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SOFTWARE FOR CONTOUR MAPS OF MOVING LEAST- SQUARES SPECTRA

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A b s t r a c t

This paper reports on software developed to compute least-squares spectra over a specified interval. This approach facilitates the viewing of a changing time structure in non-stationary time series, smaller than the observation span. The programme is illustrated by a case of solar activity, gauged by yearly Wolf numbers, for the 1700–1999 span that shows the presence of a very unstable component with a period of around-100 years and an about-11-year solar cycle. This method, although demostrated here on a geophysical example, has a broad scope of applications in biology and medicine.

K e y w o r d s

Rhythm analysis, Least-squares spectra, Software

INTRODUCTION

Life can be viewed as a transiently self-sustaining organised structure in time and space; in time it consists of chronomes, involving irregular changes and rhythms that undergo trends. The chronomes, i.e., biological rhythms, last for a period sufficient to allow for their reproduction and evolution (*1, 2*). The chronomes of organisms continuously communicate with the time structures of the environment consisting of similar elements. Indeed, biologists find more and more counterparts of biological cycles in the environment and counterparts of environmental cycles in biology (*3*).

Chronobiologists have long used serial sections to analyse changes in rhythms as a function of time by means of characteristics of an anticipated spectral component. These characteristics include the MESOR (rhythm-adjusted mean value), amplitude (measure of half the extent of predictable change within a cycle) and acrophase (a measure of the timing of overall high values recurring in each cycle). This approach has proved to be very informative in understanding, for instance, the circadian rhythms and acrophases of different body functions after a transmeridian flight.

Environmental rhythmic elements consist of photic and non-photic cycles, some of which are solar or galactic. The rhythmic elements of the chronomes in and around us are intermodulated by these environmental rhythmic elements (*1–4*). The interactions among two or more biological and/or physical entities are characterised by sequential patterns in time, involving recurrent quantitative or qualitative changes. A qualitative change can exert an effect of one entity upon another, entailing a sequence of inhibition and stimulation, recurring rhythmically and predictably (*1–5*).

The aim of this study was to facilitate the viewing of a changing time structure in non-stationary time series. For this purpose, software was developed to compute least-squares spectra over a specified interval.

MATERIALS AND METHODS

To extend the chronobiological serial section from a single spectral component to a broader frequency range, a programme was written to prepare tables (spreadsheets) that can easily be imported to extensively used and commercially available software such as Microsoft Excel. The programme can handle either equidistant or non-equidistant data, coded in arbitrary or time units (century, year, month, day, hour or minute) for each biological value studied. The least-squares spectra calculated are smaller than the observation span, displaced through (per) a time series, e.g., progressively, in specified increments (smaller than the interval) or in a fractionated form (interval = increment). The programme is interactive and prompts the user either to enter selections, such as the length of the interval to be used for the computation of the least-squares spectrum, or to use an increment by which this interval should be moved throughout the time series. This programme also offers a choice between the computation of a least-squares spectrum (in which trial periods are in harmonic relation in a specified frequency range) and that of a chronobiological window (in which trial periods are changed by a specific amount within a narrow frequency range).

RESULTS

The output of the programme consists of a set of files, constructed as matrices, each column presenting values specific to a given trial period. Different endpoints are provided in different files. The following endpoints are included: the MESOR, amplitude, acrophase, the standard error for each of these tree parameters, the percent rhythm (the proportion of the total variance accounted for by the component with the given trial period) and the P-value (from the zero-amplitude test). The utilisation of this method is demonstrated in *Fig 1.* In such a map, the matrix of amplitudes can be plotted as a contour map (surface chart) in commercially available software packages (such as Microsoft Excel). The maps show the relative prominence of all frequency components that are present in the sample analysed. In *Fig. 1* the case of solar activity, gauged by yearly Wolf numbers, available for the 1700–1999 span is illustrated. The results show the presence of a very unstable component with a period varying around-100 years and the presence of an about-11-year solar cycle. Sidebands around the latter component suggest that this is modulated in amplitude or phase.

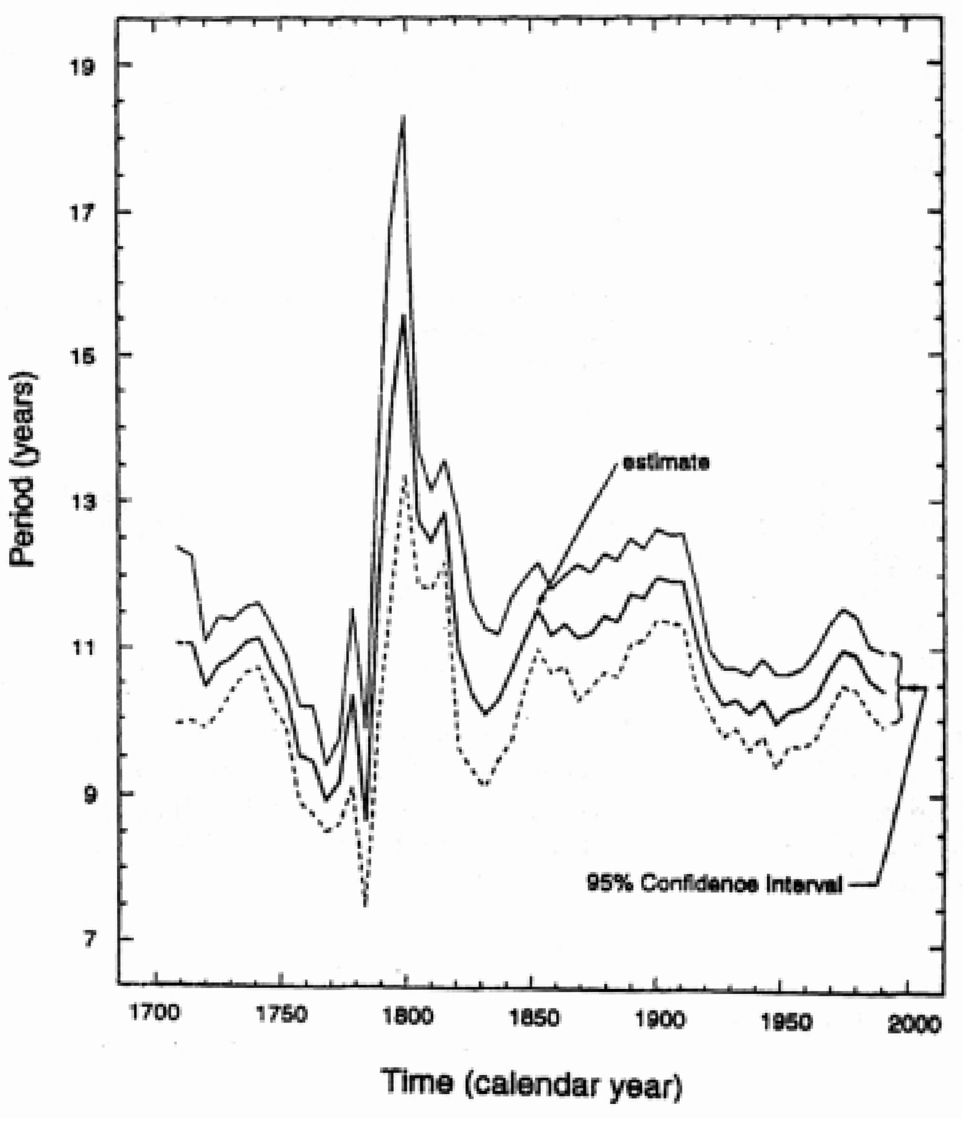

Fig 1
Chronome map showing solar activity, gauged by yearly Wolf numbers, in the 1700 to 2000 period. It is based on the data from studies by several scientists over three hundred years (kindly provided by *Schwartzkopff et al.*; 2002).

DISCUSSION

The time structure of Wolf numbers is known to differ from exact periodicities. To analyse such non-stationary data, contour maps offer themselves as a useful tool, beyond the chronobiologic serial section, which is limited to a specific spectral component. Such a tool may become of increasing importance to biologists, particularly in view of the documentation of about-10.5, -21.0, and -50-year cycles in long-term data on anthropometry, pathology, physiology and psychology, as well as the growing evidence of associations between the time structures (chronomes) of physical environmental variables and the chronomes of biological functions (*3)*.

For the study of photic effects of the sun on the earth, the amplitudes of periodicities of about-1-year and about-1-day are useful. Similarly, the amplitudes of about-half-weekly, about-weekly, about-monthly, about-half-yearly, about 10.5-, about 21-year and about 50-year cycles are important for investigations into the effects of corpuscular radiation elicited by the sun, moon and cosmos (*3,5*).

The involvement of geophysical and magnetic effects in life on earth cannot be ruled out. It is suggested that the cosmic ray flux has an effect on life on earth that is similar to magnetic storms. Both may, for instance, affect the number of bacterial colonies or mutations in a testable model (*6*).

The method of mapping chronomes presented in this paper may provide a useful tool for further analyses of chronobiological data that, particularly in clinical medicine, will contribute to a better understading and interpretation of pathophysiological states (*7,8*).

A c k n o w l e d g e m e n t

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SOFTWARE PRO MAPOVÁNÍ POHYBLIVÝCH SPEKTER NEJMENŠÍCH ČTVERCŮ

S o u h r n

V této práci je popsán počítačový program pro mapování a výpočty čtverců nejmenších spekter ve stanovených specifických intervalech. Tento přístup usnadňuje pozorování měnících se časových struktur v nestacionárních časových úsecích menších než pozorované období.Program je presentován na příkladu solární aktivity, vyjádřené ročním Wolfovým číslem, získaným pro časové období 1700-1999. Ukazuje na přítomnost velmi nestabilní periody asi 100 let a přítomnost asi 11-letého slunečního cyklu. Tato metoda, která je zde ukázána na geofyzikálním příkladu, může mít široké spektrum uplatnění v biologických i lékařských vědách.

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