COUPLING VISUAL AND DYNAMIC FEATURES TO STUDY HANDWRITTEN SIGNATURES

Jean-Jules Brault et Réjean Plamondon

Laboratoire SCRIBENS
Département de Génie Electrique
Ecole Polytechnique de Montréal
Montréal, Québec H3C 3A7

RESUME

Un outil informatique est proposé dans le but de permettre l'étude interactive des caractéristiques spatio-temporelles des signatures manuscrites. L'outil permet de faire le pont entre l'aspect visuel d'une signature et les caractéristiques dynamiques reliées à son exécution. Des commandes d'édition graphiques et de traitement numérique sont disponibles à l'usager pour respectivement manipuler et modifier à l'écran les différentes représentations reliées à une signature donnée.

ABSTRACT

A software tool is proposed for interactive study of spatio-temporal characteristics related to handwritten signatures. The tool fills the gap between visual and dynamic aspect of signature with specific graphic editing commands that can be used to manipulate on the screen the various representations of features related to a given signatures. Also, useful data processing commands allow modification of the content of these representations.

I- INTRODUCTION

Handwriting is a rather complex mechanism which results in the generation of line images. These images can be analysed by different recognition techniques based either on the visual output of the process[1] or on the dynamic information acquired by specific set up during the process itself. Among the different class of problems dealing with handwriting recognition, signature verification has been given a growing attention in the past ten years in the field of computer security. Indeed, with the increase in the number of electronic funds transfers and any other computer access, the need for an Automatic Personal Identification (API) system has become a major priority.

Signature verification techniques offer different advantages over other identification techniques[2] (passwords, PIN's, magnetic card, finger print, voice,...). It is an accepted and easily tested method. Signature cannot be lost or stolen and it can hardly be imitated dynamically. In the past fifteen years, intensive research has been made3,4,5,6,7,8 to implant an API systems based on signature. But none of the systems already proposed in the literature has put the final point on the subject. Indeed, handwritten signature is a complex task requiring a high muscular skillfulness and we believe that further fundamental research is needed on the handwritten phenomenon to improve the performances of the systems.

Different tools and methods exist that help research in handwriting. In psychology[9], for example, measurement of reaction time or movement time are often used to verify presumptions about specific handwritten task (e.g. identification of a movement unit in handwriting; the stroke). In this paper, we present an interactive software tool based on the possibility to do time coupling between visual information (that is the signature itself on the paper) and any type of dynamic information based on data sampled during the execution of the handwritten task.

In this contribution, we recall in section II the two class of features involved in signature verification (visual and dynamic) and point out their complementarities. We present in section III an overview of the features (technical and functional) implanted in the software tool. In section IV, we give a typical application showing the utility of the tool in interactive analysis of handwritten task, specifically signature.

II- VISUAL VERSUS DYNAMIC INFORMATION

Two major class of features dealing with signature can be used as input for an API system:

- the visual information
  (that is the final result on the paper).
- the dynamic information
  (that is the sequence in time of any measurable (but meaningful) characteristic).

Optical analysis of signature is a useful technique in off-line verification application like document expertise. But, sometimes, in order to pronounce a correct verdict about the authenticity of a signature, an expert needs to gather dynamic features from the static representation of a signature by examining it under microscope (the aspect of the paper fiber where the pen had passed, the variation in the thickness of the line,...). However these techniques cannot be automated (at least in a near future) and are thus unusable for API applications.

On the other hand, dynamic signals can be processed and analysed by different techniques, namely the usual signal processing approach (filtering, correlation, spectral analysis, time series, etc). But these methods rarely take into account the visual origin of these specific signals and questions like:

"Which parts of a signature was traced more rapidly than a speed threshold?"

"Are the amplitude variations of the signal more determining in the shaping of a given letter than are frequency variations?"

"Are rapid movements more accurate and easily repeated than slower ones?"

remain unanswered because only one aspect of the available information is usually analysed. We believe that signatures must be analysed by coupling the visual and dynamic information together. This requires that position and other dynamic information must be sampled simultaneously during the execution of a signature.

The source of information related to signature could be of various kind:

- Those issued directly from transducers at the execution time. The transducers could be in the writing pen (like strain gages[5], accelerometers[3,4,8], etc.), or under the writing surface (digitizer[7] or digitizer with analog computation[10])

- Those obtained indirectly after computation from the sampled data (first and second time derivative of position, radius of curvature, instantaneous frequency of the signal, or any other interesting features).

But the main requirement to make time coupling is that all sources of dynamic information must be sampled simultaneously by an adequate set-up.

III- THE SOFTWARE TOOL

To be able to illustrate the idea behind the expression "time coupling", an handwritten signature has been sampled (at 200 Hz) by a digitizer (model MM960 Summagraphic Inc.) One can redraws the signature on a graphic screen by tracing the X(t) sequence vs the Y(t) sequence as in figure.1 where the bottom signal is X(t) while the one above is Y(t).

The effective coupling of information can be made internally by software because we know "when" each upstroke and downstroke have been made. To see a desired coupling with the software tool, the user only has to localize a moving cross on the screen with the cursor arrows on the keyboard (or with a mouse) on a point of interest (e.g. a glitch on the X(t) signal or a particular stroke on the signature) and depress the space bar on the keyboard (or a button on the mouse). The software automatically finds the point of the graph that is the nearest to the cross, and indicates with numbered vertical line(s) all the couplings in time occurring on the graphs that belong to the same signature.

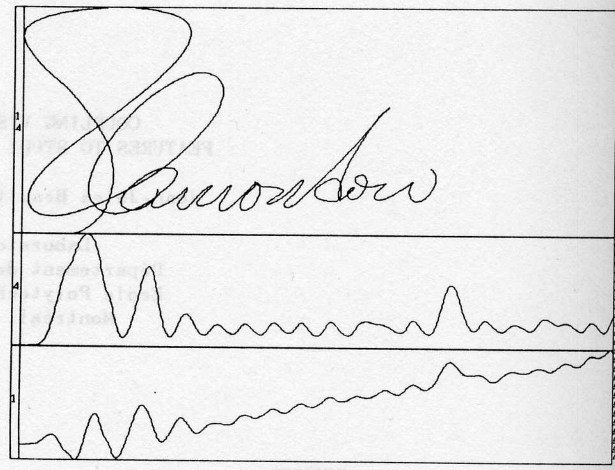

Figure 1

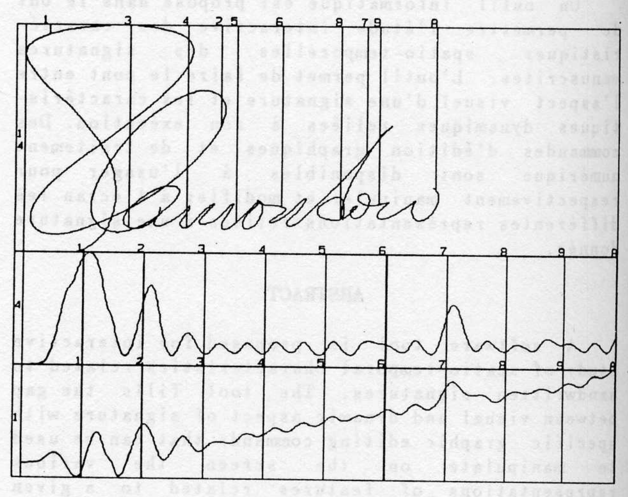

Figure 2

For example, the underlying "timing" of the signature in figure.1 can be retrieved by coupling ten consecutive samples of the position signal (e.g. one at each 100 samples representing one tenth of the total duration of the signature) to their effective positions in 2D (figure.2). The numbered vertical lines indicate the ten couplings.

Several functions have been implanted jointly to the coupling function but before saying more about that, the following describes the technical features of the software.

Technical features

The software is written in FORTRAN 66 (about 6000 statements or about 230 Kbytes of compiled code running on a mainframe IBM 4381). It uses the T.C.S. Library of subroutines and so it must be run from a TEKTRONIX 4010/4014 terminal (or a Tektronix emulator). At execution, an additional 170 kbytes is required for constants, and workspace.

At the data level, the working area consists in two regions (for eventually two signatures), each divided into seven channels. One channel can hold up to 2048 data (e.g. a ten seconds signature if sampled at 200 Hz). At start up, the program reads a data file into the system and puts it in one region of the working area. If the file contains only three non-empty channels (e.g. X position, Y position, and pressure), four channels are then left empty and could be filled with signals that could be modified by one of the 19 data processing commands (see functional features).

At the graphical level, the software can trace on the same screen:

- up to 10 figures associated to the first file and/or
- up to 10 figures associated to the second file and/or
- up to 10 figures associated to the two files together in order to make comparison. (e.g. correlation between files).

Each of these graphics can be modified in different ways by the 17 graphics commands as it is described next.

<u>Functional features</u>

The implanted functions are divided as follows:

- 19 data processing commands
- 17 graphic editing commands

As we have said, each channel of the working area can be modified by the data processing commands. These commands are menu driven. For example, one can filter, derive, interpolate or even make an FFT of a signals, or else, makes operations between signals (add, multiply, correlate...). Also one can add a customized application to the software. It is easily expandable.

Also, each figure drawn from these channels can be interactively edited via the graphic editing commands. These commands are called with a one character mnemonic and use a moving cross to manipulate the figures on the screen. Most of the graphics commands concern manipulations of two kinds of windows: a "virtual" window which determines the data to be displayed, and a "display" window which determines where, on the screen, the selected data will be plotted. Commands are available to modify the number, the disposition and the content of the windows to be drawn on the screen. It is also possible to make measurement by superimposing a user defined reference grid on a window or an other window in order to make qualitative comparison.

Obviously, we cannot discussed here the details of each of the implanted functions but we can give an application example using some commands in order to gained an insight in the way the program progress throughout the commands.

IV- APPLICATION

Suppose we have a signature sampled with a given digitizer. We want to know where, on the signature, the line has been traced at a speed higher than an arbitrary threshold value.

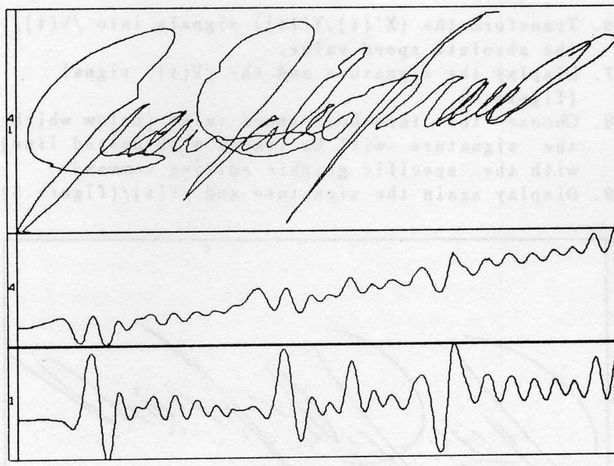

Figure 3

To answer to this question, the following procedure will be used:

1. Read the file where the X and Y coordinates of the signature are stored.
2. Make a copy of the position signals (X(t),Y(t)) in two empty channels of the working area.
3. Display the signature to see if it is necessary to filter the signals (figure.3).
4. Filter if necessary (yes in our case).

N.B.: Two kinds of filter are available in the program:
- frequency sampling FIR filter[11]
- moving weighted average filter.

5. Derive one pair of position signals to obtain the speed relative to each direction (X'(t) and Y(t).

N.B.: We use finite central difference calculus for fifth orders polynomials[12].

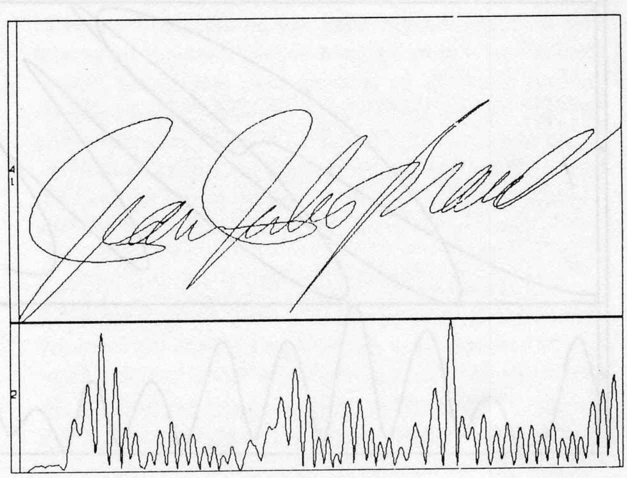

Figure 4

6. Transform the (X'(t),Y'(t)) signals into /V(t)/, the absolute speed value.
7. Display the signature and the /V(t)/ signal (figure.4).
8. Choose the threshold speed value (below which the signature will be traced with dotted line) with the specific graphic editing command.
9. Display again the signature and /V(t)/(figure.5)

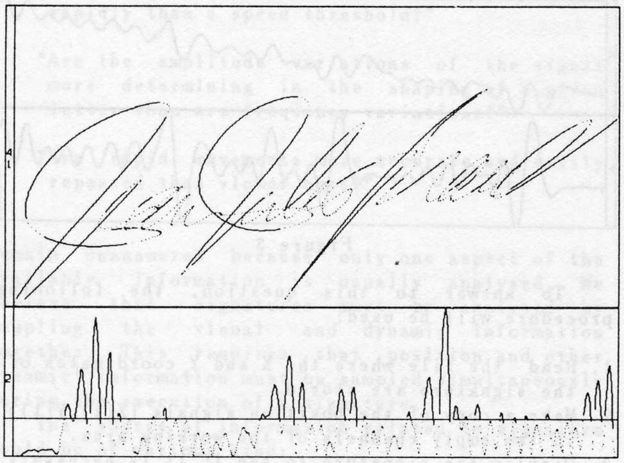

Figure 5

If we now want to "zoom" on a particular section of the whole signature, a command exist to cut the desired section and redraw it magnified (e.g. the "an" of "Jean"). Figure.6 shows the result.

As we have already said, other useful functions are available to help the user in his study of a handwritten task and figure.7 shows some of them. A more complete subset of functions will be shown at the oral presentation.

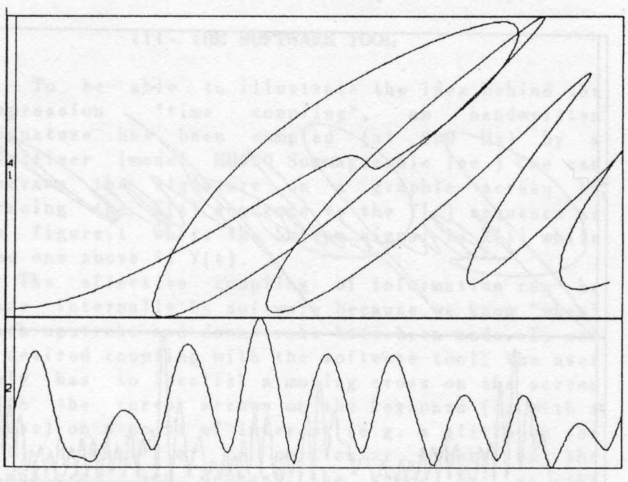

Figure 6

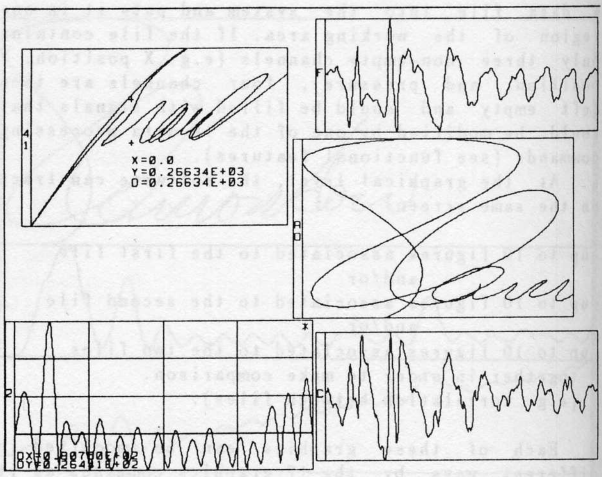

Figure 7

V- CONCLUSIONS

We have developed a tool of practical interest to study signatures (or handwriting in general) in a pleasant environment. It runs on a mainframe allowing computing power and a large library of already developed programs of mathematical transformations and digital signal processing. The program has provision for additional functions. The features extraction process can now be made interactively with this software tool. We presently use it to develop handwriting formation models (and to verify model already proposed in literature[9]) in order to better understand the nature of handwriting.

VI- BIBLIOGRAPHY

1. Suen,C.Y., Berthod,M. and Mori, S., "Automatic Recognition of Handprinted Characters - The State of the Art", Proc. of the IEEE, Vol.68,no.4, 1980.

2. Long Range Planning Service Service, "Automated Personal Identification", Stanford Research Institute, 1974.

3. Liu, C.N. and Herbst, N.M. "Automatic Signature Verification Based on Accelerometry", IBM Journal of Research and Development, Vol.21, pp.245-253, 1977.

4. Brault,J.J. "Design d'un Crayon Accélérométrique pour la Vérification Automatique des Signatures" Mémoire de Maitrise, Ecole Polytechnique de Montreal, janvier 1983.

5. Crane, H.N. and Ostrem, J.S., "Automatic Signature Verification Using a Three-axis Force-Sensitive pen", IEEE Trans. Systems Man, and Cybernetics, vol.SMC-13, no.3, pp. 329-337, 1983.

6. Brault,J.J. Plamondon,R. "Histogram Classifier for Characterization of Handwritten Signature Dynamic", Proc. 7 th Conference on Pattern Recognition, p.619-622, Montreal. 1984.

7. Lorette, G., "On Line Handwritten Signature Recognition Based on Data Analysis and Clustering", Proc.7th Conference on Pattern Recognition, p.1284-1287, Montreal, 1984.

8. Worthington.T.K., Chainer,T.J, Williford,J.D, Gundersen, S.C., "IBM Dynamic Signature Verification", Computer Security, North-Holland, IFIP, 1985.

9. Acta Psychologica: Motor Aspects of Handwriting, International Journal of Psychonomics, North-Holland, Amsterdam, vol.54, 1983.

10. Maamari,F. and Plamondon, R.,"Extraction of the Analog Pentip Position, Velocity and Acceleration Signals from a Digitizer", Neuronal and Motor Aspects of Handwriting, North-Holland Publishers, Editor Dr. H.S.R.Kao, 1985.

11. Rabiner,L., Gold,B., McGonegal,C.A. "An Approach to the Approximation Problem for Nonrecursive Digital Filters", IEEE Transactions on Audio and Electroacoustics, Vol-18, No.2, june 1970.

12. Hornbeck, R.N. "Numerical Methods", Prentice-Hall Inc, New Jersey 1975.