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【学位論文内容の要旨】

In the twenty-first century, the percentage of ageing population is increasing not only in the developed country and apparently in the developing country as well. Nearly in the future, all countries will be facing similar situation although the level of intensity and time frames are varies between each countries. This scenario will lead economic, political and social problem such as extension of retirement and pension, rising medical cost and increasing demand in health care service. Increasing number of the elderly people around the world becomes the main reason for humanoid robot research in these recent decades. This is the reason why humanoid robot researches are still needed even though there are numbers of established platform developed by universities and companies. This scenario inspired us to contribute in this field of research by developing a new mobile humanoid robot for assisting elderly people.

In performing domestics task such as cleaning, picking and carrying food or household item from one room to another, a mobile humanoid robot are required to have high mobility, and ability to manipulate object in optimized manner. There are numbers of constraints and consideration need to be considered to perform these tasks such as unknown environment, obstacles avoidance, object recognition and manipulation, the execution time, safety features and understanding human instruction. In this thesis we investigate the performance of the proposed neural controller in simulation environment and on the newly developed mobile humanoid robot. Single and multi-objective evolutionary algorithms are adapted to the system for robot manipulation and arm motion generation.

The main advantage of our method is that we employ a single neural controller for

each objective function to generate the robot arm motion in a wide range of initial and goal location. These different criteria will make the robot more intelligent when choosing the best objective function for the given task. The evolved neural controllers for the humanoid robot arm motion satisfying three conflicting objectives; minimum time, minimum distance and minimum acceleration. Another advantage of the proposed algorithm is the ability of MOEA to find multiple Pareto optimal solution in a single run. In addition, some neural controllers optimize simultaneously multiple objectives. The joint angles are acquired directly from the real robot and from these data; angular velocity, end effector velocity and acceleration are calculated. The joint angular velocities are used in the simulation and experiment to generate the kinematic properties of the robot hand.

The performance of the mobile humanoid robot is tested in a series of experiments. Initially the robot arm motion is generated via neural controller optimizing single objective function. Four different criteria are selected namely; minimum execution time, minimum distance, minimum acceleration and minimum angular acceleration. These criteria are chosen based on human arm motion while doing everyday life activities such as picking, placing and pushing. In our method we evolved a neural network that generates the best robot motion for each objective function.

The performance of our robot arm is further tested by generating the robot arm motion optimizing multiple criteria simultaneously. The motions are generated via multi objective genetic algorithm (MOGA) optimizing three criteria which are minimum execution time, minimum distance and minimum acceleration. The performance of the optimal controllers are tested and compared with one extreme solution which is similar to single objective optimization.

The level of difficulties of the robot arm motion generation are increased by considering obstacles avoidance and randomized initial and goal position. Two set of neural controllers are generated for picking and holding motions of left and right hand. The performance of the optimal solutions is tested by choosing three different position of the object on the table. In simulation, the positions are randomly chosen but in the experiment, the object is detected using laser range sensor.

In the final test, the mobile humanoid robot is required to perform a simple domestic task of picking a spray can on a table located in one of our lab room. The robot has to navigate its way from the lift into the lab room avoiding any obstacles. Once it enters the room, the robot need to move near the table and perform a picking task. The spray can will be detected using laser range sensor and once the position is determine, the robot will choose which hand to perform the pick and hold task.

The performance of the generated neural controllers shows good results both in simulation and on the real robot. The real robot arm can adapted the same neural controllers for a wide range of initial and goal positions. In the future the object recognition algorithm can be improved in order to have a wide range of different object detection. The robot navigation system can be more robust and has the ability to move in an unknown environment. An improved gripper design can also be considered in the future for better manipulation capability.

【論文審査の結果の要旨】

当学位論文審査委員会は,標記の博士学位申請論文を詳細に査読し,また論文発表会を平成 26 年 2 月 4 日(火)に公開で開催し,詳細な質疑を行って論文の審査を行った。以下に審査結果の要旨を記す。

近年、世界的に高齢化が進んでおり、高齢者に対する身体的ないし経済的な補助が急務となっている。若年者は、清掃やゴミ出し、物の運搬といった家事を容易に行うことができるが、高齢者は、身体能力の低下のためにこれらの動作を行うことが困難となる。よって、高齢者を日常的に補助するための、個人用介助ロボットの需要が高まっている。

介助ロボットは、一つの動作を繰り返し行うものよりも、様々な動作を行うことが期待されるが、ロボットの腕部の動作は特定の動作を基準として生成されることが好ましい。本論文では、ロボットの腕部動作生成のための最適化手法について検討した。本論文における提案手法は、最少時間と距離、加速度の 3 つの目的関数を最適化することで、動的環境におけるロボットの腕部動作を生成することができる。また、1 つの多目的進化型アルゴリズム (Multi-objective Evolutionary Algorithm: MOEA)によって複数のニューラルコントローラを生成することが可能である。加えて、ニューラルコントローラはロボットの動作開始地点と終了地点を変更しても、利用することができる。

本提案手法を実装するための人型ロボットを構築した。ロボットは、物体を操作するための上半身と移動のための下半身の 2 つから構成されている。上半身の自由度は、2 自由度の頭部と把持部を含む 10 自由度である。また、センサとしてステレオカメラと 2 つのレーザレンジファインダが設置されており、これらを用いて、物体認識と定位、移動を行うことができる。

提案手法を検証するために、ニューラルコントローラをシミュレーション環境で進化させ、ロボットに実装した。結果として、ロボットは良好に腕部動作を生成することができた。シミュレーション環境と実環境では差があるものの、ロボットはシミュレーション環境で獲得した腕部の軌道を保ちつつ、良好にタスクを実行することができた。

学位申請論文で提案したアルゴリズムは非常に有効で, 工学的応用のみならず, 学術的にも価値が高い。

よって, 当博士論文審査委員会は本博士学位申請論文が学位を授与することの十分値するものと認め, 合格と判断した。