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An Information-theoretic Approach to Origami Folding Sequence Generation from 3D Shape Models

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Folding presents in many fundamental aspects of life. Many things in universe simulate and construct based on this operation. The wave of light and sound repeatedly fold and unfold in space to broadcast information. We are all born with a DNA folding form. Inheriting the properties of folding, origami - the art of paper folding, also contribute to several technological products. With the main characteristic is creative, many works in space technology, automobiles, medicine, robotics, and programmable matter, which based on origami, are considered outstanding.

This thesis considers an information-theoretic approach to modeling and answering the origami folding sequence generation from 3d shape models problem. The algorithm, as input, receives an origami paper (flat sheet square of paper), a 3d model from a real life object or a creative work, and a predefined crease pattern. It, then, generates some of the possible folding sequences that will result in the desired model. By this definition, our task is properly described as a combinatorial optimization problem. A feasible solution is a list of folding actions to create creases which are included in the input crease pattern. The set of feasible solutions is called the search space. The objective function is finding an optimal solution in the search space that has the minimum Hausdorff distance with the input objective model. We present a framework to tackle this combinatorial optimization problem using particle swarm optimization (PSO). With the observation that the problem is an NP-hard problem, and the solutions are in discrete space, we proposed a modified discrete PSO (DPSO) method that can be suitable for our requirements. The characteristics of the proposed algorithm are carefully discussed. First, we introduced a discrete search space. In this space, the positions of particles (or feasible solutions) and its velocities are vectors with integer elements. Second, the behavior of the particles in the swarm is adjusted. We redefined all arithmetic operators to customize the formulae in the standard PSO that are used to move particles and change position. Based on that, the modified DPSO version can take the advantages of the standard PSO's characters, as well as, efficiently search in our discrete space. Besides, a folding simulation to convert a feasible solution (or a folding sequence) into a flat model is also adapted and developed in our work.

With this approach, some experiments are conducted for evaluation. Our system shows that it is promising. Folding sequences of input objective models have been showed with high precision in acceptable running time. The DPSO algorithm always keeps track of minimizing the Hausdorff distance between an input and feasible solutions. In someway, this work revealed the contribution to the field of origami simulator and folding multiple objects model from a single paper sheet.