states when there is proper approach to simulation of software operation. The fundamental theory of semi-Markov process is widely used for such purpose. So, the fundamental theory of semi-Markov process may be used for obtaining necessary expressions[6,7,8].

2. Generalized Models of Cyclic and Foreground Dispatching Disciplines

Models of cyclic and foreground dispatching disciplines are different in principle.

In cyclic (simplest) discipline software modules are executed in turn, one after another. Order of priority is exactly pre-determined. Generalized structure of such order is shown on fig. 1, where $A_1, \dots, A_m, \dots, A_M$ – are the software modules of robot.

In foreground disciplines there is no strict sequence on starting of software modules. In embedded systems order of execution is determined by current condition of units under control[9]. Due to the fact proper software module may be starts up in any time.

The models of both disciplines are formed from semi-Markov processes

$$\mu_m = \{A_m, \boldsymbol{h}_m(t)\}; \quad 0 \le m \le M, \tag{1}$$

where A_m – is set of states of m-th process; $\boldsymbol{h}_m(t) = \lfloor h_{j(m),n(m)}(t) \rfloor$ – is semi-Markov matrix; t – is the time; $1 \le j(m), n(m) \le J(m)$.

Without loss of generality it is possible to assume that in set $A_m = a_{1(m)}, \dots, a_{j(m)}, \dots, a_{J(m)}$ state $a_{1(m)}$ – is the initial one, and state $a_{J(m)}$ – is the absorbing one (fig. 1)[10]. Due to the fact that semi-Markov processes μ_m are the models of real software modules of embedded systems, each state of subset $a_{2(m)}, \dots, a_{j(m)}, \dots, a_{J(m)}$ is attainable from $a_{1(m)}$, and state $a_{J(m)}$ is attainable from $a_{1(m)}, \dots, a_{j(m)}, \dots, a_{J(m)-1}$. Thus in semi-Markov matrices $\boldsymbol{h}_m(t) h_{j(m),n(m)}(t) = 0$ when $0 \le j(m) \le J(M)$.

With use formulae, which were obtained in[11], time of reaching $a_{J(m)}$ from $a_{1(m)}$ may be defined:

$$f_m(t) = L^{-1}\left[{}^1\boldsymbol{I}_{1(m)} \cdot \sum_{k=1}^{\infty} \{L\,[\boldsymbol{h}_m(t)]\}^k \cdot {}^C\boldsymbol{I}_{J(m)} \right] \tag{2}$$

where ${}^1\boldsymbol{I}_{1(m)}$ – is the row vector in which first element is equal to one, and all other elements are equal to zeros; ${}^C\boldsymbol{I}_{J(m)}$ – is the column vector in which $J(m)$-th element is equal to one, and all other elements are equal to zeros; $L\lceil \dots \rceil$ and $L^{-1}\lceil \dots \rceil$ – are direct and inverse Laplace transforms, correspondingly.

Expectation and dispersion of time of reaching $a_{J(m)}$ from $a_{1(m)}$ are the next

$$T_m = \int_0^{\infty} t \cdot L^{-1}\left[{}^1\boldsymbol{I}_{1(m)} \cdot \sum_{k=1}^{\infty} \{L\,[\boldsymbol{h}_m(t)]\}^k \cdot {}^C\boldsymbol{I}_{J(m)} \right] dt;$$