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Multi-agent Based Hierarchy Simulation Models of Carrier-based Aircraft Catapult Launch

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Abstract

With the aid of multi-agent based modeling approach to complex systems, the hierarchy simulation models of carrier-based aircraft catapult launch are developed. Ocean, carrier, aircraft, and atmosphere are treated as aggregation agents, the detailed components like catapult, landing gears, and disturbances are considered as meta-agents, which belong to their aggregation agent. Thus, the model with two layers is formed i.e. the aggregation agent layer and the meta-agent layer. The information communication among all agents is described. The meta-agents within one aggregation agent communicate with each other directly by information sharing, but the meta-agents, which belong to different aggregation agents exchange their information through the aggregation layer first, and then perceive it from the sharing environment, that is the aggregation agent. Thus, not only the hierarchy model is built, but also the environment perceived by each agent is specified. Meanwhile, the problem of balancing the independency of agent and the resource consumption brought by real-time communication within multi-agent system (MAS) is resolved. Each agent involved in carrier-based aircraft catapult launch is depicted, with considering the interaction within disturbed atmospheric environment and multiple motion bodies including carrier, aircraft, and landing gears. The models of reactive agents among them are derived based on tensors, and the perceived messages and inner frameworks of each agent are characterized. Finally, some results of a simulation instance are given. The simulation and modeling of dynamic system based on multi-agent system is of benefit to express physical concepts and logical hierarchy clearly and precisely. The system model can easily draw in kinds of other agents to achieve a precise simulation of more complex system. This modeling technique makes the complex integral dynamic equations of multibodies decompose into parallel operations of single agent, and it is convenient to expand, maintain, and reuse the program codes.

Keywords: multi-agent system (MAS); multi-agent based modeling (MABM); tensor; carrier-based aircraft; catapult launch; hierarchy simulation model

1 Introduction

Carrier-based aircraft catapult launch is a complex system that involves multiple disciplines. The dynamics process of launching customarily consists of the movements of ocean, carrier, aircraft, atmosphere, and all their interactions. In addition, it also involves man-machine cooperation if considering the effects of pilot and/or commander. Concretely, the deck motion, catapult power, and ground effect of deck are related to carrier; the stroke of landing gear, power of engines, and pilot handling are related to aircraft; the special wind disturbance is related to the atmosphere[1-3]. Therefore, the catapult launch of carrier-based aircraft is a typical dynamics process of multibody with different inherent frequencies. Deck motion, characteristic of

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landing gear, power of engine, and wind disturbance mainly have effects on the process.

A large effort in calculation is generally needed for the dynamic system simulation of multibody that is usually with high orders, and is difficult to be expanded or to be separated for parallel computing[4-7]. With the development of computer technology, the bottleneck of data commutation is getting through. It is necessary now to choose an appropriate simulation modeling approach for designing a computation framework, so as to resolve these kinds of problems much easier.

Many researches on the carrier-based aircraft takeoff have been carried out, usually specialized in their own fields with supposing and simplifying the effects of other domains[8-9]. In Ref.[10], the model of carrier-based aircraft ski jump takeoff based on tensor is built, which is a simulation model of multibody including carrier, aircraft, and landing gear, whereas it is still built directly using coupled dynamic equations. However, some complex problems of large systems we may encounter usually result from multidisciplinary intersection. For instance, the synthesis of aerodynamic and control system, the match between carrier and aircraft system, and the coupling between environmental and human factors. For code reuse and unified description, to build a universal flexible and expansible hierarchy simulation model of carrier-based aircraft takeoff is necessary.

In recent years, the multi-agent based modeling (MABM), for complex system has become an important topic in a number of applications. By reason of the characteristics of complex system itself, agent-based modeling and simulation turn into a new promising research approach gradually. At present, the agent-based technique has become an effective means of researching complex system and building intelligent simulation models[11-12].

Through the use of multi-agent simulation modeling technique, the research of multibody is focused on the individual physical behaviors, more factors are easily described, such as human beings and atmospheric conditions. In addition, programming an agent-based model and capturing special phenomena of nonlinear complex system are much easier. This shows it is convenient to run a large scale system simulation with high fidelity through this modeling technique[12].

The modeling of flight dynamics with tensors is a new trend with many advantages, such as distinct physical meanings, rigorously strict structure, and the invariance under time-dependent coordinate transformations. It is easy to take more factors into consideration as well, for instance the deck motion, atmospheric disturbance, and stroke of landing gears[13-14].

To study the carrier-based aircraft catapult launch, an agent-based hierarchy simulation model of multibody with tensors is proposed in this article.

2 Hierarchy Model Based on Multi-agent System (MAS)

2.1 Catapult launching system

The standard method used for launching aircraft from carrier is the nose gear launch method, in that the aircraft is coupled to the catapult by means of a launch bar and a holdback bar located on the nose gear (Fig.1). Before launching, the carrier is steered against the wind as far as possible, the engine of aircraft is set at full throttle, and the elevator is set in the right position, then a good occasion is chosen to start launching according to the pitching motion of the carrier. During launching, the tow force applied on the aircraft builds up rapidly, as soon as the load limit of holdback bar is reached, the aircraft is released and the launching run is begun. At the end of the catapult power stroke, the aircraft automatically disengages from the catapult and continues the launch with its own power, until it runs out off the carrier and climbs up. In this process, the carrier motion induces the wind disturbance, and the aircraft is affected by the deck wind and the disturbance ahead of the bow.

The whole system of carrier-based aircraft catapult launch mainly consists of carrier, aircraft, atmospheric environment, and ocean. In more detail,