Comparing posturographic time series through events detection†

Juan A. Lara  Guillermo Moreno  Aurora Pérez  Juan P. Valente
Facultad de Informática, Universidad Politécnica de Madrid,
Campus de Montegancedo, 28660, Boadilla del Monte, Madrid, Spain.
j.lara.torralbo@upm.es  gmg@alumnos.upm.es  {aurora, jpvalente}@fi.upm.es

África López-Illescas
Centro Nacional de Medicina del Deporte, Consejo Superior de Deportes,
C/ El Greco s/n, 28040, Madrid, Spain.
africa.lopez@csd.mec.es

Abstract

The comparison of two time series and the extraction of subsequences that are common to the two is a complex data mining problem. Many existing techniques, like the Discrete Fourier Transform (DFT), offer solutions for comparing two whole time series. Often, however, the important thing is to analyse certain regions, known as events, rather than the whole times series. This applies to domains like the stock market, seismography or medicine. In this paper, we propose a method for comparing two time series by analysing the events present in the two. The proposed method is applied to time series generated by stabilometric and posturographic systems within a branch of medicine studying balance-related functions in human beings.

1. Introduction

Data mining techniques can be applied to solve a wide range of problems, including time series analysis, which has come to be highly important in recent years.

One interesting problem in the data mining field is the comparison of two time series. This calls for the determination of a measure of similarity indicating how alike two time series are.

There are many techniques for comparing time series and extracting common subsequences. Some techniques are based on the Fourier Transform, like the Wavelet Transform [2]. Another type of approach employs the time warping technique [3].

Most of these techniques compare one whole series with another whole series. However, there are many problems where it is requisite to focus on certain regions of interest, known as events, rather than analysing the whole time series [4]. This applies, for example, to domains like seismography, where points of interest occur when the time series shows an earthquake, volcanic activity leading up to the earthquake or replications.

In this article, on the one hand, we propose a method that can locate similar events appearing in two different time series, that is, events that are similar and common to the two series, and, on the other hand, we also define a similarity measure between the two time series based on the idea that the more events they have in common the more alike they will be. This similarity measure will be needed to do time series clustering, pattern extraction and outlier detection.

The method developed throughout this article will be applied in a field of medicine known as stabilometry, which is responsible for examining the balance-related functions in human beings. This is an important area within neurology, which has showed great development in the recent years in the diagnosis and therapy of balance-related dysfunctions like dizziness.

There is a device, called a posturograph, which is used to measure the balance-related functions in human beings. The patient stands on a platform to do a

† This work was funded by the Spanish Ministry of Education and Science as part of the 2004-2007 National R&D&I Plan through the VIIP Project (DEP2005-00232-C03).
number of tests (see Figure 1). We used a static
Balance Master posturograph. In a static posturograph,
the platform on which the patient stands, does not
move. The platform has four sensors, one at each of
the four corners: front-right (FR), front-left (FL), rear-right
(RR) and rear-left (RL). While the patient is doing a
test, each of the sensors receives a datum every 10
milliseconds. This datum is the intensity of the
pressure that the patient is exerting on the above
sensor. Therefore, at the end of the test, we have a time
series composed of a determined number of
observations measured at different time points.

The proposed method will be described in section 2.
The use of computing techniques in the domain of
medicine has recently come to be common practice [5, 6]. However, the application of data mining techniques
to posturographic data has a number of particularities
that, taken together, single it out from their use in other
domains. They are: (1) the structural complexity of the
patient examinations, (2) the multi-dimensionality of
the collected variables and (3) the fact that relevant
information appears in certain regions of each series
and not across the whole series.

The study carried out focused on one of the tests
performed on the posturograph: the UNI test. This 10-
second test aims to measure how well the patient is
able to keep his or her balance when standing on one
leg with either both eyes open or both eyes shut.

An ideal test would be one where the patient kept a
steady stance and did not wobble at all throughout the
whole test. The interesting events of this test occur
when the patient loses balance and puts the lifted leg
down onto the platform. This type of event is known in
the domain as a fall.

Formally, the aim is to find a function $F$ that takes
two times series $A$ and $B$ and returns a similarity value
in the interval $[0,1]$, where 0 indicates that the two
series are completely different and 1 denotes that the
two series are identical.

To determine similarity, the proposed method looks
for events that appear in both series. The greater the
number of events that the two series to be compared
have in common, the closer similarity will be to 1. If
the series do not have any event in common, similarity
will be equal to 0.

To determine whether an event in one time series
appears in another, the event has to be characterized by
means of a set of attributes and compared with the
other events of the other series. To speed up this
process, all the events present in the two time series are
clustered. Therefore, if two events belong to the same
cluster, they are similar. The goal is to find events that
are members of the same cluster and belong to
different time series.

Therefore, the proposed algorithm for extracting
events common to two time series $A$ and $B$ is:

1. Extract all the events $E_i$ of both
   series (events that appear in $A$ or in
   $B$) and characterize each event by
   means of a set of attributes.
2. Cluster all the events extracted in
   point 1.
3. For each cluster from step 2 and as
   long as there are events from the two
   series in the cluster:
   3.1. Create all the possible event
       pairs $(E_i, E_k)$ for which $E_i \in A$ and
       $E_k \in B$.
   3.2. Select the event pair that
       minimizes $\text{distance}(E_i, E_k)$.
       (This extracts the two events that
       are in the same cluster, belong to
different time series and are the
most alike)
3.3. Delete events $E_i$ and $E_k$ from the
    cluster.
3.4. Return the pair $(E_i, E_k)$ as an
    event common to both series.

By the end of this process, we will have managed to
extract the event pairs that are similar in the two series.
This is a key point for the mechanism that establishes
how alike the two time series being compared are.

A common event, $C_i$, is a pair $C_i = (E_i, E_k)$ | $E_i \in A$
$E_k \in B$, output by step 3.4 of the algorithm. If $E = \{E_j,$
j=1..m} is the set of all events present in $A$ or in $B$
(output by step 1 of the algorithm) and $C=\{C_i, i=1..m\}$
is the set of common events present in both series, \( A \) and \( B \), then the similarity can be obtained by comparing the amount of the time series that is common to the two time series \( (C) \) with the total amount of the time series of interest \( (E) \). The more events the series to be compared have in common, the closer the similarity will be to 1.

3. Results

The system developed has been evaluated by running a battery of tests. These tests were done on time series generated by a posturographic device. The study focused on the data from the UNI test. For this test, the events of interest are falls.

We received support for the evaluation from the High Council for Sports. This institution provided times series for 10 top-competition athletes of different sexes, ages and sports for this study. 10 is a reasonable number of patients, taking into account the shortage of top-competition athletes and the complexity of tests. An expert from the above institution helped to validate the results generated by implementing the proposed method (due to the lack of experts in this area, we had to rely on only one expert).

The evaluation of the research focused on two points: (I) Does the system detect falls correctly? and (II) Are the comparisons made by the system of similar quality to those made by the expert?

As regards the first of the above points, the results obtained were very satisfactory, as the system detected 16 of the 17 falls determined by the expert. Additionally, the system did not identify any fall that the expert did not consider as such (no false positive).

To evaluate the second of the above points, every two of the time series were compared (a total of 45 comparisons) and, for each of the above comparisons, the similarity rating generated by the method was checked against the similarity score determined by the expert. In each comparison, the expert was asked to determine a similarity rating from the following: \{Not at all similar, Not very similar, Moderately similar, Fairly similar, Very similar\}.

The rating Not at all similar would correspond to a similarity in between the interval \([0, 0.2)\), the rating Not very similar would correspond to the interval \([0.2, 0.4)\), and so on up to the rating Very similar, which would correspond to a similarity score in \([0.8, 1]\).

When evaluating a comparison, the agreement between the expert and the method could be Total if the similarity interval is the same in both cases, Very High if the interval determined by the system and by the expert are adjacent, and Low in any other case.

The results of the comparisons by the expert and the system were also good, as, agreement between the system and the expert was Total or Very High in 39 out of 45 cases. Only 6 of the cases showed some differences between the results generated by the system and the ratings determined by the expert.

4. Conclusions

We have developed a method to compare time series by matching up their relevant events. This method is suitable for domains where the relevant information is focused on specific regions of the series, called events, and where the remaining regions are not relevant.

The method was evaluated on time series for top-competition athletes. After performing the different evaluation tests, the results were considered very satisfactory for both the research team and the expert physicians, boosting their will to develop further cooperation in this field.

5. References


