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A SOFTWARE IMPLEMENTATION OF WATER WAVES PROPAGATION

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Abstract: This paper describes a software implementation of water waves propagation (determination of propagation speed and perturbations) using the characteristics methods. The application is written in Java, a well known object-oriented programming language, and it may run on all platforms. It is simple to use, the data being processed quickly and the results being presented in a table format and registered in a text file on disk.

1. Theoretical Basis

The initial solution of fundamental equations in the case of sinusoidal waves can be improved, based on the fact that in the case in which the profile of the wave isn't sinusoidal, it can be estimated sum of sinusoids, pursuant to mathematical results that a periodical function can be estimated by a finite sum of trigonometrically functions (Fourier series).
Thus is can improved the concordance between the theoretical results and one obtained through measurements.
The linear theory of the waves (Airy) is based on the hypothesis that the wave disturbance is such little that can be described through the first order approximation:

$$\eta = \frac{H}{2}\cos(kx - \omega t) = \frac{H}{2}\cos\alpha = a\cos\alpha \qquad (1)$$

A general expression is obvious (Stokes 1847, 1880) [4]:

$$\eta = a\cos\alpha + a^2 B_2(L,h)\cos(2\alpha) + a^3 B_3(L,h)\cos(3\alpha) + ... + a^n B_n(L,h)\cos(n\alpha) \qquad (2)$$

We can remark that in the case in which are considered just the approximations of the first order or of the second two (the order of the approximation is given by the number of considered terms) then results $a = \frac{H}{2}$, while in the case in which are considered the approximations of superior order results $a < \frac{H}{2}$.

The theory of the order two arrived at the formulas:

$$\varphi = \frac{\pi H}{kL} c \frac{ch[k(z+h)]}{ch(kh)} \sin(kx - \omega t) + \frac{3}{8k} c \left(\frac{\pi H}{L}\right)^2 \frac{ch[2k(z+h)]}{sh^4(kh)} \sin 2(kx - \omega t) \qquad (3)$$

By derivation we obtained the components of the speed:

$$u_x = \frac{\partial \varphi}{\partial x} = \frac{\pi H}{L} c \frac{ch[k(z+h)]}{ch(kh)} \cos(kx - \omega t) + \frac{3}{4}\left(\frac{\pi H}{L}\right)^2 c \frac{ch[2k(z+h)]}{sh^4(kh)} \cos 2(kx - \omega t) \qquad (4)$$

$$u_z = \frac{\pi H}{L} c \frac{sh[k(z+h)]}{sh(kh)} \sin(kx - \omega t) + \frac{3}{4}\left(\frac{\pi H}{L}\right)^2 c \frac{sh[2k(z+h)]}{sh^4(kh)} \sin 2(kx - \omega t) \qquad (5)$$

In the theory of the order two, the expressions for propagation speed of the wave and for this length are obtained by identical path with one obtained in the linear theory for the waves propagation on intermediary depth water:

$$c = \frac{g}{\omega} th(kh) = \frac{gT}{2\pi} th(kh) = \sqrt{\frac{g}{k} th(kh)} \tag{6}$$

$$L = \frac{gT^2}{2\pi} th(kh) \tag{7}$$

The form of water free surface, respective the water profile in Stokes approximation of the order two is:

- For deep water $\left(\frac{h}{L} > \frac{1}{2}\right)$

$$\eta = \frac{H}{2}\cos(kx - \omega t) + \frac{\pi H^2}{4L}\cos 2(kx - \omega t). \tag{8}$$

- For intermediary depth water

$$\eta = \frac{H}{2}\cos(kx - \omega t) + \left(\frac{\pi H^2}{8L}\right)\frac{ch(kh)}{sh^3(kh)}\left[2 + ch(2kh)\right]\cos 2(kx - \omega t) \tag{9}$$

Notation List:
η – wave's perturbation, H – wave's height, a – wave's amplitude, L – wave's length, T – wave's period, ω – wave's pulsation, c – wave's propagation speed, h –water deep, k – wave's number, α – slope angle of solid bed, g – gravity acceleration, x – calculus current section (independent variable), t – calculus time (independent variable).

2. Java Programming Language

The presented application is written in Java, a high-level object-oriented programming language, developed by JavaSoft, a group inside the Sun Microsystems company. The main characteristics are:

- Simplicity: it removes the so called benefits that may cause an ambiguous code (for instance, the multiple inheritance, the overloaded operators etc.);
- Robustness: it eliminates the most frequent sources of errors that may appear when writing code and it accomplishes this by removing pointers and by self-managing the memory through the instrumentality of garbage collector program that runs in background and removes those objects that aren't used anymore. A Java program that passes the compilation step will never break the system which it runs on;
- Completely object-oriented - it removes the procedural programming style;
- Very secure: it's one of the most secure programming language available, offering high level security tools like dynamic code checking, imposing strict rules for running programs on remote computers, etc;
- Portability: Java is an independent-platform programming language, namely, the same application can run without modifications on different systems like Windows, UNIX or Macintosh. This property brings hefty profits to companies that develop network application over the Internet;
- Dynamic language;

- Compiled and interpreted: Java source code compiles into portable byte codes that require an interpreter to execute them; this interpreter is called JRE (Java Runtime Environment).

3. Application Flowchart

For made the calculus of wave propagation we apply the characteristic method. This method, initiated by Riemann, has a general character, which is applied for solution linear equations with partial derivate of the order two, hyperbolic type. In hydraulic, the method is usual used in hydraulic shock (water hammer) problems in pressure systems.
The execution flow of the application is presented by the following flowchart (fig. 1):

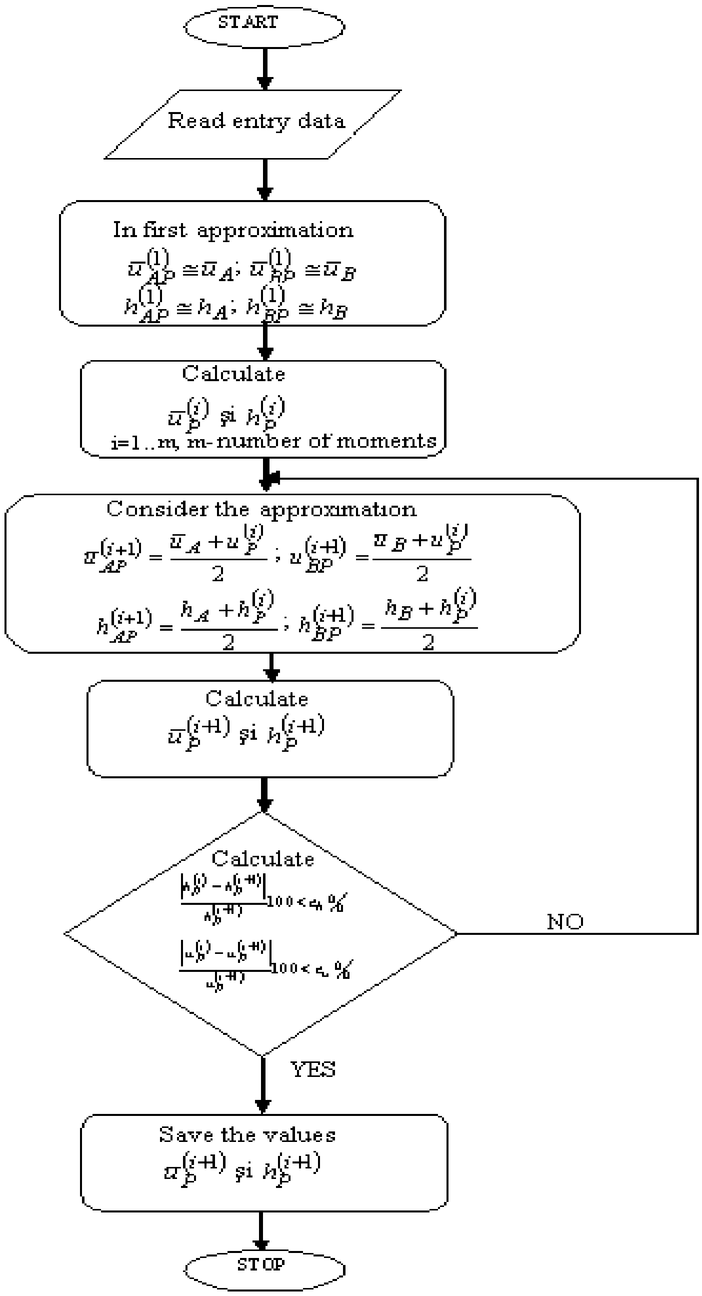

Fig.1.

4. Application Description

The application named "Waves", represents a Java implementation of the formulas presented in this paper, that calculate waves propagation velocity and elongations. Due to Java portability, the program may run on all platforms (Windows, UNIX, Macintosh), the only condition being that the Java Runtime Environment package, which may be downloaded from the official site www.sun.com (version 1.5.0 or later), has been installed on the user computer and it's working properly.
The graphical interface of the program is very friendly and simple to use in order to make the necessary steps to execute the calculus algorithm.
The application offers support for:

- Loading the entry data (number of sections, the type of wave, the initial characteristics, the section's characteristics) from a text file;
- Capturing the entry data from the user input (fig. 2.);

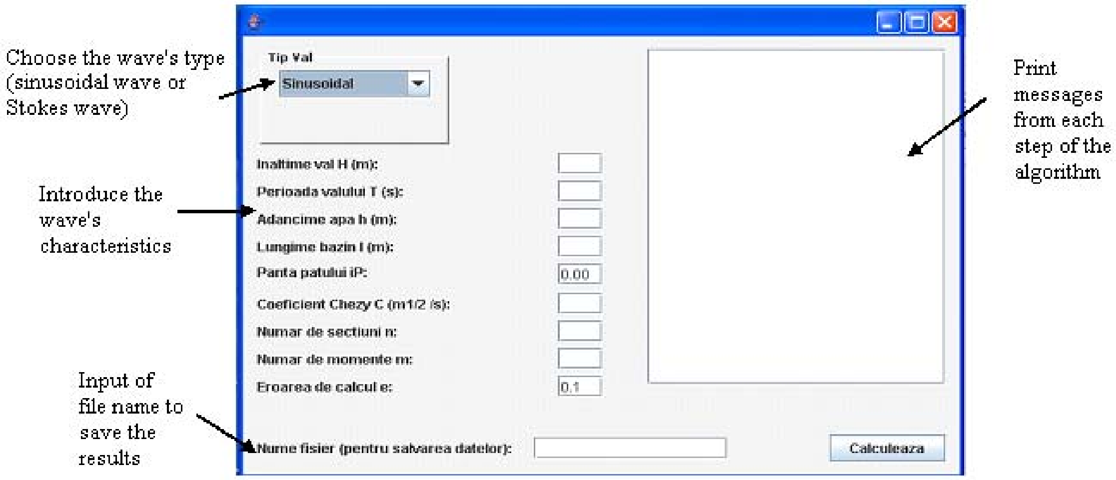

Fig.2.

- Modifying the entry data once they are loaded from the text file or after they have been captured from the user input;
- Validating the entry data and showing suggestive messages when an error is detected (for instance, when the user input is a string instead of a number);
- Showing the entry data, so that the user may check them;
- Saving the results in a text file;
- Loading the results from a text file and showing them to the user in a table format.

The application is well documented; describing each step the user has to make to apply the algorithm.
In order to install and execute the application, the user has to double click the jar archive Waves.jar.

5. Numerical Application

We consider two types of waves (sinusoidal wave and Stokes wave), which propagate in dock with rectangle form of transverse section. The bed is horizontal $(i_P = 0)$ and the water depth is h = 6 m. The dock has one of extremity close and the other open. The dock length, between two extremities, is 100 m, the Chezy's coefficient is C = 50 $m^{0,5}/s$. The wave has the following characteristics: wave's height H = 1m, wave's length L = 60 m, wave's period T = 7,24 s.

The boundary conditions are:

- at the open extremity of dock $(x = 0)$ the variation of water depth (h) by time is known, beginning about initial moment $(t = 0)$.
- at the closed extremity of dock $x = 4800m$, anytime the average speed vertical is null $(\overline{u} = 0)$.

Initial conditions: in the initial moment $(t = 0)$ the water from whole dock is at rest$(\overline{u} = 0)$.
We consider eleven equidistant transversal sections, noted 0; 1; 2; 3 and 10, situated at distance $\Delta x = \dfrac{100}{10} = 10m$. Is followed what is happening in these section in each moment.
We will compare the profiles of two wave's types and the variation of the speed temporally in all the sections.
We utilise the application „Waves", presented in preview paragraph.
In figure 1 is presented the presented the graphic interface of applications with the introduced data and the results. The calculus was effectuated for 200 moments.

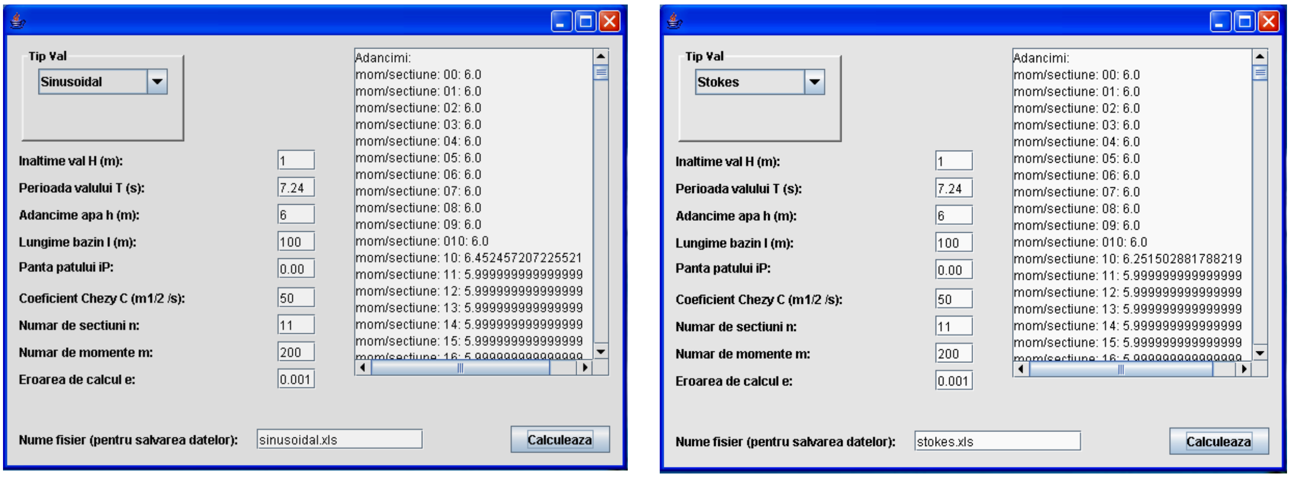

Fig. 3. The input data and the results for the two types of wave (Sinusoidal wave and Stokes wave)

We presented a representative section (section 5 – middle section).

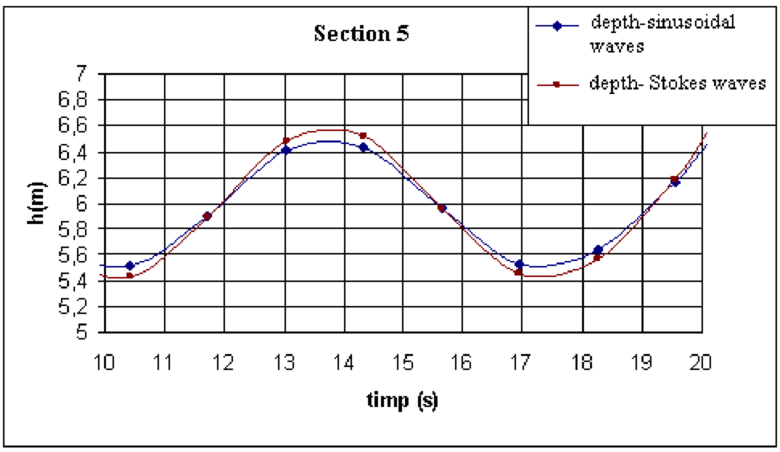

Fig. 4.

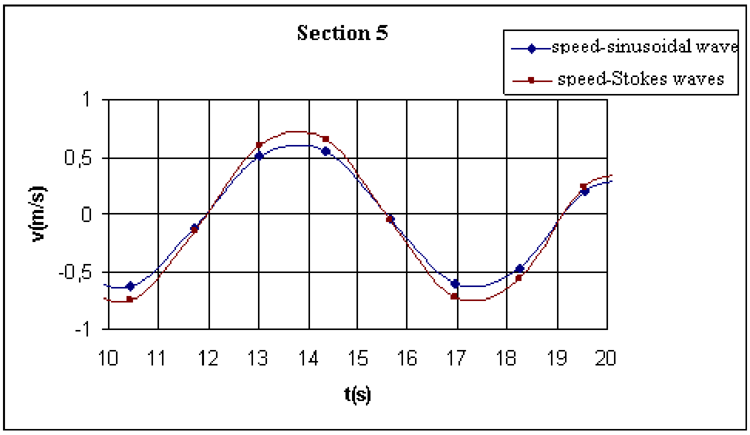

Fig. 5

5. Final Considerations

In the chart 4 we represented two profiles. Consisted that the profile given by the theory of the order two (Stokes) is else sharp to still more crest and widen to bottom than the profile of sinusoidal wave. The lift crest given by the theory of the order two is elder with about 20 per cent against lift crest given by the linear theory, against the unperturbed level of the water, which in the case of linear theory coincides with the average level. Conversely the descent of waves bottom given by the theory of the order two is else little with about 20 per cent against the descent of waves bottom given by the linear theory. Hence and the conclusion that the average level, in the case of the theory of the order two, is above the level of the unperturbed water, respectively above the level given by the linear theory. In the chart 5 we represented the variations of propagation speed temporally for the two considered waves. Like the waves profiles, we can observe that the speed values of Stokes waves are bigger than the speed values of sinusoidal wave.

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