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NEURO-CONTROL OF FORCE APPLIED BY A ROBOT IN FABRIC HANDLING TASKS.

PANAGIOTIS N. KOUSTOUMPARDIS†, NIKOS A. ASPRAGATHOS‡

†University of Patras, Department of Mechanical Engineering and Aeronautics, Machine Tools Engineering Lab., 26110 Patras, Greece, koust@mech.upatras.gr
‡University of Patras, Department of Mechanical Engineering and Aeronautics, Machine Tools Engineering Lab., 26110 Patras, Greece, asprag@mech.upatras.gr

Abstract. In this paper, a control scheme based on Neural Networks is described for handling fabrics using robots to feed automated sewing stations. Fabric handling tasks such as sewing demand regulation of the appeared forces and orientation of the fabric. The proposed control approach calculates the appropriate velocity of the robot hand holding the one end of the fabric, while a constant tensional force is applied, when the other end of the fabric is pulled by the sewing machine with an unknown velocity. The effectiveness of the proposed controller lies in the fact that it is independent from the properties of the fabric, as only the measurement of the desired tensional force applied along the fabric is necessary.

Key Words. Fabric handling, Robotic Sewing, Neural Network, Force Control

1. INTRODUCTION

The commercial automatic handling and sewing systems for fabrics are typically semi-automatic sewing units that are fitted with a variety of mechanical attachments (e.g. jigs, belts, guides, tensioning devices, etc.) to complete a specific sewing operation [3]. The robotic systems promise flexible units for such tasks if they are guided by intelligengt controllers.

The fundamental difference between the automation technology in clothing industry and the conventional manufacturing automation is the need to accommodate the unpredictable, non-linear and complex mechanical behaviour of limp fabrics. On top of the difficulties encountered in handling rigid objects (e.g. geometrical uncertainty, obstacle avoidance, etc.), the limp materials pose additional problems since they distort and change shape easily, and do so without exhibiting measurable forces. For most applications and much less in sewing tasks, cloth must be held taut and unwrinkled.

Gershon [2] clearly describes the need of force feedback control in order to fulfil the above requirements. Furthermore, he underlines that the conventional control methods are inadequate to handle a fabric tension problem due to nonlinear fabric properties, the noisy cloth tension signal, etc. Therefore, it is vital to develop more sophisticate and intelligent control methods.

G. Stylios [6] mentioned that there is a direct association between intelligence and human brain behavior. This behavior can be expressed in terms of sensing, processing, actuating, learning and adapting without any knowledge about the properties of the system that the human is processing. This approach to complete a task can be accomplished by using the well-known Neural Networks based control systems.

The structure of Neural Networks with their ability to learn from examples and their capacity to modify themselves from experience mistakes, approaches this human behavior.

This paper investigates a part of the sewing procedure and particularly the robotic handling of fabrics during the sewing procedure. The proposed controller is based on Neural Networks and works without any knowledge of the fabric properties and the co-operating environment. Even the FIGARO system [2] [3], which present an integrated robotic system for sewing, during the tension control uses an estimated cloth velocity and computes a correction to this estimation in order to derive the robot velocity. In addition, the gains of the proportional-integral controller were chosen by trial and error and should be modified for a new type of fabric [3].

Since, the implementation of the proposed controller was realized through simulation, in Section 2 the system (fabric-cloth) that will be controlled is analyzed by presenting some approaches to describe its dynamic behavior. The morphology of the proposed Neuro-controller is described in Section 3, and its efficiency is presented in Section 4 where the results are discussed.

2. THE SYSTEM TO BE CONTROLLED

Fig.1 illustrates the controlled system, which is simply a piece of fabric. An automated sewing station pulls the right edge with a *machine velocity* while the robot end effector tries to follow the left edge of the fabric with the *robot velocity*. In order to achieve this the only measured variable is the force applied by the robot end effector when the robot velocity integration compared with the machine velocity integration produces an extension or compression to the initial length of the fabric.

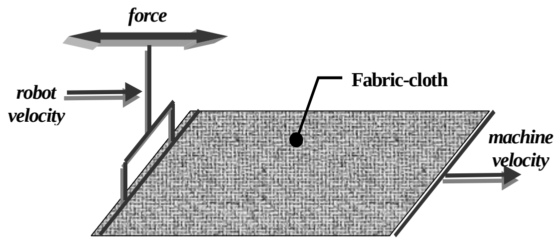

Fig.1. Appeared forces and applied velocities to the fabric.

The sensor on the robot end effector measures tensional forces when the distance between the two acting points of the velocities is greater than the initial length of the fabric, or measures compressive forces when it is less than the initial length of the fabric. This distance is calculated by the integration of the velocities.

The mechanical model [3][5], which describes the tensional part of the viscoelastic behavior of the fabric, is shown in Fig.2. The fabric properties: spring with stiffness ***k***, damper with damping ***b*** and the friction ***f*** between the fabric and the table, are nonlinear parameters and functions of time.

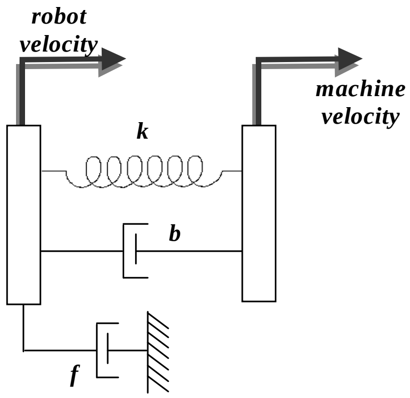

Fig.2. Mechanical model of fabric tension

Moreover, this model is valid only in the case of tension because the fabric cannot support compressive forces in contradiction with the mechanical model. Therefore, another model to describe the performance of fabrics is indispensable for this handling task.

A lot of publications [4] present stress-strain curves for fabrics, which can be used for the case of tensional forces. The typical stress-strain curve for most textiles is shown in Fig.3.

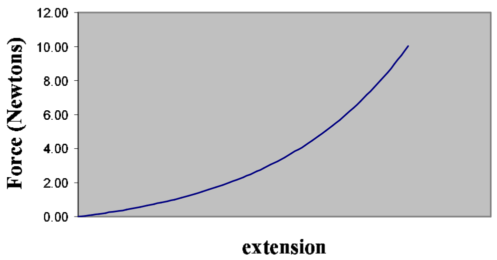

Fig.3. Typical stress-strain curve of knitted fabrics [4].

For the requirements of the presented work experiments on fabric tension and compression have been materialized. For a haphazardly selected piece of cloth the tension and compression experimental curves are shown in Fig.4 and Fig.5 respectively.

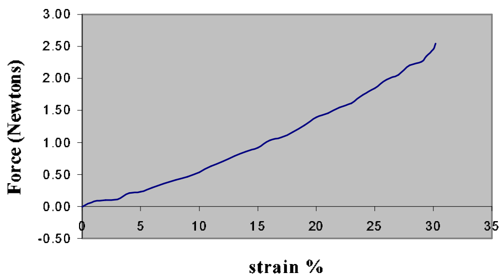

Fig.4. Tension curve for a piece of cloth.

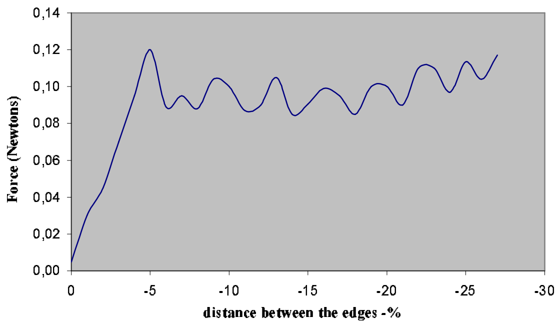

Fig.5. Compression curve for a piece of cloth.

The proposed controller was tested by using an approximation of these curves shown in Fig.6 and Fig.7.

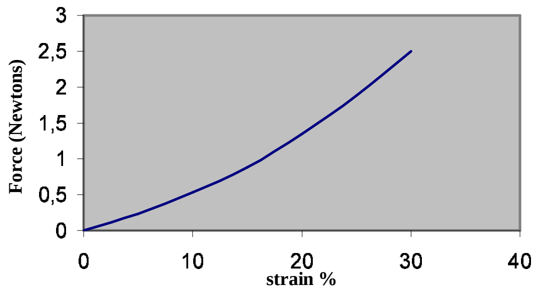

Fig.6. Approximated tension curve for a piece of cloth.

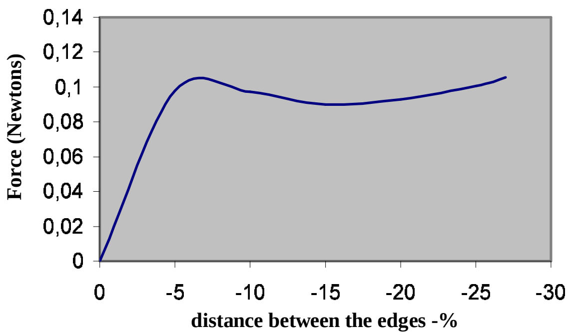

Fig.7. Approximated compression curve for a piece of cloth.

3. CONTROL SCHEME

Fig.8 shows the controller implemented in the simulated system. The simplicity of this scheme was the target of intense efforts.

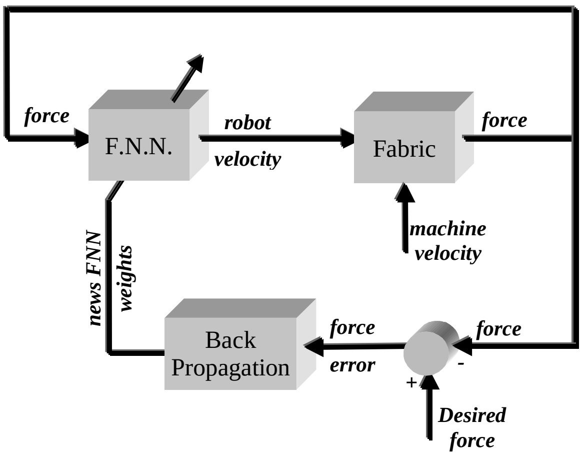

Fig.8. The controller scheme.

This scheme is considered successful when the tensional force applied along the fabric is kept constant and equal to the desired value specified by the type of the fabric.

The controller is a Feedforward Neural Network (FNN). It consists of three layers (1-3-1), with one neuron in the input layer, three in the hidden and one in the output. The controlled force is the input to the FNN and the velocity command passed to the robot controller is the output of the FNN.

For each *robot velocity*, as the output of the FNN, the strain of fabric is calculated. The corresponding *force* to this strain is calculated using the curves shown in Fig.4 and Fig.5 (for real experiment this force will be produced by a sensor on the end effector). The feedback of the calculated *force* closes the controller loop. The force error is used for the backpropagation method, which trains the FNN for the next loop.

4. RESULTS

The results presented in the following illustrate the performance of the proposed Neuro-controller. All the numerical data are normalized in order to feed them into the FNN and all the outputs data are presented in normalized form.

For the initialization of the controller the desired tensional force was set to (0.12) and the machine velocity was assumed to be (0.8).

In Fig.9, the output of the FNN, which is a command to the robot end effector, is compared with the machine velocity. The controller is capable to produce a good approximation of the machine velocity after 150 training loops.

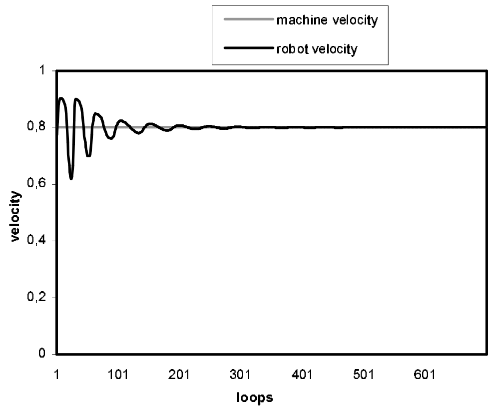

Fig.9. Machine and Robot velocities diagram.

As the robot velocity approaches the machine velocity the tensional force must reach the value of the desired force so that a specific extension is applied to the fabric. This procedure is shown in Fig.10.

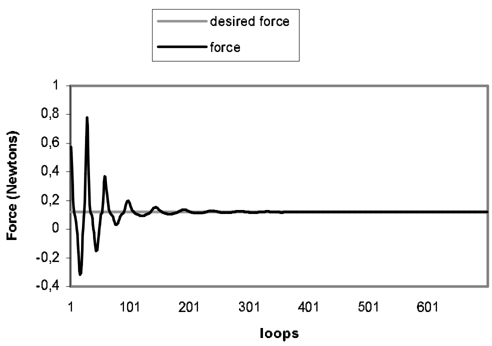

Fig.10. Desired and real force diagram.

5. CONCLUSIONS

In this paper a robot force controller, based on Neural Networks, for handling fabrics is described.

The basic advantage of the proposed system is that the controller is able to regulate the force applied to a non-rigid material such as a fabric without any knowledge of its characteristics. The fortuity of the cloth selection and the effectiveness of the controller, as the results reveal, to this arbitrary cloth verify this advantage and furthermore prove the generalization of the controller.

The fact that only the desired tensional force is necessary to the controller makes it independent from the handled fabric and its properties.

As the results from the simulation of the controller report, a very simple Feedforward Neural Network (1-3-1) is capable to control the force after 150 loops only. Since, the backpropagation training method modifies the FNN weights continuously, the state space error fluctuates in the range of third decimal (for the force) and seventh decimal (for the machine velocity) after the last loop.

The further elaboration, of the idea the proposed system, is that structure of the controller that will be able to manipulate the entire handling task for sewing the majority of possible appeared non-rigid materials such as fabrics. Therefore, for further improvement of the controller performance a more flexible system, which will be capable to acquire in an automated way the desired force for each fabric, is essential. So that finally the robotic system will be fully independent and autonomous. Furthermore a way to control the orientation of the fabric must be incorporated in the control scheme.

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