The tele-gesture: problems of networked gesture

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Abstract

This paper focuses on the problems of networked gestures. The tele-gesture is the achievement of a remote gesture. To reach a good sensory perception of the distant scene, it is necessary to create a specific flow for the haptic data: position, orientations, and feedback forces. This flow presents intrinsically a bi-directional characteristic. Its quality is extremely dependent on the latency of the intermediary telecom network. In this paper we will present the results of our experiments on the tele-gesture.

1. Introduction

The tele-gesture is the achievement of a remote gesture, i.e. to touch a distant object, that is real or virtual, for example, a human body, and to feel its mechanical characteristics, sensitivity specific to the bones, muscles, tendons and joints which give information about its static, balance and the displacement of the body in space, see [3], [5]. To reach a good sensory perception of the distant scene, it is necessary to create a specific flow for the haptic data: position, orientations, and feedback forces. This flow presents intrinsically a bi-directional characteristic. Its quality is extremely dependent on the latency of the intermediary telecom network. To ensure an encoding of the gesture, it is advisable to use a virtual 3D object, of which it is necessary to build a coherent visual and haptic representation. Each scene is duplicated on the two connected sites: on the local machine and on the distant machine. The haptic device frequency is too high, typically 1KHz, so it would not be possible to go forwards and backwards through the network at such a rate! On each machine, one must thus establish a local loop operating at the rate of 1KHz, from which the data is extracted and sent to the network at a desired lower rate.
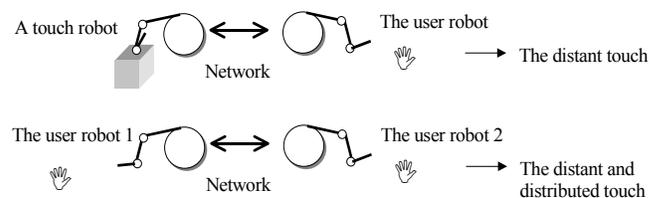
Figure 1. Distant Touch and distributed touch

A SensAble PHANToM haptic robot is used. This device has 6 degrees of freedom and renders a three-dimensional force information. It can track the position and orientation of the tool within a workspace of 16 cm wide, 13 cm high and 13 cm deep. The maximum exerted force is 6.4 Newton. We employ a second PHANToM as the distant system, i.e.: the slave system, see Figure 1. There are three main kinds of experiments of the tele gesture:
•Distributed touch like the example of the fencing,
•Touch of ballistic object, whose trajectory is foreseeable, like tennis games,
•Static touch of object, the tele-echography is an example of static touch, with a pressure sensor on the patient abdomen.

2. Local model and distant model

The 3D geometrical model of the distant scene is coded with polygonal objects. The grid is deformed under the gesture. The fine touch is the notion of touching free forms. Two approaches were studied in our projects: touch of the facets and touch of the nodes.

Touch of the facets: it is the calculation of the position of a point that is named the haptic point[1] , compared to a selection of facets to touch - when the scalar product between the normal to the touched face and the vector going from the haptic point to its projection on the same face changes sign, the haptic point crosses the facet. The force will then be calculated as F = - K X. (K is the stiffness of the virtual object at the considered face and may be fixed or dynamically adjusted and X outdistance the haptic point to the facet). For this approach the continuity of the force is not induced and the processing of smoothing is necessary. Indeed, the force must be continuous when the user makes the handle slide along the surface of the object so that the haptic point projection changes facet.

Touch of the nodes: it is the calculation of the haptic point's position compared to a selection of points: this approach considers a sphere of radius R, the object nodes: the vertices[ ], and the haptic point. When the sphere, attached virtually to the haptic point, contains polygonal object nodes, then a force is returned proportionally to the number of touched points, and the nodes move under the gesture. A zone of forces is produced to allow a feeling as realistic as possible of the 3D scene. The effort feedback is calculated starting from a physical model of the virtual 3D form that is touched.

Table 1. Local model: the qualitative results of experiments. These tests have been performed, works in local loop i.e. without information coming from the network concerning the distant slave workstation.

Touch	Feel	Haptic rendering	Conclusion
on a set of vertices	Discontinuous	Correct	Not realistic for the fine gesture.
on one polygon	Comfortable	Good	Realistic
on one polygon and on its vicinity	Natural, comfortable	Very good	Realistic, Precise

The material point is heavy, elastic and viscous. The state of the material point is governed by mechanical equations. The 3D scene objects are flexible, deformable and their mechanical characteristics, viscosity, rigidity, and mass can be adjusted. We tried out three ways of feeling this modelling dependent on the contact with a polygonal object. The first is a calculation of force feedback based on the nodes of the geometrical 3D model. The second allows a force feedback according to the nearest polygon to the haptic point position. The third comes from the second, and allows an effort feedback

according to the polygon closer to the haptic point, but also according to its vicinity. We note the qualitative results of our experiments in the Table 1.

Gesture sequences can also be recorded to make a simulation, or to replay these sequences. We can build gesture cards. We must take into account the physiological constraints of the human gesture for the tele-gesture to be possible. The haptic loop is fed at a frequency of 1kHz, because below this frequency the gesture perception would be of bad quality, i.e.: unpleasant vibrations would be perceived in the hand.
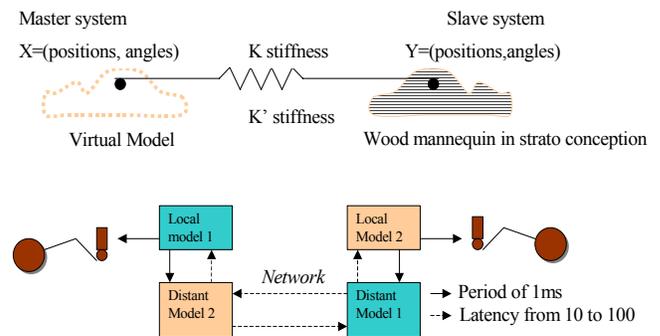
Figure 2. Distant control of the robot in position

We use the local model of the distant scene to calculate the force feedback at this rate. The network will feed this local model, see figure 1. The network is materialized as a spring. It appears necessary to have a local vision: a geometrical model, mechanical 3D from what occurs to the distant one. The local model is a precise model of what occurs locally. This model interacts at the frequency of the robot with the local robot. The distant model summarizes and memorizes for the local model all that is held within the distant one. The distant model is fed by the network messages. The distant model feeds the local model directly.

Contrary to the wave transform approach [2], we exchange haptic data directly in space of the temporal signals. Our approach is based on distant virtual mechanical model.

3. Evaluation of haptic flow

Through the network, the data are encapsulated in messages. In general, the messages contain: the positions X, Y, Z, the angles α, β, γ, and the date. The size of the messages is dependent on the workspace that is to be encoded. The working area for the handle, the workspace is 160x130x130 and the precision is of 0.02mm, for a SensAble PHANToM type desktop.

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[1] The haptic point is the extremity of the phantom arm which is the point of application of the force, in the virtual world.

Equation 1 Evaluation of number of points to encode

$$\frac{\text{maximal handle ambitus}}{\text{precision}} = \text{maximum number of points to be coded} \in D^3$$

where D^3 is the working area

By applying Equation 1, one obtains the maximum number of points to be coded : 8000 points. Then, the positions can be coded on 13 bits as $2^{12} = 4096$ and $2^{13} = 8192$.

Equation 2 Message size limits

$$\frac{\text{network flow}}{\text{sampling period}} = \text{maximum size of message}$$

The message-sampling period is one of the parameters that regulates experimentation, see Table 2. The network flow and the size limits of messages are correlated. For example, the ISDN network flow is 64 kbits per second. If the sampling period is 10ms then the maximal size of a message is 640 bits, see Equation 2.

The latency of the networks is: 30 ms for ISDN, 100 to 200ms for ADSL[2], around 10ms for the local area network LAN. The ADSL network is not recommended for tele-gesture, whereas the ISDN is adequate.

4. The predictive coding of 0, 1 and hybrid order

Messages contain at least a stamp and haptic point position coordinates through a network supposed "ideal". It means that the only disturbance applied to the data is a delay corresponding to the duration of the data's route. We use the local model of the distant patient to calculate the force feedback at a 1kHz rate. The network will feed the expert master interface device with real measurements at a lower rate. So we need to use a predictive algorithm to calculate the signal to send to the robot.
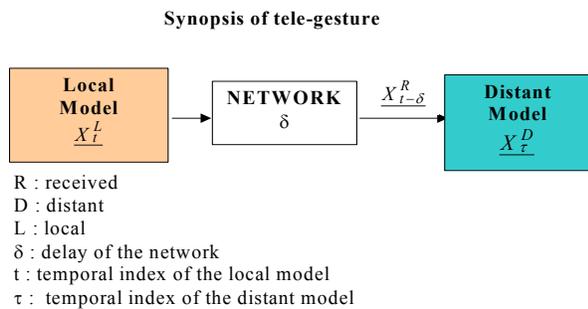
Synopsis of tele-gesture

R : received
D : distant
L : local
δ : delay of the network
t : temporal index of the local model
τ : temporal index of the distant model

Figure 3. Synopsis of tele gesture

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[2] Asymmetric Digital Subscriber Line

The network is like a delay line. It results: $X_{\tau}^{R} = X_{t-\delta}^{L}$. We want to evaluate X_{τ}^{D} and we dispose of the following information:

$X_{t-\delta}^{R}, X_{t-(\delta-1)}^{R}, ..., X_{t-(\delta-n)}^{R}$ the serie of position vectors which transit through the network, and n the buffer's length in which the received data is written. The real time imposes the implementation of the distant model, see Figure 2. The distant model is a reproduction closer as possible to the local model, knowing that we have only the past data of the local model. This past data are separated from the present of our distant model by the incompressible network's latency, i.e. the route's duration of the information. We are going to look for creating a relation of the type:

$$^{1}X_{\tau}^{D} = \Psi\left(\left(^{1}X_{t-\delta}^{D}\right),\left(^{1}X_{t-(\delta-1)}^{D}\right),...,\left(^{1}X_{t-(\delta-n)}^{D}\right)\right),$$ for each

of three position vectors.

For a predictive coding of order 0, there is a brutal modification of the distant model state when the message arrives, see Figure 4. The variable state representing the distant model is equal to the just-received data. In this case: the function ψ is the simplest, following this relation: $X_{\tau}^{D} = X_{t-\delta}^{R}$. From the arrival of the message we modify brutally the distant model's state, we equalize the state's variable representing the distant model to the just received data.

In a continuous haptic flow transmission case, a secure network (without loss) case and a constant transmission speed case: the distant model determines the signal, which is in fact the position of the haptic point and is equal to the signal of local model's signal but displaced in time.
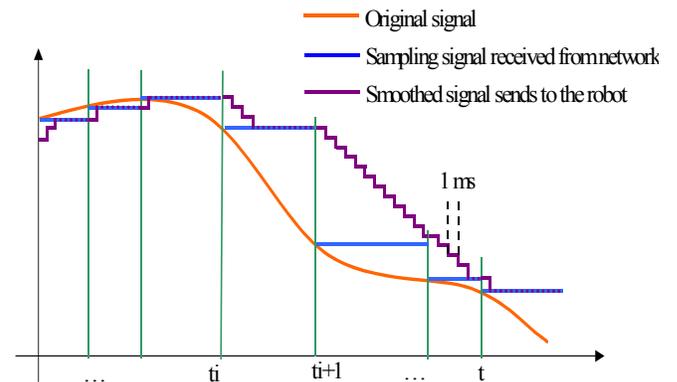

Figure 4. Predictive coding of order 0

For a predictive coding of order 1, information on the slope of the original signal is used to predict the signal between two messages from the network, see Figure 5. In

that case the function ψ is affin: $\Psi(x) = a * x + b$. The following relation is deduced: $\underline{X_\tau^D} = \underline{X_\tau^D} + \delta * \underline{P}$, with $\underline{P}(P_x, P_y, P_z)$ the slope vector composed of the slope calculated on axis X, of the slope calculated on axis Y, and of the slope calculated on the axis Z. The slope is estimated in the following way:

$$\left(P_X = {}^1\underline{X_\tau^R} - {}^1\underline{X_{\tau-1}^R} \right), \left(P_Y = {}^2\underline{X_\tau^R} - {}^2\underline{X_{\tau-1}^R} \right), (...)$$

By proceeding in this way, there is a weak noise of quantification on the signal representing the position of the haptic point; this noise is amplified in our construction of the predicted signal because it is multiplied by the factor δ corresponding to the network's latency. It is important to smooth the received signal to decrease the disturbance generated by this quantification's noise. We observe that the frequency of this noise was included between 150 and 200 Hz. We smooth the slope by using a temporal window of length n=10 ms.

The new slope's calculation is:

$$\left(P_X = \frac{{}^1X_\tau^R - {}^1X_{\tau-1}^R}{n} \right), \left(P_Y = \frac{{}^2X_\tau^R - {}^2X_{\tau-1}^R}{n} \right), (...)$$

This signal is better than the one predicted with the order 0, especially in the straight lines. However, it has poor results during the breaks in the slope of the original signal.
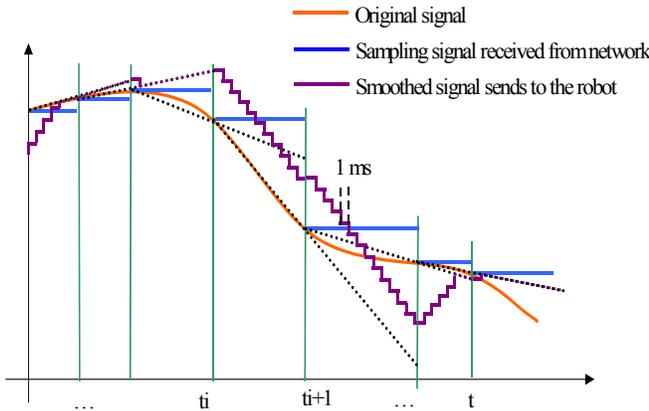

Figure 5. Predictive coding of order 1

For a predictive coding of hybrid order, the calculated signal is the half sum of the signal obtained by a predictive coding of order 0 and the one obtained by a predictive coding of order 1, see Figure 6.
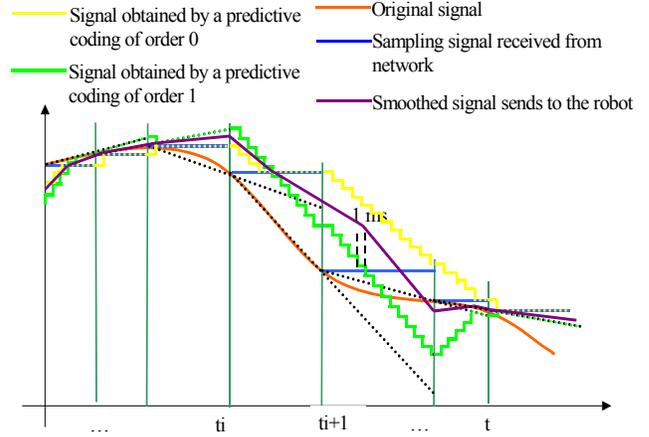

Figure 6. Predictive coding of hybrid order

We have smoothed the predicted signal as this last one results from an affin function of the input signal. The input signal arises from the digitalization of an analogical signal representing the hand movement, which acts on the robot arm. As the hand of the user vibrates slightly it appears teeth in the digitized signal, see the Figure 7, it is observed in a tenth of millimeter scale. The smoothing method consists in using a linear regression.
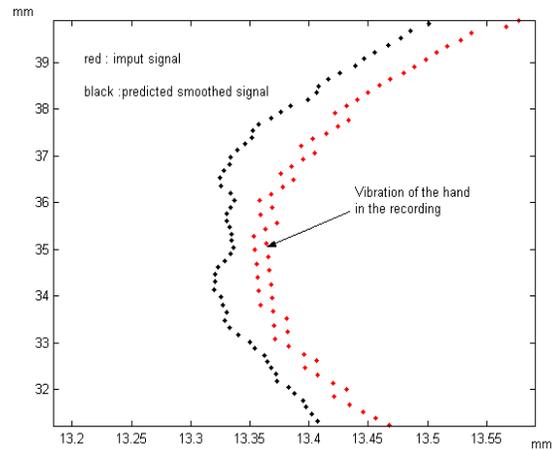

Figure 7. Example of the smoothing method

5. Tele gesture experiments

These experiments were performed using two PHANToM systems communicating through the network [1]. Each device sends its position and receives the position of the other. We tested the initialisation and shut down of the haptic session, the transmission of the position to the distant device, and the calculation of the efforts at 1khz with a data refreshment at the reception

with various rates ranging from 10 to 500ms. The first experimental results are reported in Table 2.

The case of the synchronous network (as ISDN) allows an interaction of the real gestures regularly. The up-to-date handing-over of the extrapolator of gesture is thus carried out regularly, according to a fixed period, dependent on the network.

The first experiments make it possible to test the first exchanges of gesture agility by the intermediary of the ISDN[3] network:
•Initialization of the haptic scene,
•Stopping the haptic scene,
•Sending the position of the local robot,
•Reception of the distant one at various rates: 500, 100, 10 ms,
•Calculating the efforts at a frequency of 1khz with a distant robot data refreshment at reception.

The first experiments are carried out with an ordering of position control on both sides of the network, and it was done the first time for tele-echography [4]. The predictive coding is of order 1, and the signal is smoothed. We use a second PHANToM to simulate the distant system, ie: the slave system. Each robot sends its position and receives the position of the distant robot, see figure 2.
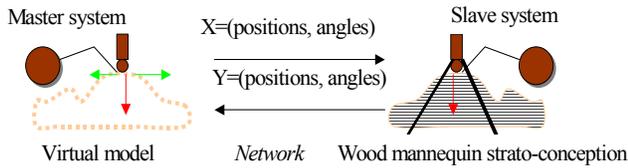
Figure 8. Position control on both sides of the network.

The mechanical model used in the first experiments is a link between the local model and the local perception of the distant model. At this point, the best way of sampling the messages must be found, the latency time due to the network, the robot 1kHz period of sampling, and to the optimal period of sampling for the gesture signal. We redefine the extrapolation algorithms of the positions and forces, and we test the predictive coding of 0, 1 and hybrid order of the distant mechanical models. Specific filtering of emissions and receptions of the gesture data is introduced. At the emission, it is a question of filtering the natural noise made by the hand. At the reception, it is a question of filtering the jitter introduced by the variable times of message transport, such as adding a low-pass filter on the speed of the gesture signals.

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3 Integrated Services Digital Network
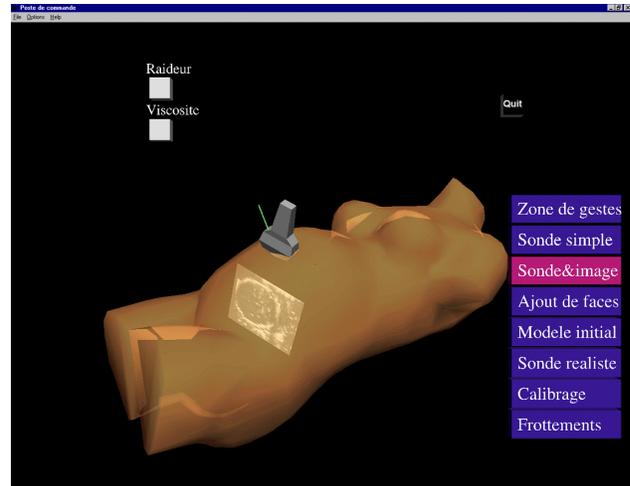
Figure 9. The tele-echography command station - a slow gesture

To improve gesture ergonomics of the expert within the tele-echography, we will create the virtual tangential forces, which increase quickly if the medical expert moves his hand too quickly, because the distant robot will have its own speed limits, see the green vectors on figure 2. The medical expert feels the force exerted on the patient and measured with a sensor, perpendicularly. Figure 3 shows the current interface of the haptic command station for tele-echography. The green segment materializes the intensity of the force perceived by the medical expert.

Table 2. Transmission experiments using the ISDN network:

Sample	10 ms	100 ms	250 ms	500 ms
Flow	100Hz	10Hz	4Hz	2 Hz
Haptic behaviour	Very good	Good	Some vibrations	Some vibrations and oscillations
Command ability	Natural	Restricted in term of the gesture speed	Difficult	Very difficult
Conclusion	Realistic	Realistic for slow gestures	Need to set up finer extrapolators of gesture	Need to set up finer extrapolator and stabilizer of gesture

The case of the asynchronous network (as internet) allows an irregular interaction of the real gestures. The up-to-date handing-over of the extrapolator of gesture is thus carried out irregularly, according to a non-fixed period, dependent on the network.

The fast gestures, such as the sword gesture, require a very low latency time of the intermediary telecom network. It should be less than 50 ms. Figure 10 shows the example of the swords, a "game" of gestured agility.

The current application calculates the intersection of two lines in space, i.e. the two swords. One of the swords is brought under control of the local robot; the local player handles it. The second sword is the local model from what occurs on the station according to the distant player.
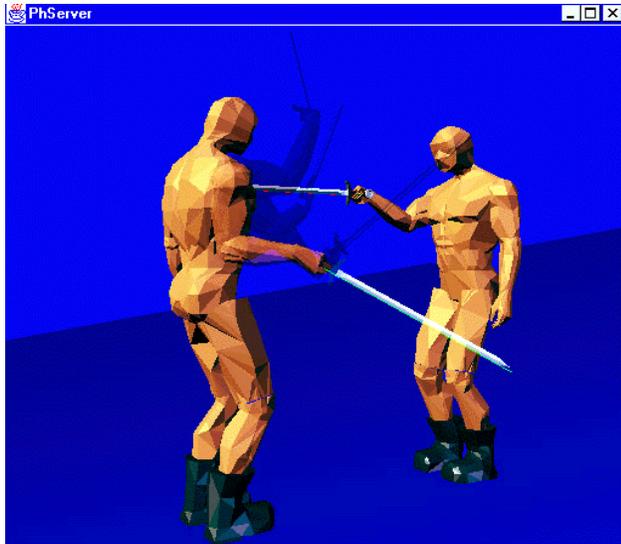
Figure 10. Sword gesture- a fast gesture

This game uses the LAN[4] network with UDP/IP[5]. The client side has to:
•Initialize the client,
•Create a socket,
•Receive messages at least at the message-sampling rate,
•Send messages to the sending message client, at the message-sampling rate 500, 100, 10 ms,
The server side has to:
•Initialize the server,
•Create a socket,
•Send messages at the message-sampling rate 10 ms,
•Receive messages at least at the message-sampling rate,
For the "game" of swords, the sampling period was 10ms. The predictive coding was of order 1, and the signal is smooth. The IP network is not a secure network and messages can be lost. It is also asynchronous network. In our experiment the latency was almost less than 10ms so, the results and the feeling were realistic and natural.

6. Conclusion

We experimented the transmission of haptic data on the ISDN network and also on local network (LAN). The results of our experiments are very encouraging and prove that the gesture can be transported with the help of some ad hoc filtering, by ISDN network, or on IP. The transport of the gesture data via the network allows an immersion even more complete and realistic for distant manipulators.

7. References

[1] Howe R.D., Debus T., Dupont P, "Twice the fun: Two Phantoms as a High-Performance Telemanipulation System" PUG 1999.
[2] Kline-Schoder R., Wilson J., "Algorithm for Network-Based Force Feedback", Creare Incorporated Neville Hogan, Massachusetts Institute of Technology, PUG 1999.
[3] Singhal S., Zyda M., "Networked Virtual Environments", Design and Implementation, Addison Wesley
[4] Vilchis Gonzales A, Cinquin P, Troccaz J, Guerraz A, Hennion B, Pellissier F, Thorel P, Courreges F, Gourdon A, Poisson G, Vieyres P, Caron P, Mérigeaux O, Urbain L, Daimo C, Lavallée S, Arbeille P, Althuser M, Ayoubi JM, Tondu B, Ippolito S, "TER: a system for robotic tele-echography", MICCAI 2001.
[5] Wing A-M., Haggard P., Flanagan J-R., "Hand and Brain - The neurophysiology and Psychology of Hand Movements", Academic Press, 1996.

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4 Local Area Network
5User Datagram Protocol / Internet Protocol