Intelligent Vision Determination of Material’s Wrinkles in Robotized Handling

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Abstract—An approach for the intelligent determination of the appeared wrinkles in the robotized handling of non-rigid materials such as fabrics is presented. A machine vision system reads the wrinkles and a robotic manipulator controller is used to eliminate the wrinkles of a fabric. The machine vision system is used in order to capture an image of the wrinkled or wrinkle-free fabric. The direction of a wrinkle is determined using the bio-mimetic technique of Neural Networks performing a necessary image processing. The Network has been trained with a set of wrinkled and wrinkle-free fabric images; and is capable to recognize the direction of any wrinkle appeared in the fabric. The results show that the use of the proposed method passed on Neural Networks leads to the minimization of the image processed information.

Index Terms—wrinkle, fabric handling, robotized handling, machine vision, Neural Networks.

I. INTRODUCTION

The non-rigid materials such as fabrics usually present wrinkles, when they are handled or when they are arbitrarily placed onto a horizontal surface. The wrinkles of a fabric are not desirable in the majority of the fabric handling tasks. In the automated sewing tasks where the fabric must be kept taut [2] the appeared wrinkles could be harmful to the seam quality. Therefore, when a robot manipulator handles a piece of fabric, the automated system must be capable to identify the presence of a wrinkle in the handled fabric. Furthermore, the angle of the direction of the wrinkle is determined and used as an input to the robot intelligent controller inferring the appropriate movements of the robot end-effector towards to eliminate the wrinkle.

One solution to wrinkle elimination problem is based on mediate approximations [8]; i.e., the fabric straightening is performed through a force applied by the robot end effector. The research in the field of automated fabric handling is mostly focused on the automated orientation of the fabric and on the detection of the presence and determination of the location of the fabric sheet [9]. Since the machine vision is used in the robotized handling of fabrics for several reasons such as detection of cloth presence, determination of cloth orientation etc., it is suitable and convenient to use the already needed machine vision in order to determine the wrinkle direction of a fabric, if such a wrinkle exists.

Some recent examples that reveal the potential of machine vision in the area of the robotic manipulation are reviewed in the following. A system for the identification of machine-tool wear [4] uses a neural network embedded with fuzzy classifiers to analyze several images obtained by laser scattering from the machined surfaces of the work piece. Another example [5] is a face recognition system in which eyes, mouth and nose locations are detected and its facial feature provides evidence for neural classifiers with varying degrees of reliability.

The basis of machine vision involves the image processing techniques. An acquired image of the fabric is processed in order to determine the direction of the wrinkle. The methods for feature recognition include very complex algorithms for 3D reconstruction demanding high computational time. In this field a method called shape from shading [10] is based on mathematical forms, which had to be modified or changed if the examined object properties are changed.

The use of Computational Intelligence for image processing has been investigated widely and successfully in other applications involving pattern recognition, classification etc. [6]. A reason to use machine intelligence in computer vision is the uncertainty associated with the environment within which the automated systems have to operate. The difficulties appeared in a non-rigid material handling, require the use of intelligent and flexible approaches that can employ parallelism in order to perform such tasks in real time.

The significance of the proposed approach is that the problem of straightening the non-rigid materials is directly worked out by focusing on the wrinkling through the processing of an image of the wrinkled fabric, in a way similar with the one followed by an expert seamstress-tailor.

The innovation of this paper lies on the use of an intelligent computational mechanism based on Neural Networks, in order to extract only the useful information contained in an image of a wrinkled fabric. The Neural Networks can surpass the deficiencies and weakness of the analytical methods, since they don’t have to modify its structure in order to come to a decision when the object is changed. In
our case, there is no need for an exact and complete image processing of the wrinkled fabric. Only a rough estimation of the wrinkle direction is needed; and so the complete flow of information coming from the machine vision system can be trimmed off. Therefore, a reduction in the total computational time is obtained.

The determination of the direction of a fabric wrinkle is based on computational intelligence. The image processing is performed through a Feedforward Neural Network (F.N.N), which has been trained to recognize any wrinkle direction from 0 to 180° degrees. Then a robot manipulator straightens the fabric wrinkles.

In this paper, only the method for the determination of the wrinkle direction is presented. The problem is described in details in the next section, while the hardware configuration, i.e. the machine vision system and the robot manipulator is presented in Section III. The intelligent mechanism is illustrated in Section IV and the effectiveness of the proposed approach is examined in Section V where the results are discussed.

II. PROBLEM DEFINITION AND OBJECTIVE

The controlled system is a non-rigid material such as a sheet of fabric, which could be wrinkled when it is handled by a robot. The problem could appear when a fabric is sewed with the assistance of a robot manipulator [2], as shown in Fig. 1.

![Fig. 1 The wrinkling of a fabric when it is fed by a robot in a sewing station.](image)

When a robot manipulates a sheet of fabric in a sewing station, due to the non-rigid nature of the fabric behaviour a wrinkle could appear on the fabric if the robot end-effector velocity is greater than the velocity of the sewing station mechanism or when the robot end-effector turns the fabric around the sewing needle. In the first case, a wrinkle usually appears along a vertical direction to the robot movement, while in the second case a wrinkle could appear along various directions.

A CCD camera is positioned above the working table and acquires an image of the fabric into an active area in front of the robot end-effector. Fig. 2 shows an acquired image of the fabric that contains a wrinkle in a direction about 30° degrees from a horizontal line. The aim of the present work is the detection of that wrinkle and the determination of its direction from the acquired image.

![Fig. 2 Image of a piece of fabric: a) unwrinkled b) wrinkled.](image)

The proposed system is focused on the on-line determination of the wrinkle angle in order to eliminate the wrinkle by the robot end-effector motion, so efforts are devoted to minimize the necessary information to be processed.

III. THE ROBOTIC STATION

The problem of straightening a wrinkle panel is only a part of the complete automated sewing process. This process starts with the main movement that the robot performs to sew the cloth. This movement is linear, but as it was mentioned in the previous paragraph, when the sewing process takes place a wrinkle could appear. To solve this problem the robot must be controlled by a controller scheme shown in Fig. 3. So the robot is fed with movement information, which modifies the linear movement of the robot and the wrinkle is avoided. This combined movement information comes from the proposed controller.

![Fig. 3 The controller scheme.](image)
Fig. 3 illustrates the structure of the proposed controller, which is based on the intelligent approach of the following sequence: sensing, processing and actuating, learning and adapting.

The machine vision system captures an image of the handled fabric and passes the image signal to the input of the computational intelligence mechanism (Feedforward Neural Network). The Neural Network mechanism performs the appropriate image processing in order to determine the direction of the wrinkle if any exists. Finally, this direction is transformed into a new robot end-effector position orientation in order to eliminate the wrinkle; and the new end-effector position orientation is passed as a command to the robot controller for the appropriate joint movements.

IV. USING NEURAL NETWORKS TO DETERMINE THE WRINKLE DIRECTION

The input data to the Neural Network are pixels from a bitmap image and not some features that could be extracted from the original picture. It is avoided to use feature extraction approach [1], a technique commonly used for pattern recognition, because the aim was to keep the solution of our problem as simple as possible toward a real-time system. Therefore, the network itself extracts the useful features through the training process.

The grayscale image (256-colors) has the form of a two-dimensional data-matrix (width × height in pixels) where each element represents a pixel color. This matrix is transformed into a vector, and the elements of this vector are the pixels from the image taken in a serial way starting from the top left of the image and fed into the trained Neural Network as an input signal. The output of the F.N.N is a number that represents the direction of the cloth wrinkle between 0 and 180°.

The image taken from the digital camera is represented by 100x100 pixels. Although a very small percentage from the whole image (768x435) is used, this is really a very large input vector for the network. The input data would increase dramatically if a larger image were captured. It is known that neural networks with a very large input layer are unable to make the correct classification due to “The Curse of Dimensionality” [1] and also they present a very high computational cost. Therefore the initial input data are preprocessed, in order to reduce the dimension of the input vector by decreasing the accuracy.

As Fig. 4b shows, the necessary information for the wrinkle direction is still present in the digitized image of reduced accuracy. This image is represented by 20x20 pixels. This is allowed since it isn’t necessary to determine exactly the wrinkles direction. In this way, the computational time is reduced since the number of the input neurons of the F.N.N is diminished considerably.

The type of Neural Network, used to solve the problem of wrinkle determination, is a multi-layer perceptron with error back propagation. The choice of this network is based on the following criteria. Error back propagation networks are the most common, there is a lot of knowledge on how to apply them in practical problems and this network is easily implemented.

The F.N.N consists of an input layer with a number of neurons equal to the number of the image pixels, a hidden layer, and a one-neuron output layer, as Fig. 5 illustrates. This structure is preferred in order to keep the network as simple as possible and consequently to reduce the computational time.

For the hidden and output neurons the sigmoid activation function was used which is given by:

$$f(net_i) = \frac{1}{1 + e^{-net_i}}$$

A. The Neural Network Structure

For the output layer, the sigmoid activation function was used which is given by:

$$f(net_i) = \frac{1}{1 + e^{-net_i}}$$

Fig. 4 Wrinkled fabric a) acquired image 100x100, b) digitised image 20x20.
The term $Q_0$ is called the temperature of the neuron [7] and the term $net_i \in [0,1]$ is the input to the neuron $i$. The higher the temperature, the more gently the sigmoid changes. In the training process, the most common value of $Q_0$ used for starting the experiments is $Q_0=1$.

The selection of the number of hidden neurons is one of the most critical decisions. In this problem, with so much input information, the “overfitting” was avoided, because in the case of “overfitting” the network starts learning insignificant aspects of the training set and therefore is incapable to make the right classification. Since only the direction of the wrinkle has to be determined the minimum number of hidden neurons is adopted in order to form a network able for the right classification [3]. One rough guideline for the choice of the number of hidden neurons in many problems is the “geometric pyramid” rule:

$$\text{Hidden} = \sqrt{m \cdot n} \quad (2)$$

where $n$ is the number of inputs of the network and $m$ the number of the neurons of the output layer.

After some trials, it was found out that this rule must not be applied strictly. With the number of hidden neurons given by Eq. (2) the network was unable to generalize and make the right classification, therefore some more hidden neurons are added to the number given by Eq. (2). Finally 31 neurons were used to make the network able to extract the desired features from the input images, for training the network, but the same results are obtained with 27 neurons and more repetitions.

In the output layer there is only one neuron, which gives the angle of the wrinkle by an appropriate normalization.

### B. Training And Testing The Neural Network

As described above the input data to the Neural Network are threshold pixels from an image of the fabric. Each acquired image represents the handled fabric with a wrinkle in a specific angle or without wrinkle. The angle of a wrinkle is ranged from 0 to 180 degrees. We assign that 0 degrees are straight lines, which are parallel to the top and bottom edge of the square image that the camera captures. These images are positioned in a Cartesian system as shown in Fig. 6.

The Network must be able to recognize images of fabric with any wrinkle direction into the above-defined range. Hence, the used images training set contains 20-images, i.e. 18-images each one having one wrinkle with a direction angle from 0° to 180° with a step of 10°, and 2-images with a wrinkle at 45° and 135°:

In real-world problems of fabric wrinkling, a wrinkle could appear anywhere inside the acquired image; i.e. a wrinkle in a direction of 0° could appear in the middle of the image, at the upper or lower part of the image etc. Therefore, for each angle of a wrinkle three possible locations of the wrinkle were considered. In Table I, each row represents a fabric with a wrinkle of the same angle, but in different locations. In this way, the Network that has been trained with these cases has the capability to generalize in a real-word problem where a specific wrinkle appeared anywhere into the image. Finally, a single image (Image No.21) free of wrinkles was used in the training set, since the Network has to determine if a wrinkle exists on a fabric or not. It is worth to mention that in this paper, only photos with a single wrinkle are considered, and these wrinkles are of simple straight-line shape. Following the above description, the final training set includes 61-images of a fabric.

### Table I Training set images.

<table>
<thead>
<tr>
<th>Image No.</th>
<th>Angle of the wrinkle</th>
<th>Wrinkle at Bottom</th>
<th>Wrinkle at Middle</th>
<th>Wrinkle at Top</th>
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<tbody>
<tr>
<td>1</td>
<td>0°</td>
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<td>2</td>
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After a large number of trials, it was found that the training set images must be fed into the network with a very specific way in order to achieve satisfactory performance of the Neural Network. The training inputs were split in three categories, as Table I illustrates. The first category (first column of Table I) includes images with all the 20-angles of wrinkles and the wrinkle-free image. The second and third categories include images with the same angles but the wrinkles are presented in different places. These categories fed into the network, one category after the other, starting from the first one.

For each training example, a desired Network output had to be considered, raging from 0 to 170 degrees. Therefore, the desired-target outputs were normalized between 0 and 1 with steps of 0.05. The case of wrinkle-free fabric was considered to have a desired output of 0°. The images with 0° of a wrinkle have a desired output of 0.05, the images with 10 degrees of a wrinkle have a desired output of 0.1, etc. The error used for the backpropagation algorithm presents the difference between the normalized angle of the wrinkle of the input image and the corresponding one computed by the network.

The usual practice is to set the initial values of the weights and thresholds randomly between −1 and 1 [11]. The attempts to train the Network with these initial values for the weights and thresholds were unsuccessful. The Network was trained successfully using the proposed by Pandya and Macy [7] initial values, which are random numbers between 0 and 0.2. Between the input and the hidden layer there are 400x31=12400 weights. And between the hidden and the output layer there are 31x1=31 weights.

V. EXPERIMENTAL RESULTS

The problem of straightening a wrinkled fabric sheet is solved using a robotic manipulator UMI RT100+, which performs the appropriate movements-actions in order to straighten the fabric panel. A machine vision system composed by a PULNIX CCD camera and a DATA TRANSLATION frame grabber supported by a PC (Pentium 133MHz) with the necessary image-capture software.

It is very important to notice that the images used to train the network, as well as the test image, were taken with a very specific way. A white cotton cloth, was put onto a white background, and there was light coming from a specific direction.

Finally the input data are threshold pixels, where the pixels closest to gray are transformed to black, but the white pixels are left unmodified (Fig. 7).

![Fig. 7 Threshold Image.](image-url)
The utilization of the proposed method can be extended in the determination of an object direction in a plane surface. The same Neural Network structure is trained to recognize the deviation of the object direction from a specified fixed direction.

The proposed controller structure for the task of fabric orientation in a robotized sewing handling process is under development. The same Neural Network structure could be used to determine the direction of the fabric edge in a small image region in the front of the sewing needle as a robotic end-effector manipulates the fabric in order to stitch it around its contour.

REFERENCES


VI. CONCLUSIONS

A new approach of the direction of a wrinkle on a fabric that is handled by a robot has been presented. This approach is based on the Neural Network processing of an image from the wrinkled or wrinkle-free fabric. For the needs of an automated sewing station, the wrinkled fabric is straightened by the robot end-effector, which receives the appropriate movements by the designed controller.

From the results it is obvious that it is possible to extract 3-D features, such as the direction of a wrinkle in a non-rigid material (fabrics), from 2-D images, which have been taken using only one camera. In order to achieve this successfully and irrespective of the environment, the lighting conditions are determinantal. Therefore, a methodical research is necessary. The effects of lighting from different angles and brightness have to be investigated.