Project no.: IST-6549

HAPTEX

HAPtic sensing of virtual TEXtiles

Instrument type: **STREP**
Thematic Priority: **Priority 2: Information Society Technologies**

Deliverable D5.1

Pre-final Demonstrator

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The HAPTEX Project Consortium groups the following Organizations:

ORGANIZATION	SHORTNAME	ROLE	STATE
MIRALab - University of Geneva	UNIGE	Coordinator	Switzerland
University of Exeter	UNEXE	Partner	United Kingdom
Scuola Superiore Sant'Anna	PERCRO	Partner	Italy
University of Hanover	UHAN	Partner	Germany
Tampere University of Technology	SWL	Partner	Finland

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1. Introduction

This report describes work in Workpackage 5: *Multimodal integration and validation*. The original project workplan envisaged the construction and evaluation of a single system, in pre-final and final versions, with the pre-final demonstrator as deliverable D5.1. However, the workplan has been modified to include progressive stages of system development (see Figure 1), as follows:
Development level DL1: 2-digit force feedback and visual
Development level DL2: 1-digit tactile (palmar mechanism) and visual
Development level DL3: 1-digit force feedback, visual and tactile (palmar mech.)
DL3 not implemented -- replaced by DL4a
Development level DL4a: 1-digit force feedback, visual and tactile (dorsal mech.)
Development level DL4b: 2-digit force feedback, visual and tactile
Development level DL5: hand exoskeleton for force feedback, visual and tactile

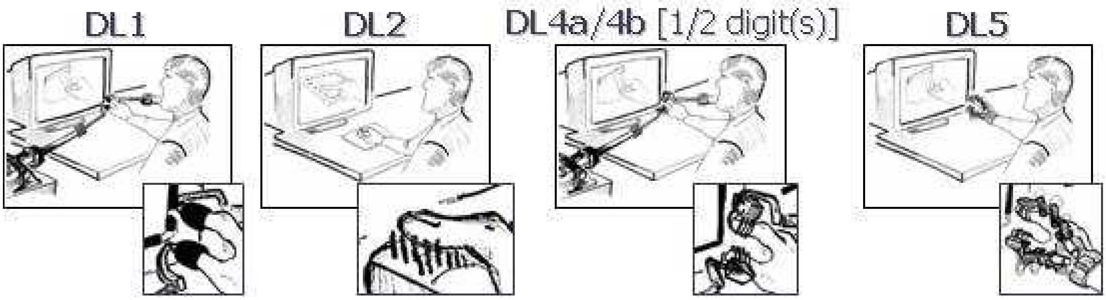

Figure 1. Development Levels for the HAPTEX hardware and software.

Consequently, deliverable D5.1 is here presented as report on system development and validation for development levels DL1 and DL2. A further deliverable (D5.2) relates to the final demonstrators for DL4 and DL5.

2. Development level DL1

2.1. Summary of system development for DL1

DL1 is based on two examples of the GRAB device, developed by PERCRO (see Figure 2). The end effector of the GRAB is a thimble for the digit, whose orientation is determined by the user. For the HAPTEX project, it is necessary to measure the orientations of the digits in order to specify the interaction with the

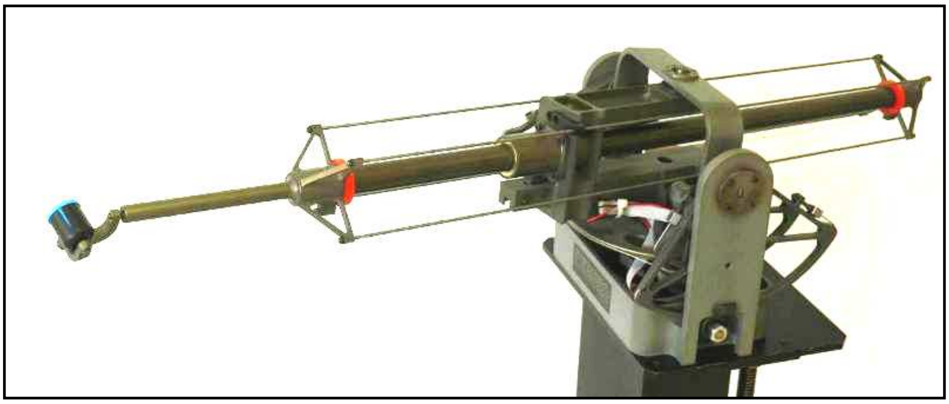

Figure 2. The GRAB device, developed by PERCRO.

virtual textile. Consequently, for DL1 each GRAB has been modified by adding instrumented gimbals to measure the orientation of the end effector. In addition, in order to provide a more precise control of force output, the velocity control of the original GRAB has been augmented by force control. This has required 3D force sensors to be added, positioned next to the end effectors (see Figure 3).

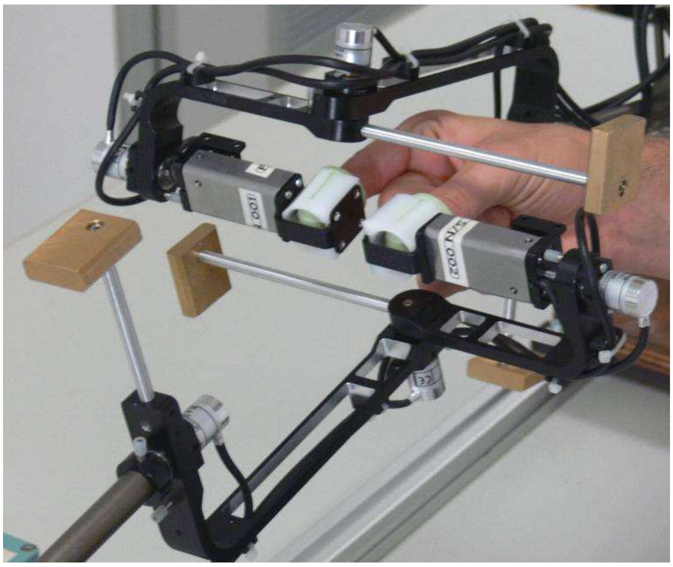

Figure 3. Two digit interaction with the two GRAB devices, showing the instrumented gimbals and the force sensors which carry the end effectors.

2.2. System validation for DL1

Appendix 1 describes the various manipulation strategies which have been specified for the assessment of real and virtual fabrics in the HAPTEX project. In a series of informal evaluations, it was established that the DL1 system offers the appropriate range of movements to support all of these manipulations.

A single modified GRAB was used to investigate the system's capability to provide accurate forces while tracking finger motion. Users were asked to move the finger at constant velocity and the system was set to display no forces. The maximum force magnitude in this task was observed to be typically 0.1 N (10 grams force), as shown in the example recording (Figure 4).

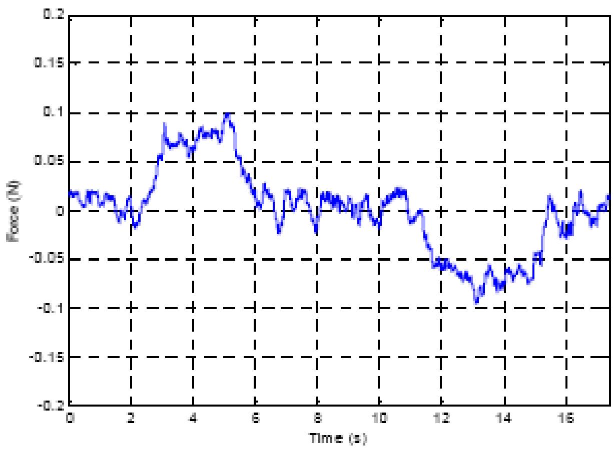

Figure 4. Force versus time during finger tracking at constant velocity

Two-digit operation was satisfactory when the system represented a generic deformable object between thumb and finger. However, system instabilities were sometimes observed when the parameters of the virtual object were set to match those of a textile sample. This apparently relates to the effect of a relatively rigid virtual link between the two end effectors, such that small movements of one effector are associated with large changes of force at the other effector. Such instabilities have become more of a problem in the subsequent development level DL4, and the resolution of this problem is discussed in deliverable D5.2, which describes further system development and validation in WP5.

3. Development level DL2

3.1. Summary of system development for DL2

DL2 is based on a stand-alone tactile actuator that can be used to explore the 2D workspace provided by a graphics tablet or mouse. Finger position and the locations of virtual objects within the workspace are indicated on a monitor screen. The tactile actuator in DL2 is in the first of the two configurations developed for the HAPTEX project – with a palmar mechanism (i.e., a mechanism positioned below the finger). Figure 5 shows the DL2 system installed at Exeter. A second system is installed in Hannover – based on a mouse rather than a graphics tablet, but otherwise similar.

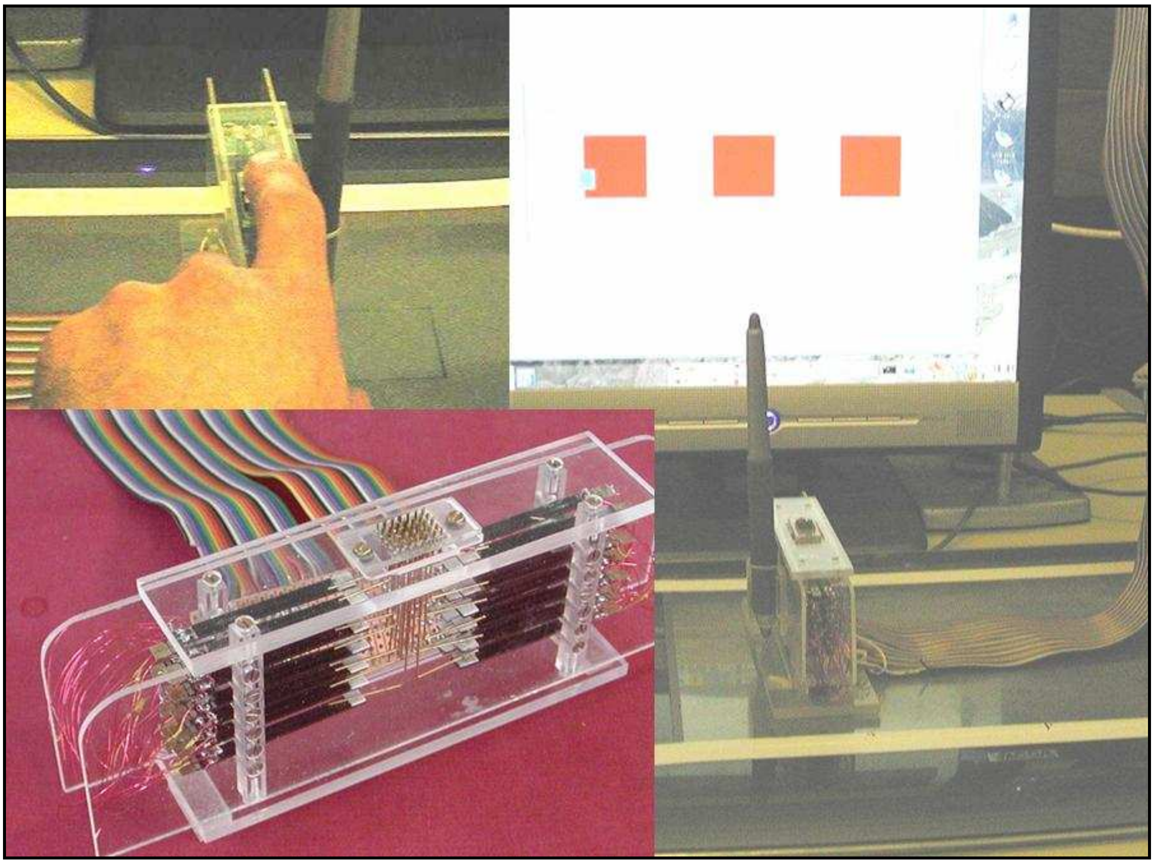

Figure 5. System for DL2, showing (right) the visual display and the tactile actuator with graphics tablet to provide positional information in 2D; (left) the position of the finger and a view of the tactile actuator.

3.2. System validation for DL2

Preliminary evaluations at Exeter have involved an "odd-one-out-from three" task, with three virtual surfaces presented within the workspace (see Figure 6). Surfaces are differentiated by:

- ◊ the overall intensity of the tactile stimulation;
- ◊ the overall spectral distribution of the tactile stimuli (balance between 40 Hz and 320 Hz components);
- ◊ the spatial distribution of the tactile stimuli (variation over the surface).

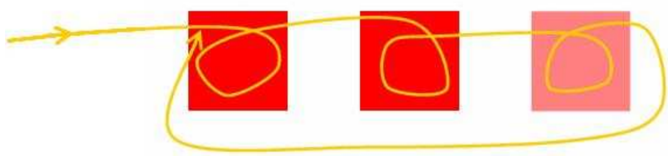

Figure 6. Diagram of the workspace for the "odd-one-out-from three" task. Subjects are asked to follow a similar trajectory to that shown, using a constant speed of exploration (so that a single pass takes around 10 s).

Results suggest that the intended perceptual dimensions (subjective intensity and spectral balance) are available to test subjects. For uniform stimuli (i.e., stimuli with no spatial variation over the surface), the spectral dimension appears relatively weak – changes in spectral balance at constant subjective intensity tend to be less noticeable than changes in subjective intensity at constant spectral balance. (There are perhaps 4 to 5 discriminable steps of spectral balance along an equal-intensity contour.) Perhaps the most interesting observation from these preliminary experiments is a strong interaction between the perceived spatial aspects of the texture and the stimulation frequency. If the stimulation frequency is changed from 40 Hz to 320 Hz, the perceived sensation during active exploration changes much more if the texture is spatially non-uniform than if it is spatially uniform. It is clear that the spectral dimension provides a significant enhancement to the available range of tactile sensations.

Further experiments in Hannover have involved discrimination of virtual surfaces which are intended to represent real textiles. These experiments use tactile rendering software which has been developed within the Haptex project – during exploration of a virtual textile, tactile stimuli are specified on the basis of a software model of the textile and information about the user's exploratory movements. Software models of different textiles are based on measurements from real textile samples, provided by SWL (deliverables D3.1, D3.2 and D3.2 Part 2).

The experimental scenario involves a textile sample on a horizontal table, represented in the virtual case by the 2D workspace of the DL2 system. The experiment is based on a set of real textile samples, and a corresponding set of virtual textiles which are intended to represent the real textiles. The test subject feels one of the real textiles (the "example"), followed by two of the virtual textiles – one of which is intended to represent the real example, and the other of which is intended to represent a different real textile from the set. The subject is asked to identify which of the virtual textiles is closest to the real example. Blurring glasses are worn by the subject, to eliminate visual cues.

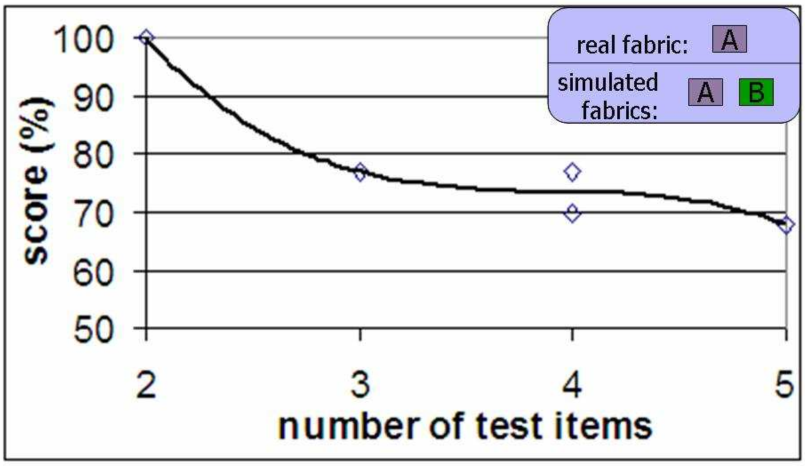

Figure 7. Mean scores from 5 subjects for matching real and virtual textiles, as a function of the number of textiles in the stimulus set. Chance scores are 50%, in all cases.

Results from five subjects are shown in Figure 7, for different numbers of items within the stimulus set. When only two textiles are involved, chosen to be clearly distinguishable in the real case, all subjects score 100%. When additional “intermediate” textiles are added to the set, the task becomes more difficult and scores fall progressively. This is an encouraging result – it demonstrates that it is possible to achieve a correspondence between subjects’ perceptions in the real and virtual cases.

4. Conclusion: Towards DL4 and DL5

The work described in this report provides the foundation for subsequent work in WP5, described in D5.2. Development level DL4 involves the integration of DL1 and DL2 – for a single digit in DL4a and for index finger and thumb in DL4b. To achieve DL4, the modified GRABs from DL1 will be further modified so that they can accommodate tactile actuators. This will involve replacement of each force transducer by a smaller device which will fit within the tactile-actuator mechanism. In addition, the tactile actuator with a palmar mechanism from DL2 will be replaced in DL4 by a new design with a dorsal mechanism (i.e., a mechanism positioned behind the finger). This will avoid interference from the mechanisms when the index finger and thumb are moved together, as required during manipulation of the virtual textiles.

Development level DL5 will use the same tactile actuator and force transducer as DL4, i.e., for each digit, the tactile actuator with a dorsal mechanism, built around the smaller force transducer. A significant new development for DL5 will be the replacement of the two GRABS by a hand exoskeleton, purpose-built for the HAPTEX project by PERCRO.

Annex 1. Subjective evaluation procedures
(Version October 7, 2007)

1. Samples

1.1 Fabric selection
Selection of five (5) different fabrics and five (5) similar fabrics from already measured samples (if possible) from the first, second and third set of fabrics.

1.2 Number and size of test specimen
One specimen or two parallel specimen per evaluator (depends on the availability of sample) are cut in one direction, size of 200 mm x 200 mm. Cut all specimen in same size and shape. Code the specimen and mark the length and width directions and the face and back sides of the samples but not by evaluator (labels may not be used). [1)]

1.3 Conditioning
Condition the specimen for a minimum of 4 h at 20±2°C and 65±5% RH prior to evaluation if possible. Use the same conditions for evaluation if possible.[1)]

2. Evaluators

2.1 Selection of evaluators
Altogether five (5) evaluators (1 or two skilled and 2 or 3 semi-skilled) are selected e.g. from TUT Fibre materials Science and from textile and clothing industry or other appropriate area agreed between interested parties.

2.2 Preparation of evaluators
Evaluators wash their hands 0.5 h before the evaluation using the same washing procedure and hand soap (no moisturizers are allowed). Hands are dryed with paper towels. Temperature changes and moisture are avoided after the hand washing. [1)]
Evaluator should be free of distractions and relaxed. [1)]
Evaluation may be performed seated or standing. [1)]
Evaluator may not view the samples during the first evaluation round. Evaluator closes eyes using a blindfold. [1)]

2.3 Facilitator
Facilitator gives relevant instructions for evaluation: evaluated properties, rating scale, number of samples, the order of procedure and duration of evaluation. [1)]
Facilitator records the hand sensations given by the evaluator on a rating form. [1)]
Facilitator turns and fixes the specimens for the evaluation of each direction and side.
Facilitator follows the position of the hand and the hold on the sample all along the evaluations.

A learning session before actual evaluation is recommended.

3. Procedure

3.1 Sample and reference fabrics holding
Sample holding is arranged according to scenario 3. The fabric is hanging from a stand, fixed at its upper edge (see figure 3.1) so that the size of workspace is 400 mm x 400 mm. The evaluator can rub and stretch the fabric. The evaluator can experience both force and tactile feedback.

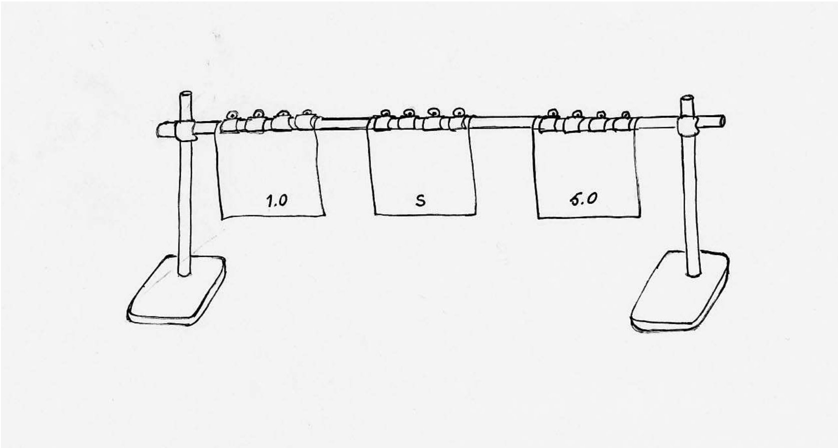

Figure 3.1 Sample (S) and reference fabrics (1.0, 5.0) holding arrangement (a sketch).

Place the reference fabrics on a stand - one on either side of the test fabric (reference fabric corresponding rate "1" on the left and reference fabric corresponding rate "5" on the right).

3.2 Subjective evaluation
Subjective evaluation of bending, shear, tensile, surface roughness and friction and compression is made using two fingers (thumb and forefinger). Front side of the fabric facing the tester; thumb on front side, finger on back side; concentrate on thumb to evaluate front side, concentrate on finger to evaluate back side; no rotation of the hand; no inversion of the fabric. Evaluate the sample separately in length and width directions and face and back sides when necessary. Rate each property of the sample. Use slow manipulation movements for all properties.

3.2.1 Bending
Grasp the free end of the sample with thumb and forefinger. Lift the corner of the fabric forwards and allow it to bend around the finger. (Fig. 3.2) Bend the test piece first forwards and then backwards.

3.2.2 Shear
Grasp the sample close to the fixation with thumb and forefinger and shear the sample to the right and to the left. (Fig. 3.2)

3.2.3 Tensile
Grasp the free end of the sample in the middle with thumb and forefinger. Pull the sample downwards and then let it return. Do not let the fabric loose from your fingers. (Fig. 3.2)

3.2.4 Surface roughness
Grasp halfway up sample with thumb and forefinger and slide your fingers downwards. (Fig. 3.2) To slide your fingers upwards fix the free end of the sample with your other hand.

3.2.5 Friction
Grasp the sample close to the fixation with thumb and forefinger and slide your fingers downwards. (Fig. 3.2) To slide your fingers upwards fix the free end of the sample with your other hand.

3.2.6 Compression
Grasp the sample with thumb and forefinger and compress your fingers together. (Fig. 3.2)

3.3 Rating scale and rating system
Select two reference fabrics for each property representing the end points of the rating scale. Compare the sample to the standard references. The same rates can be given to more than one sample if necessary. Use rating scale from 1.0 to 5.0 with intermediate points of 0.1 (i.e., 1.0, 1.1, 1.2 ....4.8, 4.9, 5.0) as follows:

3.3.1 Bending
1.0 = very weak resistance to bending, 5.0 = very strong resistance to bending
(take the average of forward and backward bending unless otherwise agreed)
3.3.2 Shear
1.0 = very weak resistance to shearing, 5.0 = very strong resistance to shearing

3.3.3 Tensile
1.0 = very weak resistance to stretching, 5.0 = very strong resistance to stretching

3.3.4 Surface roughness
1.0 = very smooth surface, 5.0 = very rough surface
(take the average of downward and upward roughness unless otherwise agreed)

3.3.5 Friction
1.0 = very slippery surface, 5.0 = very rough surface
(take the average of downward and upward friction unless otherwise agreed)

3.3.6 Compression
1.0 = very weak resistance to compressing, 5.0 = very strong resistance to compressing

3.4 Visual evaluation

3.4.1 Hand properties
Remove the blindfold. Repeat the evaluation procedures from 3.2.1 to 3.2.6 and rate the samples again for each property if agreed between interested parties.

3.4.2 Weight and drapeability
For evaluating weight push the fabric in the middle forwards with forefinger. Avoid fast movements, so that contact is continuous and the sensation of weight

comes from the transition between "no weight" and "weight". Weight can be evaluated also non-visually if necessary.

Evaluate the weight as follows: 1.0=very light, 5.0=very heavy

For evaluating drapeability lift the corner of the fabric vertically, perhaps using a curved trajectory to ensure that the fabric folds towards the evaluator. (Fig. 3.2)

Evaluate the drapeability as follows: 1.0=very weak draping, 5.0= very strong draping

3.5 Second day evaluation
Repeat the both evaluation procedures on a second day again and rate the samples.

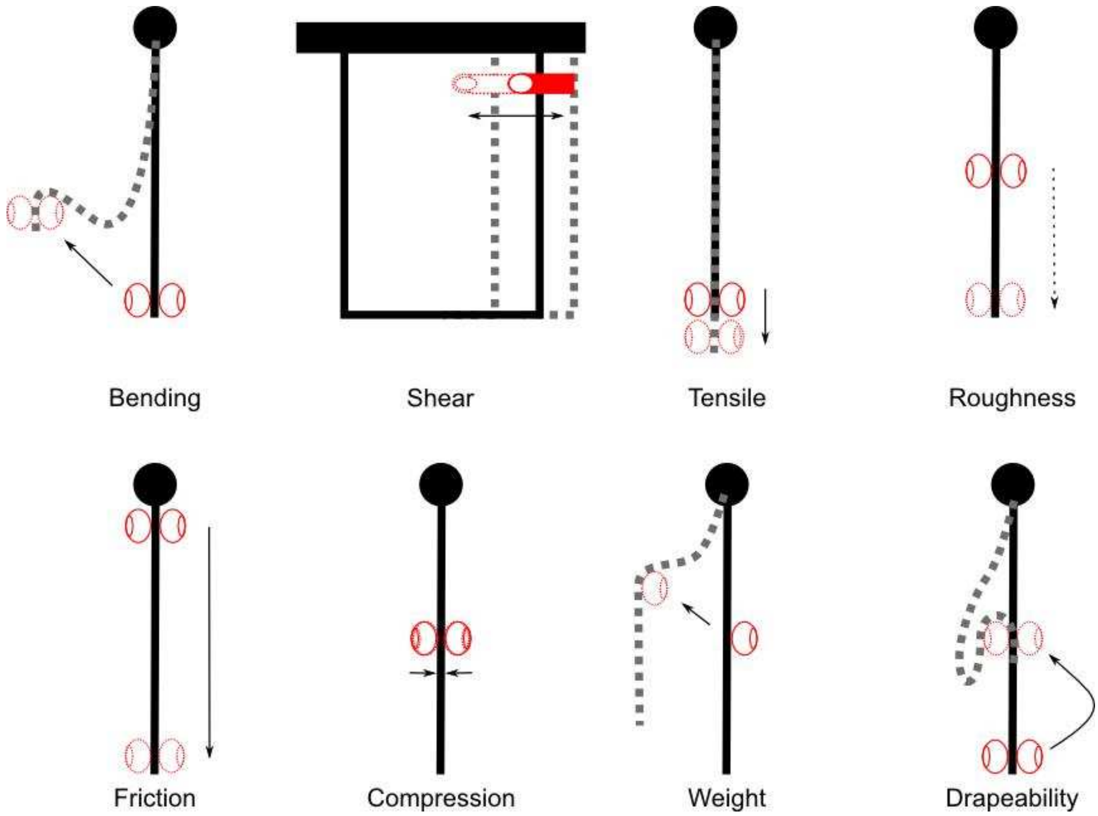

Figure 3.2 Finger positions and manipulation of each property.

4. Results

Compare the results between the evaluators. Compare the real-fabric results between the objective measurement results and between the virtual fabric results.

[1)] Adapting the evaluation of AATCC Evaluation Procedure 5 (2001) (Fabric Hand: Guidelines for the subjective evaluation of AATCC Technical Manual/2002).