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Navigation equipment test table multi-agent computer-aided design system architecture

A new approach of reinforced learning multiagent design of navigation inertial unit dynamic test table is proposed. The test bench is a complex mechatronic system that requires simultaneous optimization of parameters related to different disciplines. This paper presents a new architecture of the multi-agent model based on the test bench design process. The use of reinforced learning and game theory is intended to solve the problem of coordination and optimal decision-making in the process of test bench design.

Multi-agent computer-aided design system.

Procedures for the development of test table (TT) used in practice in the engineering industry can be described in accordance with the general model of procedures of the VDI 2206 standard. During the development of TT, the complex functional structure of it leads to the emergence of many tasks that require competencies from different disciplines. As a rule, the tasks of mechanical design, electrical design and control system design are solved by departments that are divided by the organization of processes in a very sequential development process. In order to shorten the development time, the process of simultaneous and integrated processing of all subtasks and stages using co-development methods is used. The use of standard externally supplied components or complete functional units such as rotary tables or drive control systems is common.

The TT design process consists of the following stages:

1.Development of the design task:

- Determination of target cost, performance characteristics, operating conditions, test tasks, degree of automation.

2. Preliminary design:

- Selection of the type of dynamic tests.
- Determination of the type of TT and number of gimbals.
- Selection of type and number of devices for installation of navigation equipment on the TT, devices for connection to the data processing system and necessary additional equipment.
- Means of movements of individual components of the TT.
- Determination of the spatial position of the axes of movement.
- Selection of feedback sensors and motors.

3. Detailed designing:

- Selection, determination of dimensions and spatial position that determine the design of TT components: components such as sensors, motors, elements for installation of navigation equipment.

- Connections that define the structure of the components through the gimbal components. These are components that depend on the shape of the TT elements.
- Selection and dimensioning of the appropriate gimbal frame structures, functionally determined openings and detailed geometric shapes for gimbal components and supporting structure

4. Preparation of TT for production:
   - Geometric detailing in specialized CAD systems.
   - Preparation of production specifications of TT.
   - Detailed definition of the exact structure of the TT subsystems.

The restrictions imposed by the requirements for testing a particular type of navigation equipment are the main ones for the preparation of the technical task for the design of the test table.

The task of designing the test table is to identify the properties of the test complex that would ensure its maximum efficiency in any application conditions.

The formalization of the problem of optimization of the design parameters of the test table using CAD design methods can be presented in the form:

$$x = \underset{x \in \Omega,\ y}{\arg\ extr} \{C, M, A, T, R\}$$

$x = opt;\ C = min;\ M = max;\ A = min;\ T = max;\ R = max,$

where x, C, M, A, T, R - design parameters; cost; weight of the tested equipment; maximum deviations of parameters from the specified; durability; reliability, and corresponding criteria constraints $y = \{y_{Cmin} \leq y_C \leq y_{Cmax}, y_{Mmin} \leq y_M \leq y_{Mmax}, y_{Amin} \leq y_A \leq y_{Amax}, y_{Tmin} \leq y_T \leq y_{Tmax}, y_{Rmin} \leq y_R \leq y_{Rmax}\}$, and $\Omega = \{x | x_i \geq 0, x | x_{imin} \leq x_i \leq x_{imax}, i \in [1, n]\}$, x is a vector of design parameters and constraints represented by a set of n elements.

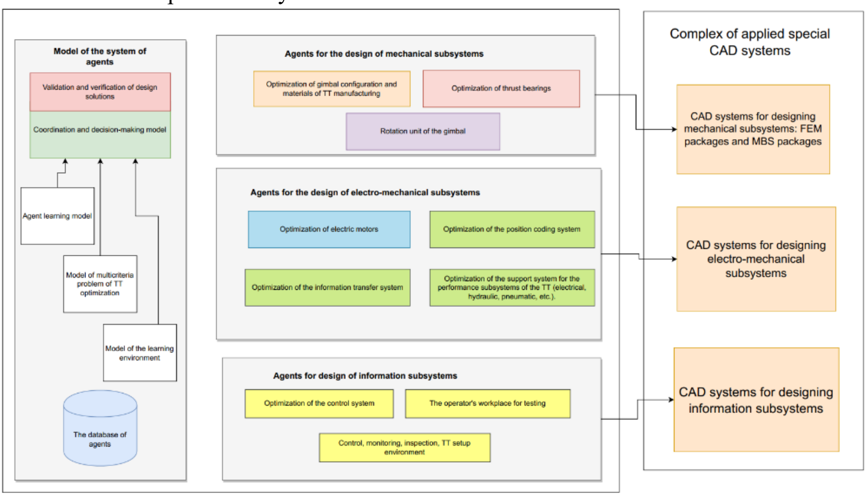

Fig. 1. Computer-aided design system of TT design

Fig. 1 shows the proposal of a system model of the process of development of navigation equipment test table. Based on the consideration of the TT as a mechatronic system as a whole and using the RAMI 4.0 model, a procedure for the structured processing of the task of designing and manufacturing navigation equipment test table is proposed, which is based on a common design system in accordance with the VDI 2206 directive and IEC PAS 63088.

Traditional approaches to design an optimal test table use analytical and stimulation methods. However, these approaches often require complex models with an accurate description of the characteristics and functions of the TT subsystems. The engineering design for these systems is often a crucial aspect that limits the implementation of an optimal navigation equipment test system. For these reasons, model-free design methods and new artificial intelligence algorithms are considered as a complement to existing methods.

The proposed development procedure is aimed at ensuring the characteristics of the TT at the development stage to such an extent that it is possible to reliably ensure the required performance and exclude functional defects.

First, a multi-criteria TT optimization problem is formulated in the form of an observable Markov game. Then, on its basis, an agent learning environment is created that models a network of flexible design tasks with the ability to change and improve TT subsystems. To create an agent learning model, several multi-agent tasks with goals are used, where different agents must not only learn to optimize their parameters, but also coordinate the learned strategies to achieve the game theory equilibrium condition. The result of the training and system construction is that the design agents of the TT subsystems have to coordinate to improve the parameters of the whole TT and to fulfil the design objectives. Modification measures based on the results obtained during the commissioning and testing of the real TT prototype should be kept to a minimum and limited to fine-tuning. But even these activities can be limited only to changes in software, such as parameterization of the trajectory controller of motion control, and no longer require design stages. Tests of a real TT prototype additionally allow to evaluate the results of calculations. In this context, experimental tests of the system and components are understood as integral components of the development methodology, which are sufficiently necessary and cannot be completely dispensed with. They serve both to continuously validate and, if necessary, improve the modelling methods and to determine parameter information that cannot be determined in any other way.

This process model can be used as a methodological basis for TT design and development in order to achieve high product quality with low development risk. At the next stage of detailing, the optimized design of the TT is completed and prepared for production. Then the process is completed with the production and commissioning of the first real sample of the TT.

Conclusions

Designing specialized intelligent CAD systems for TT is a challenging task not only because of the increasing complexity of TT and design requirements, but also because of the complex multidisciplinary process of its design. Currently, there is no generally accepted methodology for the conceptual design of mechatronic systems, and even more so for the design of TTs using AI. To support the TT design process, we have developed and presented a new approach using AI. We propose the introduction of intelligent agents to find the optimal solution of intelligent CAD subsystems. This model of the multi-agent system will allow all participants of the TT development process to use a systematic approach to the design of a three-axis dynamic test bench.

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