Intelligent robot systems for manipulation of non-rigid objects

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In this speech the methodology for the development of intelligent robot systems for the manipulation of linear and sheet like objects with low and/or very low bending rigidity. In the beginning the non-rigid objects are defined and classified. The industrial and service applications of these systems and the state of the art approaches for the manipulation of various categories of the non-rigid objects are presented.

Deformable or non-rigid objects are the objects that deform “easily” along (about) all directions or some directions. A large number of state variables are required to represent their state. Some of them are sheets or flexible rods with almost zero rigidity such as fabrics, and strings and other objects with low to medium bending rigidity such as paper, foam, meat fillet. The development of robotic systems for handling deformable objects requires the synergy of researchers from different disciplines since these are really the most representative mechatronic systems. A survey on the methodologies for the manipulation of flexible objects could be found in [1]. In this paper, planning strategies are categorized according to the type of manipulation goal: path planning, folding/unfolding, topology modifications and assembly. Approaches appeared for manipulation of sheet form objects with low rigidity such as foam sheet based on visual perception [2], and for motion planning string like objects as well as sheet like objects of very low rigidity that is the main subject of this speech.

The applications for robotic manipulation of deformable objects could be in industry, services or home. In industry the fabric and leather assembly for making cloths and shoes, fabrication of composites, knotting and cabling as well as food processing could be automated [3]. In services, robotic surgery and therapy training and at home cloth unfolding-folding, and ironing are possible applications.

A major challenge for the robotic research is the development of intelligent control systems for perception and control of robots that could be able to manipulate sheet like objects of extremely low bending rigidity. A methodology for the picking, placement, and folding of fabrics [4] as well as the development of a hierarchical intelligent control system for sewing fabrics and leather based on force and vision feedback [5, 6] will be presented in details.

Fig. 1. Robotic folding, sewing and co-manipulation

Another area of robotic manipulation is the unfolding and folding of cloths with possible applications at home, hospitals and hotels. A methodology will be presented for the manipulation planning of cloths to be unfolded based on the gravity reduction of their possible states as well as the classification of the features of the fabrics for the recognition of the upper layer of a cloth placed on the table to be unfolded [9]. A robust method will be presented for successively detecting boundary points on images of garments hanging from a single point in order to lay on a flat horizontal surface the manipulated garment and then these points to be matched to a set of foldable templates using shape analysis techniques towards unfolding [7].

Mechatronics design of grippers for the grasping and handling of fabrics will be presented along with suitable strategies for the motion planning of fingers for succesful grasping of a piece of fabric [8]. The development of an intelligent mechatronic system based on force-vision feedback for human-robot collaboration in manipulating the folding of large sheet fabrics[9] will be illustrated acccompanied by videos from laboratory demonstrators. The speech will conclude with the main theoretical and technological challenges that should be considered in the development of robotic systems able to understand the task and the state of deformable objects and dexterously manipulating them. Hints for future trends in research for enhancing the robot capabilities to successfully and autonomously handle a great variety of deformable objects for accomplishment of manipulation task in industry, services and at home.

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