The Journal of the Korean Society of
Coastal and Ocean Engineers
Vol. 5, No. 1, pp. 19~24, March 1993

Computer Animation of Marine Process
-Tsunami Events-
海洋過程의 컴퓨터 動畫化
-地震津波(쯔나미)의 境遇-

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Abstract□With the use of Supercomputer and engineering workstations, high quality computer graphic representation of the modeling of marine process is feasible. In this work, major tsunami events occurred during recent years were simulated by numerical models and the computed water levels were viewed as three-dimensional surfaces in an animated sequence. Photorealistic images are constructed by advanced rendering technique with light, reflection and shadows. It has demonstrated that video animation of numerical results reproduced the behaviour of propagation of real tsunami events remarkably well.

要　旨：슈퍼컴과 워크스테이션을 사용하여 해양과정의 모델링 결과를 고화질의 컴퓨터 영상으로 제시할 수 있게 되었다. 본 연구에서는 근년에 발생한 지진진파(쯔나미)에 대한 수치모형을 적용하여 산정된 수위를 3차원적으로 연속적인 동화로서 제시하였다. 이 결과 광원, 반사 및 음영을 나타내는 최신 렌더링 기법에 의한 사진과 같은 효과를 갖는 영상들을 구축하였다. 비디오 동화에 의한 수치모형의 결과는 실제적인 쯔나미의 파급거동을 잘 제시하였다.

1. INTRODUCTION

With the rapid advance of numerical methods in science and engineering and continuing increase in computing power via Supercomputers, the volume of complex data being produced is becoming severe problem. In the field of oceanography, data sets representing complex three and four-dimensional information generated by computer models, frequently utilizing finite-difference and finite-element modeling techniques, these data sets will be variables of scalar and vector quantity.

Tsunami is gravity waves in water bodies mainly due to earthquakes or events connected with them (e.g. landslides) and to volcanic islands explosions or man-made nuclear explosions (Murty, 1977). Tsunami simulation requires intensive computation and produce vast amount of information (e.g. elevation and velocity field, inundation area etc), only a few of which are used at present. Utilizing the recently available scientific visualization system, the evaluation of simulated results were possible through rapid comparison of multiple images representing change over time and ultimately image sequences in the form of video tape are worthy of presenting the results to others.

2. MODEL

The visualization technique described here are of general applicability in output from computer models for various marine process, which produce fully two-dimensional data sets with regular and irregular grid system linking deep water models to

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shallow water calculations.

The numerical model chosen for far-field tsunami is based on the Boussinesq or linear Boussinesq equations which includes dispersion term and for the coastal deformation or near-field tsunami, two types model are generally used; the linear long wave theory for the offshore region deeper than 50m and the shallow-water theory with bottom friction in the near-shore region shallower than 50m. When the dispersion term is not required for computing propagation in deep sea, linear long wave theory can also be used. Criterion to adopting dispersion effect can be followed by Kajiura (1963) as $Pa=(6h/R)^{1/3}$ (a/h) is smaller than 4, the dispersion effect is not negligible. Here h is the water depth, R is the travel distance, a is the length of the tsunami source measured along the direction.

In the model, the leap frog scheme is assumed for discretizing fundamental differential equations. To preserve numerical accuracy, it is recommended that local tsunami wave lengths are covered by more than 20 grid elements of finite difference grid system. (Shuto *et al.*, 1986). The state-of-the-art of tsunami computation via numerical simulation is documented from generation to run-up (Shuto, 19 91) in detail. The three-dimensional nature of tsunami run-up is still being investigated.

Four tsunami events of the East Sea (Japan Sea) in 1983, Mariana Seas in 1990, Yalta-tsunami in the Black Sea, Nicaraguan tsunami in September, 1992 were chosen for numerical simulation and computed results were used to generate photorealistic images and then, computer-graphic-aided video animation. Numerical parameters for each tsunami simulation are summarized in Table 1.

Table 1. Numerical parameters for the models

Tsunami events	dx	dy	total grids (nx×ny)	time step (sec)
East Sea Tsunami	5′	4′	179×245 (43855)	24
East Sea Tsunami (Subregion 1)	1.67′	1.33′	138×261 (36018)	8
East Sea Tsunami (Subregion 2)	1030m	820m	216×357 (77112)	4
Maniana Tsunami	5′	5′	480×600 (28800)	10
Nicaraguan Tsunami (Intermediate Region)	5′	5′	397×290 (115130)	20
Nicaraguan Tsunami (Near field)	1189m	1308m	400×280 (112000)	3
Yalta Tsunami	1/9°	1/9°	130×55 (7150)	30

3. VIDEO ANIMATION PROCEDURE

Video animation is produced by sequentially recording each computer image on the video recorder. Each image from each time step from the tsunami model constructed is recording onto video tape.

Each image is constructed by following procedure using visualization software (such as Advanced Visualizer used to generate the example in this study)

- create 3D objects and applies surface textures and colors
- edits surface properties like texture, color, reflection and atmosphere
- animates objects, cameras and colors
- render photorealistic images to the screen to reveal the full effects of lights, textures, materials and colors

Sets of rendered images are subjected to dynamic playback which provide a vital evaluation capability, accessible without requiring output to a video or frame store device in preliminary stage. Bit blitting approach is employed and it allows multiple images to be stored and then rapidly cycled through for viewing dynamics. Although its usefulness depends on large amounts of memory, dynamic playback will provide a vital evaluation capability. In the present study graphic workstation used was Personal IRIS 35 MHz Turbo Super Graphics with Z buffering, 24 color bit planes, 1280× 1024 color RGB monitor. It operates as a stand alone system and/or a system communicating in time-sharing mode with CRAY 2S in System Engineering Research Institute, KIST and with ACOS 3600 in the Computer Center, Tohoku University. It is desirable to equip the system to accurately and automatically output rendered files in a range of formats. Output device for rendered files was Avanzar video board system and desktop software which supports wide

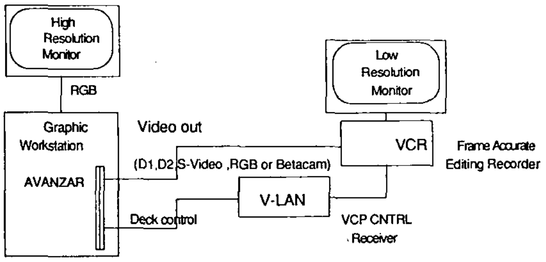

Fig. 1. Hardware configuration.

range of analogue and digital video formats, multiple output formats simultaneously, quadruple frame buffer that holds four 525 or 625 line frames in 10 bit or 8 bit D1 format and flipcard animation capability which allows quick, real-time motion studies on TV monitor without VTR equipment. The system also provide Chroma Metrix which allows NTSC/PAL verification of RGB imagery on the workstation through analysis of signals for color saturation and illegal transition levels and resizing function that convert computer graphics from files or display to video resolution. Video device control was performed by V-LAN which provide frame accurate for tape transports, enabling the recording of animation frames onto several different transports at the same time. Frame accuracy means that all images and animation sequences creates in the Graphic Workstation have been laid to videotape in a continuous sequence. Frame accuracy is an absolute criterium for animation to ensure smooth continuous motion throughout the animation sequence. Alternatively video recording also can be performed either real-time scan-converting procedure or directly recording the viewed images during dynamic playback with high quality professional video camera. In Fig. 1 overall hardware configuration used for present study is shown.

4. MODEL RESULTS AND ANIMATION

Four tsunami events were simulated via numerical tsunami simulation models described in section 3.

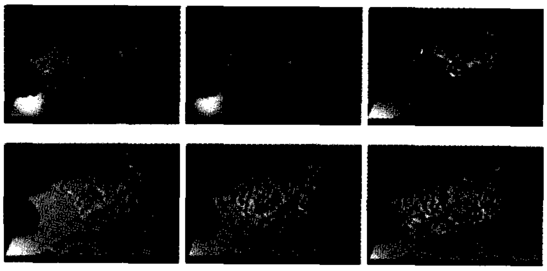

Fig. 2. A series of rendered images showing tsunami propagation due to 1983 East Sea (Japan Sea) earthquake.

Fig. 3. An example of wire-frame image of model results (East Sea Tsunami).

4.1 East Sea (Japan Sea) Tsunami

At noon on the 26 May 1983, a huge earth-quake occurred in the East Sea (Japan Sea). A tsunami followed. Its highest run-up was measured at more than 15m above MSL along Japanese Coast. Tsunami crossed the East Sea and damaged middle part of eastern coast of Korea, especially inundating ports of Mukho and Imwon. Along the northern Korean coast maximum runup of 1.7m was reported in Sinchang. On the coast of Primorsky Territory the maximum run-up of 4.5m in the Valentine Bay was reported. Preliminary model results from the models of overall region and locally fine-meshed region showed that there are general agreements between observations and hindcast (Choi *et al.*, 1993). Subsequently initial results were applied to produce video-animation of tsunami propagation and run-up. Fig. 2. shows the series of rendered images of computed water surface elevation. Fig. 3 shows wire frame representation of model results before rendering. At land region, global topographic

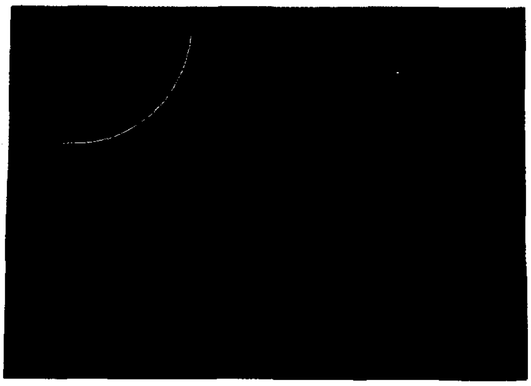

Fig. 4. An example of rendered image treating the tsunami wave as transparent media (East Sea Tsunami).

Fig. 5. An example of rendered image from Mariana tsunami simulation.

elevation data set from World Data Center (NODC) were utilized to visualize the process in more realistic manner.

Another set of visual animation was made to present the effect of Yamato Rise (shallow mount area in the middle part of the East Sea) on the tsunami propagation effectively by treating the surface tsunami waves as transparent medium, leaving the sea bottom topography beneath, as shown in example of Fig. 4. It has shown that strong effects of the shallow Yamato Rise have been demonstrated by present visualization process. Coastal modeling of tsunami runup, inundation and harbour oscillation is presently being performed to provide visual animation. In the preliminary fine grid modeling study the focussing process of tsunami due to a lens effect of sea bottom, previously reproduced by the fine grid modeling system (Shuto *et al.*, 1986) is again numerically explained for Korea side of Japan Sea (East Sea) (Choi *et al.*, 1993). The present model takes less than one minute by supercomputers for three hours real time simulation, thus feasibility of setting up of tsunami forecasting system is being studied.

4.2 Mariana Tsunami

On 5 April, 1990 at 0913 PM Greenwich Mean Time a earthquake (Ms=7.5) followed by tsunami waves occureed in the Mariana (15.4 deg North, 147.3 deg East). The 1990 event was the largest earthquake since 1902 in the Marianas (Yoshida *et al.*, 1992), but the tsunami was not large enough to cause damage however the amplitude of tsunami showed abnormal geographic distribution. This event was numerically computed by Imamura *et al.* (1991) and Satake *et al.* (1992). The simulated model results by Imamura *et al.* are then scientifically visualized through video animation. Fig. 5. represents snapshots of rendered image of propagation pattern of tsunami wave. It has again well represented by visual animation that tsunami wave travels faster along the trench in the north-south direction while the slower propagation in the direction perpendicular to the trench (Satake *et al.*, 1992).

4.3 Nicaraguan Tsunami

A recent tsunami event at off Nicaraguan coast occurred on 2 September was numerically computed using near field and intermediate region tsunami models. Due to this disastrous tsunami at least 168 people were killed, or missing 489 injured and 3166 homeless resulted in Nicaragua. It was reported that Nicaraguan tsunami is catagorized into 'tsunami earthquake' that produced anomalously large tsunami relative to earthquake magnitude. The observed height is as 9m as high (Imamura *et al.*, 1992). Two sets of computation were performed to simulate the event; first was done with initial fault parameter provided by Imamura *et al.* (1993). Fig. 6. shows a series of rendered images of tsunami propagation from intermediate region model of which the model coverage is 6 deg S~18 deg N and 77 deg W~110 deg W. Diffraction of tsunami

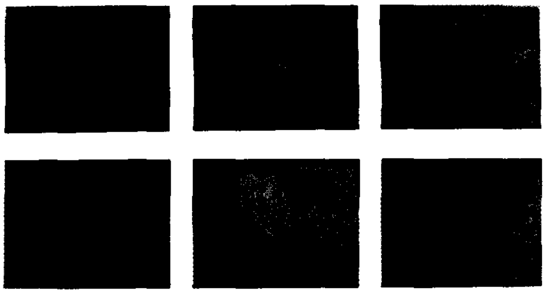

Fig. 6. A series of image from Nicaraguan tsunami simulation (intermediate region model).

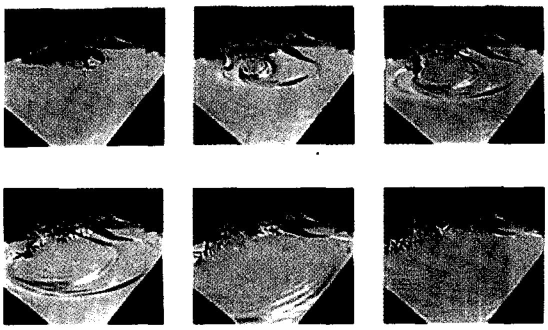

Fig. 7. A series of image from Nicaraguan tsunami simulation (near field model).

waves due to Galapagos Islands are presented distinctively. Fig. 7 show a series of images from near-field model showing the initial deformation of water surface due to earthquake. Another set of video animation using the corrected fault parameter was performed treating the transparent water media and preserving the bottom bathymetry. An example of rendered images from this animation is shown in Fig. 8. Preliminary results show that the Nicaraguan earthquake can make us confirm to be a tsunami earthquake with a slow source process with the rise time of less than 100s and the tsunami heights expected from the seismic data are much smaller than measured heights.

4.4 Yalta tsunami

The Black Sea as the largest inland marine water body also renders many oceanographic and geophysical issues. As a first step a tsunami occurred at off Yalta in 1927 (Engel, 1974, Grigorash, 1959) was hindcasted with simple fault model. A series of rendered images shown in Fig. 9. are basin oscillation due to this tsunami events.

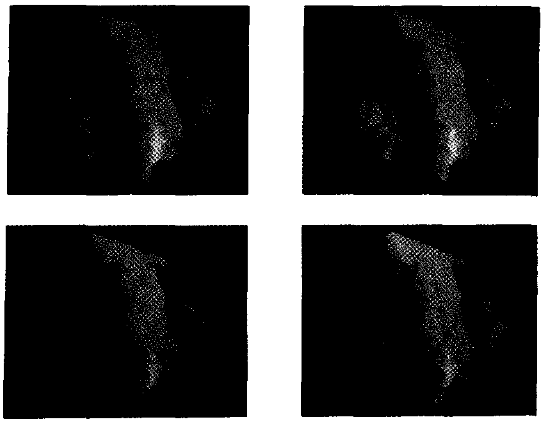

Fig. 8. An example of rendered image treating the tsunami wave as transparent media (Nicaraguan tsunami).

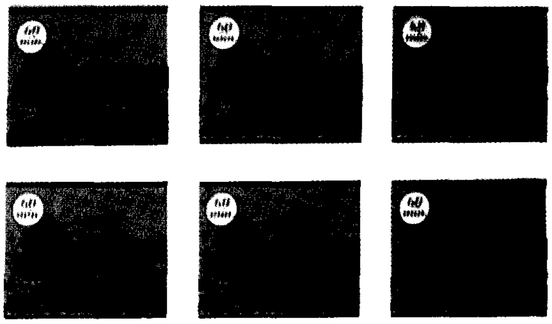

Fig. 9. A series of image from Yalta-tsunami simulation.

The video animation of recent tsunami events thus performed are now being prepared in multiple video formats-firstly in NTSC, and then S-Video and Betacam for presenting purposes.

5. CONCLUDING REMARKS

It has demonstrated that the computed results of tsunami models via Supercomputers would be efficiently used through the introduction of computer graphic-aided video animation although the graphical method presente here attempt only to portray the model results as an exaggerated three-dimensional surface. It has also shown that the detailed dynamic movement of the tsunami from several viewpoint can be visualized. Present postprocessing technique in visualization of tsunami offers one means of studing and understanding data characteristics. The present collaborative work of Tsunami Research between Sung Kyun Kwan University and Tohoku University is being progressed as TIME (Tsunami Inundation Modeling Exchange) programme as a joint IUGG/TC, ICG/ITSU project to address tsunami disaster mitigation as a part of the IDNDR (International Decade for Natural Disaster Reduction).

ACKNOWLEDGEMENT

The study was partially supported by CRAY University R&D Grant Program through System Engineering Research Institute, KIST, Korea and was also partially supported by a Grant-in-Aids No.04 306013 by the Ministry of Education, Science and Culture, Japan.

REFERENCES

Choi, B.H., Lee, H.J., Imamura, F. and Shuto, N., 1993. Computation and visualization of a tsunami event for the east coast of Korea, Submitted to XXV IAHR Congress, Tokyo, Japan.

Engel, M., 1974. Hydrodynamical-numerical investigation of motions in the Black Sea., Mitleilungen des Instituts für Meerskunde der Universitat Hamburg, No. 22.

Grigorash, Z.K., 1959. Propagation of tsunamis in the Black Sea in 1927, Transactions of the Marine Hydrographical Institute, Academy of Science of the USSR, Vol. 18.

Imamura, F., 1981. Observation and analysis of 1990 Mariana tsunami by bottom pressure transducer, Proceedings Jap. Coastal Eng. Conference.

Imamura, F., Ide, S. and Abe, K., 1992. The tsunami source of the 1992 Nicaraguan earthquake estimated from tsunami data, Submitted to *Geophysical Research Letters*.

Imamura, F., Shuto, N., Choi, B. and Lee, H.J., 1993. Visualization of Nicaraguan tsunami in September, 1992, Submitted to International Tsunami Society Meeting in Wakayama, Japan.

Kajiura, K., 1963. The leading wave of a tsunami, Bull. Earthq. Res. Inst. **41**: 535-571.

Murty, T.S., 1977. Seismic sea waves-Tsunamis, Bulletin of the Fisheries Research Board of Canada, No. 198, Department of Fisheries and the Environment, Fisheries and Marine Service.

Satake, K., Yoshida, Y. and Abe, K., 1992. Tsunami from the Mariana earthquake of April 5, 1990: its abnormal propagation and implications for tsunami potential from outer-rise earthquakes, *Geophys. Res. Lett.*, **19**(3): 301-304.

Shuto, N. *et al.*, 1986. A study of numerical technique on the tsunami propagation and run-up, *Sci. Tsunami Hazard* **4**: 111-124.

Shuto, N., 1991. Numerical Simulation of tsunamis-its present and near future, *Natural Hazard* **4**: 171-191.

Yoshida, Y., Satake, K. and Abe, K., 1991. The large normal faulting Mariana earthquake of April 5, 1990 in uncoupled subduction zone, *Geophys. Res. Lett.*, **19**(3): 297-300.