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Basic Science Advances in Energy, Health and Environmental

February 12 - 13, 2014
Batu, East Java, Indonesia

Faculty of Mathematics and Natural Science
University of Brawijaya

PREFACE

All praises are due to Allah, God Almighty, Who made this annual event of successful of " The **"4th Annual Basic Science International Conference 2014 *in conjunction with* The 5th International Conference on Global Resource Conservation 2014, both annual** scientific events organized by the Faculty of Mathematics and Natural Sciences, Brawijaya University.

In this year, the conference took a theme of "**Applying science to conserve nature**". These conferences are concerned about our current challenge on how to explore, utilize and apply our knowledge and science to conserve water, soil, earth, air, plants, animals and microorganisms that involved multi disciplines. As a conjunctive conferences, these covered a wide range of topics on basic sciences: physics, biology, chemistry, mathematics and statistics as well as conservation biology and applied science.

The conference in 2014 was the continuation of the preceding conferences initiated in 2011 as the **International Conference on Basic Science (ICBS)** and **International Conference on Global Resource Conservation initiade in 2010. Therefore** the proceeding was also divided into two books, each with, each with a different ISSN. The proceedings were also published in electronic forms that can be accessed from BaSIC website.

I am glad that for the first time both types of publication can be realized. These international conferences are held to to increase dissemination of applying science to conserve natural resources, to present new research findings, ideas and informations and to discuss topic related to conference theme and to develop collaboration among multi discipline sciences and to find potential young researchers. This is in line with university vision as a World Class Entrepreneurial University.

I am grateful to all the members of the program committee who contributed for the success in farming the program. I also thank all the delegates who contributed to the success of this conference by accepting our invitation and submitting paper for presentation in the scientific program. I am also indebted to PT. Fajarmas, PT. Makmur Sejati, KPRI, CV. Gamma, PT. Tata Bumi Raya and CV. Enseval Medica Prima for their support in sponsoring this event.

I hope that you enjoy in this seminar. We wish for all of us a grand success in our scientific life and for the coming conferences and even better.

Thank you,

Malang, February 2014

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Conference Chairperson

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Prof. Dr. Chow Son Chen, School of Earth Science, National Central University, Taiwan
Dean Faculty of Mathematics and Natural Sciences
And
All participants

Assalamualaikum Warahmatullahi Wabarakatuhu

First of all let us pray to Allah the Almighty for His blessings bestowed to all of us that today we can all be here to attend the The 4th annual Basic Science International Conference and the 5th International Conference of Global Resources Conservation.

It is indeed an honor and privilege for me to welcome you warmly at this Conference. My great appreciation to all of you the distinguished participants of this important event, and trust that this conference will be an valuable input to the empowerment of Applying science to conserve our nature. I would like to take this opportunity to offer my appreciation to Dean Faculty of Mathematics and Natural Sciences, and committee from Biology Department University of Brawijaya who have organized this Seminar.

Distinguished Guests, Ladies and Gentlemen,

University of Brawijaya (UB) as oneof the leading university in Indonesia with its mission of World Class University, should take actions to participate in conserving our nature where we are living inside through innovation of science. We encourage all of academician here, as the backbone of nation building for continuous learning to save our planet for best interest of human being and living thing. Therefore, We should work together, across institutions and across discipline. We should start thinking how to be leader and control the world with our resources, knowledge and technology to achieve an equitable welfare.

Distinguished Guests, Ladies and Gentlemen,

UB with combination between International standard and local culture has been educating communities who have made positive impacts in their Communities-throughout Indonesia. Hence we warmly welcomes collaborative works of mutual partnership with many other institutions; especially universities, industry, government and other institution; both at national and international level. Moreover UB has dedicated itself to be a world class university. Based on spirit we belief that only with international partnership able pursue multinational connectivity on business, established in the higher education institution, for future generations. In this case, this occasion is really necessary to initiate cooperation beyond national border to supply comprehensive knowledge to be a winner in the global competition.

Distinguished Guests, Ladies and Gentlemen,

Science, technology and education will determine the well-being of people and nations in the future. Therefore, academician and scientist as Scholar who will bear the future of this nation have to work hard, and the ability to create brilliant innovation to supply environmental technology to solve human problem. UB rely on and encourage increased international partnership, as well as greater staff mobility. The partnership, it will be able to supports economic and social development. In Another word, whatever challenges that will arise, it should be challenges for all of us, and it should be solved with partnership.

As a conclusion, I propose to strengthen our collaboration to create synergism at any levels, especially all stakeholders, locally, regionally, as well as internationally. By working together all over the world through sharing information and resources, we can make the bright future. Finally, let us hope that the fruitful points aimed from this conference will develop the new concept and networking based on science and technology to save our nature.

During the organization and execution of this conference, and the one I am currently opening "The 4th annual Basic Science International Conference and the 5th International Conference of Global Resources Conservation".

Ladies and gentlemen, I hereby wish you a fruitful Conference.

Wabillahitaufiqwalhidayah, Wassalamualaikumwarahmatullahiwabarakatuh

Thank you for your attention.
Malang, February 15th, 2014

Rector,

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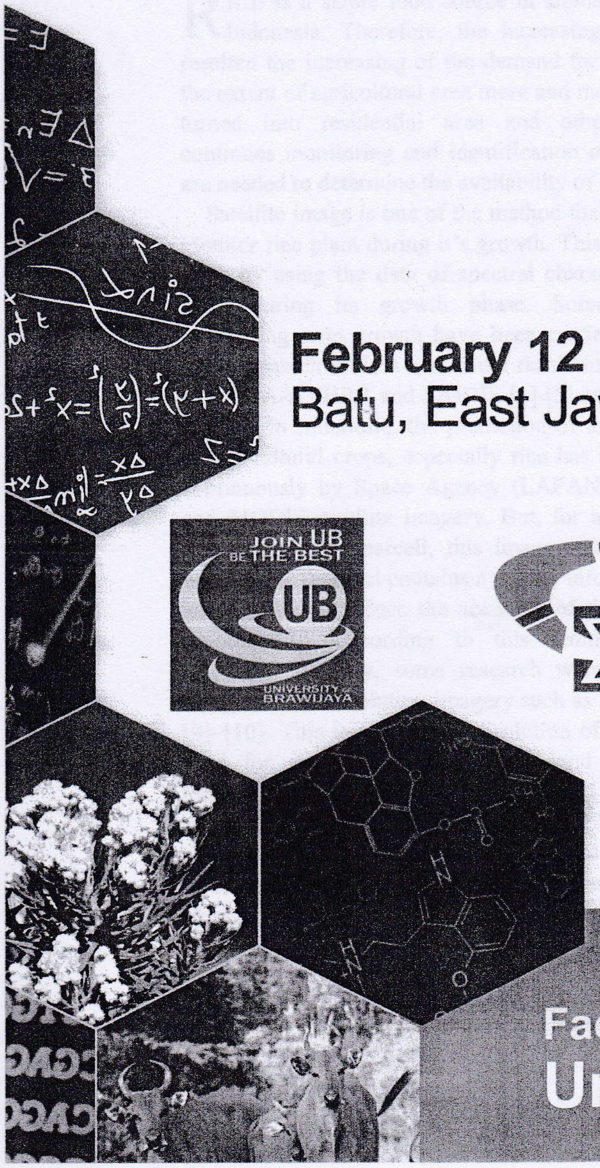

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The Courant–Friedrichs–Lewy Number Influences the Accuracy of Finite Volume Methods

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***Abstract*— The shallow water (wave) equations govern shallow water flows. We solve the shallow water equations using a finite volume method. A necessary condition for a consistent finite volume method to be stable (hence, convergent) is that the method satisfies the Courant–Friedrichs–Lewy (CFL) condition. Numbers representing this condition are called CFL numbers. In this paper, the effects of CFL numbers to the convergence rate of the finite volume method are investigated. Setting a CFL number to the method gives varying time steps in the numerical evolution. We compare results between those produced by imposing a CFL number and imposing a fixed time step to the numerical method. We shall show which strategy is more efficient and produces more accurate solutions in solving the shallow water equations.**

***Keywords*—convergence rate, Courant–Friedrichs–Lewy, finite volume method, shallow water equations.**

I. Introduction

THE system of shallow water equations is a well-known mathematical model that describes shallow water waves and flows. We are interested in solving these equations as the solutions are useful in the simulations of real world problems such as dam break floods and tsunamis. In this paper we implement a finite volume method to solve the shallow water equations. The method is chosen due to its robustness in dealing with smooth and non-smooth solutions [9, 10].

In finite volume methods, a necessary condition for convergence is that the Courant–Friedrichs–Lewy (CFL) condition be satisfied [3, 9, 10]. This condition is related to the time stepping in the integration of the shallow water equations with respect to time after the equations are discretized with respect to space. This means that we can use either a fixed time step as long as the CFL condition is satisfied at every time step or a varying time step based on a fixed CFL number. Here a CFL number represents a positive number such that the CFL condition is satisfied.

This paper investigates the influence of CFL number to the accuracy of numerical solutions produced by the finite volume method. The accuracy of the finite volume method, of course, depends on the accuracy of the integration technique implemented to the space and time. To focus on our investigation, we use a single integration technique for the space variable, that is, we use a second order method for the space integration. Then we compare the performance of a second order method for the time integration by presenting the errors between implementing a fixed time step and a fixed CFL number.

This paper is organized as follows. In Section II we recall the shallow water equations in one dimension. The finite volume method is presented in Section III. Numerical results are given in Section IV. Finally some concluding remarks are drawn in Section V.

II. Governing Equations

The shallow water equations are

$$h_t + (hu)_x = 0\,, \tag{1}$$

$$(hu)_t + \left(\tfrac{1}{2} g h^2 + hu^2\right)_x = -ghB_x\,. \tag{2}$$

where t denotes the time variable, x denotes the space variable, $h(x,t)$ is water height or depth, $u(x,t)$ is velocity, $B(x)$ represents the bottom elevation or topography, and g is the acceleration due to gravity. The absolute water level (stage) is defined as

$$w(x,t) := h(x,t) + B(x)\,. \tag{3}$$

A number of authors have proposed numerical techniques to solve these shallow water equations (1) and (2). Some of them are [1, 2, 5-8, 11, 12, 15, 16].

III. Numerical Method

As we mentioned, we use a finite volume numerical method to solve the shallow water equations. In a semi-discrete form, the finite volume method is

$$\frac{d}{dt}\mathbf{Q}_j(t) = -\frac{1}{\Delta x}\left(\mathbf{F}_{j+\frac{1}{2}}(t) - \mathbf{F}_{j-\frac{1}{2}}(t)\right) + \mathbf{S}_j^n \tag{4}$$

where $\mathbf{Q}$ is an approximation of the conserved quantity, $\mathbf{F}$ is an approximation of the analytical flux and $\mathbf{S}$ is a discretization of the analytical source term. See the References [1, 6, 15] for more details of this type of scheme. This scheme is called semi-discrete because we have discretize the shallow water equations with respect to space, but the time variable is still continuous [3, 9, 10].

To get a second order method in space, we use a linear reconstruction for quantities stage, height, bed, velocity and momentum. Then in order to suppress artificial oscillation due to the space reconstruction, we implement the minmod limiter. This limiter gives a limitation to the values of the gradients in the linear reconstruction of the aforementioned quantities. After that, numerical fluxes are computed based on these reconstructions. We use the Lax-Friedrichs numerical flux function. We refer to [9, 10] for the formulation of this flux function.

The next step is to integrate the semi-discrete form (4) with respect to time. We actually can use any standard method of Ordinary Differential Equations (ODEs) solver. However, because we have used a second order method in space, it is better to use either a first or second order method in time. This is because we will never get a finite volume method of order higher than two, even if we use higher order method in time. In this paper we implement the second order Runge-Kutta method to integrate the semi-discrete form (4) with respect to time.

IV. Numerical Results

This section provides numerical results regarding two different strategies for the numerical evolution. The first strategy is imposing a fixed time step in the second order Runge-Kutta integration. The second strategy is imposing a fixed CFL number where in our simulations we use CFL number to be 1.0 in one case and 0.01 in another case. Details about CFL conditions and CFL numbers can be found in the References [9, 10, 17].

Numerical settings are as follow. We use SI units for measured quantities, so we omit the writing of units. Errors are quantified using absolute L1 formula as used in [13, 14]. In this paper we consider one test case. Standard test cases are available in the References [4, 18].

As a test case we consider the dam break problem. We assume that the topography is given by a flat horizontal bottom $B(x)=0$, where $-1 \le x \le 1$. Therefore we have that stage equals to water height. The water height is initially given by

$$h(x,0)=\begin{cases}10, & x<0,\\ 4, & x>0.\end{cases} \tag{5}$$

The analytical solution of this problem has been found by Stoker [18] and an extension to the debris avalanche problem has been solved by Mungkasi and Roberts [13, 14].

TABLE I

Comparison of stage errors between imposing a fixed time step and imposing fixed CFL numbers. The fixed time step is 0.05 times the cell-width, whereas fixed CFL number are 1.0 and 0.01.

Cell number	Fixed time step		CFL=1.0		CFL=0.01	
	Error	RC	Error	RC	Error	RC
100	0.0589		0.0582		0.0569	
200	0.0308	0.9343	0.0304	0.9359	0.0296	0.9405
400	0.0144	1.0940	0.0143	1.0917	0.0140	1.0823
800	0.0072	1.0014	0.0071	1.0014	0.0070	0.9994
1600	0.0036	0.9925	0.0036	0.9900	0.0035	0.9860
Average rate of convergence		1.0055		1.0047		1.0020

TABLE II

Comparison of discharge errors between imposing a fixed time step and imposing fixed CFL numbers. The fixed time step is 0.05 times the cell-width, whereas fixed CFL number are 1.0 and 0.01.

Cell number	Fixed time step		CFL=1.0		CFL=0.01	
	Error	RC	Error	RC	Error	RC
100	0.4714		0.4652		0.4520	
200	0.2448	0.9455	0.2416	0.9453	0.2341	0.9488
400	0.1177	1.0562	0.1164	1.0533	0.1138	1.0414
800	0.0589	0.9984	0.0583	0.9964	0.0571	0.9938
1600	0.0299	0.9791	0.0296	0.9778	0.0291	0.9707
Average rate of convergence		0.9948		0.9932		0.9887

TABLE III

Comparison of velocity errors between imposing a fixed time step and imposing fixed CFL numbers. The fixed time step is 0.05 times the cell-width, whereas fixed CFL number are 1.0 and 0.01.

Cell number	Fixed time step		CFL=1.0		CFL=0.01	
	Error	RC	Error	RC	Error	RC
100	0.0732		0.0724		0.0705	
200	0.0388	0.9157	0.0384	0.9156	0.0373	0.9166
400	0.0178	1.1276	0.0176	1.1268	0.0172	1.1209
800	0.0088	1.0090	0.0087	1.0088	0.0085	1.0067
1600	0.0044	1.0032	0.0044	1.0035	0.0043	0.9966
Average rate of convergence		1.0139		1.0137		1.0102

Our simulation results are summarized in Tables 1-3. Table 1 shows error comparison for stage (water surface) between three scenarios of simulations. Errors for discharge (momentum) and velocity are summarized in Table 1 and Table 2 respectively. From these three tables, the highest convergence rate is achieved by setting a fixed time step, rather than imposing a fixed CFL number. We should note that the average rate of convergence for imposing CFL number 1.0 produces a very close average rate of convergence to the fixed time step setting. Furthermore imposing CFL number to be 1.0 gives the most efficient computation as it takes the shortest running time. Setting CFL to be too small such as 0.01 gives a low rate of convergence. Of course setting CFL number too small makes the computation be expensive, so the running computation is long. Here the fixed time step scenario used is $\Delta t = 0.05\,\Delta x$, with the time step Δt and the cell width Δx.

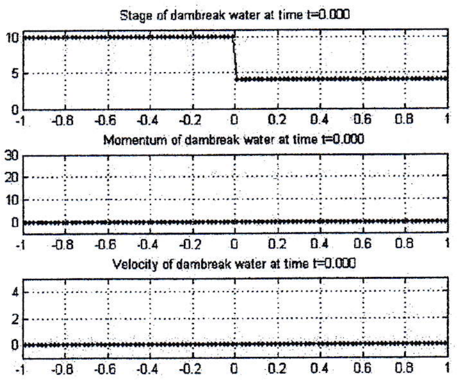

Fig. 1. The initial condition of the dam break problem (at time $t=0$ using 100 cells. Solid line represents the exact solution. Dotted line represents the numerical solution.

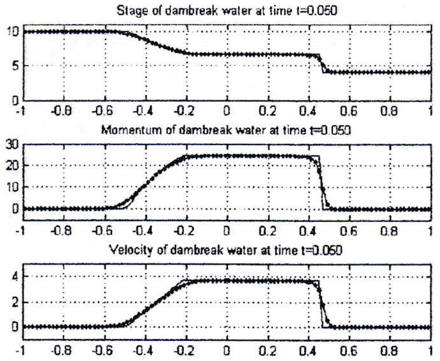

Fig. 2. Solution to the dam break problem at time $t = 0.05$ using 100 cells with the fixed time step. Solid line represents the exact solution. Dotted line represents the numerical solution.

Figure 1 shows the initial condition for the test case. The first subfigure is the stage or water level (free surface). The second and third subfigures are the momentum and velocity respectively. It is clear that initially we have only discontinuity in the stage, while the momentum and velocity are continuous.

Figure 2 shows the stage, discharge and velocity of water after 0.05 seconds of dam break using the fixed time step. The numerical solutions approximate the analytical solution well based on this Figure 2. Here we see discontinuities in the stage, momentum and velocity.

The convergence rate in our simulation is about 1.0 even though we have implemented a second order finite volume method, that is, second order in space and second order in time. This is because the discontinuities of the solution occur. The discontinuity appears in the measured quantities as well as the derivative of the quantities. Again, see Figure 2 for these discontinuities.

It is worth to note that the formal convergence rate of our numerical method is two, because we use a second order method in space as well as in time. However this formal order is true only when the solution of the shallow water equations is smooth [9, 10]. As our solution in this paper is nonsmooth due to discontinuities, it is not surprising that we obtain that the rate of convergence is less than two, that is, about one.

Even though we have a fixed formal order, the numerical order or rate of convergence is obviously dependent on the numerical strategy that we use. This has been shown in this paper. Taking a fixed time step in the finite volume method gives different convergence rate from taking a varying time step with imposing a CFL number. In addition, imposing a specific CFL number gives different convergence rate from imposing another CFL number.

V. Conclusion

We have investigated the CFL effects on the convergence rate of finite volume methods used to solve the shallow water equations. Our simulations indicate that the use of CFL number 1.0 for solving the dam break problem gives the best combination between efficiency and accuracy. Note that setting the CFL number greater than 1.0 may make the numerical method unstable when we solve the shallow water equations in general.

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