Construction and Verification of Virtual-Reality-Mixed System for Bio-inspired Collective Algorithms

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ABSTRACT

There are interesting and mysterious biological collective behaviors in nature, such as ant colony foraging, bird migration, fish anti-predation, wolf hunting, etc. The principles behind the biological collective behaviors need to be explored. The research on a variety of bio-inspired collective algorithms inspired by behaviors mentioned above has attracted extensive attention. The simulation and physical platform for collective algorithm verification have been built one after another, and have been tried to be applied to task scenarios such as regional aggregation, configuration change, cooperative hunting, etc. It is difficult to accurately describe the dynamic characteristics of physical objects in the simulation verification of bio-inspired collective algorithm, and the research results are difficult to be directly transferred to scene of physical applications; However, the corresponding physical experiments have some problems, such as high cost, tedious preparation, difficult reconstruction of scenarios, and so on. During the verification process, the experimental objects are vulnerable to site constraints. Therefore, in view of the needs in the bio-inspired collective algorithm verification in large-scale swarm tasks, this dissertation builds a "Virtual-Reality-Mixed" bio-inspired collective algorithm verification system that can realize the complementary advantages of virtual and physical verification. The main work and contributions are summarized as follows:

(1) A Virtual-Reality-Mixed system for bio-inspired collective algorithm verification is constructed, which can realize the complementary effect of "virtual platform supporting group size and physical platform maintaining physical characteristics". Considering that the physical platform can reflect the real physical characteristics and task environment, combined with the advantages of the virtual platform that is easy to adjust parameters and expand the scale, the information exchange between the physical nodes composed of physical objects and the virtual nodes simulated by computer is opened up, and a set of Virtual-Reality-Mixed verification system that can verify different types of swarm intelligence algorithms is built. The system consists of a variety of modules, including the physical robot module containing the real ground robot, the physical environment module containing the visual measurement system, the virtual robot module containing the mapping of the real robot in the simulation environment, and the simulation environment module mapping with the physical environment. In order to meet the communication requirements between different modules, a communication scheme based on User Datagram Protocol and Publish-Subscribe communication mechanism is designed. For the part of physical verification, a physical verification platform based on visual measurement is built; In this paper, the ground wheeled robot is selected as the research object, the physical module based on visual measurement and the simulation module based on the Open Dynamic Engine are built, and a general process from model design to algorithm implementation is developed, which can provide platform support for

algorithm verification such as bio-inspired collective encirclement, migration, defense and other algorithms.

(2) The sensor models of vision, inertial measurement, laser ranging verified for bio-inspired collective algorithm are built, and the time, perception and motion synchronization technology based on ROS architecture between virtual environment and physical environment is studied. Facing the needs of the ground mobile platform for environmental awareness, combined with the input conditions of different types of bio-inspired collective algorithms, the sensor models of visual measurement unit, Inertial Measurement Unit and Lidar are built. On this basis, the key parameters such as the internal parameters of the camera model and the zero bias error of IMU model noise are determined, and the simulation results of the built sensor model are compared with the measurement results of the real sensor to verify the authenticity and reliability of these models. Aiming at the problems that the robot and environment of virtual platform combined with virtual platform and physical platform have systematic errors and various physical parameters cannot be completely consistent, the synchronization verification of physical platform and virtual platform is carried out. Time stamp synchronization method is used to realize time synchronization between platforms, data fusion method is used to realize perceptual synchronization, and coordinate transformation and motion tracking control method are used to realize coordinate unification and motion synchronization. The effectiveness of the synchronization technique is verified by a random walk example of a cluster of 100 large-scale ground mobile robots.

(3) The comprehensive experiments of three kinds of algorithms based on the bio-inspired collective Virtual-Reality-Mixed system, respectively group hunting, group migration and group defense, are carried out to verify the applicability and scalability of the swarm scenario of the Virtual-Reality-Mixed system. Based on the Virtual-Reality-Mixed verification system built in this dissertation, the typical functions of the physical environment are reproduced in the virtual environment, and the Virtual-Reality-Mixed experimental verification of the bio-inspired group hunting algorithm based on the artificial potential field method inspired by the wolf swarm hunting is carried out in this environment, which preliminarily verifies the effectiveness of the system for the verification of bio-inspired algorithm; The verification of distributed configuration algorithm of ground robot based on visual measurement inspired by bird migration was carried out. The algorithm verification starts from the experimental scene, solves the problem of large difference in site size between the virtual environment and the physical environment through equal scaling, and completes the algorithm verification through the combination of virtual and real experiments, which reflects the scalability of the system built in this dissertation to the bio-inspired algorithm of visual measurement; Inspired by ant colony defense, the distributed configuration algorithm is adopted, and different numbers of ground robots are used to carry out the bio-inspired collective defense

algorithm verification in the Virtual-Reality-Mixed system, which verifies that the Virtual-Reality-Mixed system has the ability to support the verification of large-scale collective algorithm.

Key Words: Biological collective behavior, Bio-inspired collective algorithm, Ground robots, Virtual-Reality-Mixed