論文の内容の要旨

Imitating Human Regrasping Movements with a Robotic Hand using Tangle Topology

（ タングルトポロジーを用いたロボットハンドによる
人間の持ち替え動作の模倣 ）

氏　　名　　ビナヤウェキン　　ポンタリン

There have been many developments of anthropomorphic robotic hand in recent years. These hands have become very advanced in term of the hardware. They have also become more and more similar to human hand. Unfortunately, there are only a few evidences that have displayed the capabilities of their usages due to the lack of efficient method to control them. This thesis proposes a methodology to control these robotic hands through human demonstration. The method focuses on a dexterous manipulation of a hand referred to as regrasping. Regrasping is an ability of a hand to change its grasping posture with an object by moving the fingers. The proposed method teaches a robot to imitate these movements. It allows a robot to observe a human perform regrasping movements, recognise, and finally reproduce the regrasping movement.

The proposed method is based on a representation referred to as tangle topology. Tangle topology is a representation that derived from a numerical invariant that describes a relation between two curves called Gauss Linking Integral (GLI). When hand and a manipulated object are considered as strands, it allows regrasping movements to be perceived as a change of tangle relation over time. The tangle relation is described by an attribute called writhe matrix. Writhe matrix is categorised into two types, which distinguish a contact relation between the hand and object. Using this topological information, movement primitives for recognising regrasping movement and skill parameters for mapping each movement primitive to a robotic hand are defined.

Three movement primitives are defined based on changes in type of writhe matrices during regrasping. The regrasping movement is first segmented into smaller segments using parameters that describe writhe matrix. Then by considering the change in type of writhe matrices, each small segment is recognised into a movement primitive. Once all movement primitives are recognised, the original regrasping movement can then be represented as a sequence of movement primitives.

To reproduce a regrasping movement, all movement primitives that represent the movement must be sequentially mapped to a robotic hand. Skill parameters for all movement primitive are observed and extracted from human demonstration. They are key information for mapping the movement primitives to a robotic hand. Skill parameters are defined differently for each type of movement primitive. A method to refine the observed skill parameters is also given to make them suitable to be used during mapping process. Movement primitives are mapped to a robotic hand in topological space. A method to interpolate writhe matrix from its initial to final state is given. A trajectory of the hand for each movement primitives is generated by following these intermediate writhe matrices.

The proposed methodology is validated by reproducing a regrasping movement in a robotic hand. Human regrasping movements of a pen-like object are considered. A custom-made robotic hand is attached to the Mitsubishi PA-10 robotic arm to maneuver and reproduce the movements. The successful reproduction of the regrasping movement verifies the proposed methodology to be useful and proved that it is feasible to control a robotic hand by imitating human.

In short, this thesis describes a novel method to control a robotic hand by imitating human movement. It focuses on hand movements referred to as regrasping movements. The thesis shows that by observing and representing human movements as a sequence of movement primitives, a robot can duplicate the movement on its hand.