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# **A Real Time Simulation and Modeling of Flood Hazard**

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**Abstract:** - The increasing flash flood hazards in major cities like Kuala Lumpur have caused tremendous damages to the society and this requires more essential countermeasures to be implemented. With the advancement in 3D Computer Graphics and fluid simulation technologies, movie experts can now produce realistic visual effects for fluid objects such as water. This paper describes a study made to model and simulate the flash flood incident that struck Kuala Lumpur on 10 June 2007 using 3D Computer Graphics and fluid simulation techniques. The main goal was to study and examine the stability and effectiveness of this approach as a solution tool for environmental studies. Particle-based technique called Smoothed Particle Hydrodynamics (SPH) method were used to model the flash flood behavior. This was done using MAYA plug-in software called GLU3D which was developed based on SPH architecture. Geographical Information System (GIS) data such as Light Detection and Ranging (LIDAR) Digital Elevation Model (DEM) and remote sensing imagery were used to model the study area. Results show an adequate realism of water movement for the area studied. A prototype of a flood system was developed using MAYA Application Programming Interface (API) to examine the real-time effectiveness of flood movement. The study has verified the usability of 3D computer graphics and fluid simulation particle based technique for environmental study purposes. The main contribution the study was to show that this approach can produce a realistic visualization thus enable more precautions and countermeasures to prevent the disaster.

**Key-Words:** Three Dimensional (3D), Computer Graphics, Fluid Simulation, Computational Fluid Dynamics (CFD) Smoothed Particle Hydrodynamics (SPH), Application Programming Interface (API), Geographical Information System (GIS), Light Detection and Ranging (LIDAR), Digital Elevation Model (DEM).

## **1 Introduction**

Flood can be categorized as one of the main problems faced by Malaysian citizens. Every year, during the monsoon season and heavy rainfall, this disaster will strike flood risk areas in our country no matter whether it is rural areas or urban areas. The disaster results in tremendous damages to people and their belongings and causes such a great loss to the country and economic growth. It was stated that the total damage caused by this disaster from 1926 to 2001 estimated around RM 915 million [1]. Government agencies have been have working out for solutions including creating multi purposes dams, bunding of rivers, the development of SMART tunnel and Flood Warning System to control the impact of flood hazard in Malaysia. Various kinds of software and computer system have been developed by foreign experts to provide a better decision making and superior analysis for

flood mitigation. Most of the software is based on hydrological and hydraulic modeling. However the attempt on using computer graphical method is still considered as new.

Computer simulation allows users to convert real world data into a computer program and allows better observation and visualization. The usage of Geographical Information System (GIS) techniques and remote sensing imagery tend to be useful for environmental studies. With the capability to provide 3D viewing, this approach can be extended and applied with 3D computer graphical method.

Fluid simulation has become as a tool in the computer graphics arena for generating realistic animations of water, smoke, explosion and other fluid objects. Computer graphics experts modified the physic-based formula to define fluid and created various algorithms in computer graphics arena.

Among the common ones are Eulerian grid-based methods, Smoothed Particle Hydrodynamics (SPH) methods, Vorticity-based methods and Lattice Boltzmann methods. These algorithms were used to create fluid objects and mostly were applied in movie industries for visual effects.

## 2 Problem Formulation

Lately, the increasing incident of flash floods have been reported. Some of the incidents involved major cities like Kuala Lumpur. Among the identified factors that led to this incident was localized thunderstorm development and heavy rain that occurred in such a short period of time in several places in the city. However, the past study already stated that rapid urbanizing in major cities was the main cause. Major cities such as Kuala Lumpur grew at the confluence of the Kelang and Gombak river and is exposed to flood risk. Situated in a flood plain, Kuala Lumpur has been experiencing a number of major flood hazards. The 1971 flood incident resulted in extensive damage with nearly 445 hectares of the city were inundated. The damage was estimated around RM 36 million [2]. Over the past decades, the flash flood has become more frequent and the recent incident dated 10 June 2007 was reported among the worst.

With the current ability of GIS, the 3D fluid simulation approach can be applied to produce a better and realistic visualization and animation. The 3D computer graphics are able to produce a real-time simulation and realistic animation. Current environmental studies have already incorporated 3D computer graphics approach as part of their method, mostly by means of virtual reality platform. However, most of the current visualizations only produce non real-time animation especially fluid related objects.

In this paper, we describe a method to model and simulate fluid objects using Smoothed Particle Hydrodynamics (SPH) methods. The aim was to examine the adaptability of these techniques for environmental studies, in this flood case and its effectiveness in a real time environment system. GIS LIDAR DEM data and remote sensing images were utilized to create a 3D ground model for the study area. MAYA software was used to animate the fluid objects which represent a flood movement. GLU3D plug-in for MAYA was tested to create particle based objects. GLU3D was developed based on the SPH architecture. A final prototype of a real time system which depicts the flood movement was

developed using MAYA. The flash flood incident that struck Kuala Lumpur on 10 June 2007 was used as a reference for this study.

### 2.1 Previous Works

GIS and remote sensing data are substantial in environmental studies especially for the ones that related to flood hazard. Many environmental experts said that GIS technology has played an instrumental part in the development of a real-time simulation. With the powerful data such as LIDAR and DEM, and the support from remote sensing high-resolution imagery, it is clear that these techniques are significant for environmental studies. Most of flood related studies used these data. A research done by University of Texas on evaluation of GIS that was used for hydrological and hydraulic modeling, stated that during a sent out to the fifty state highway agencies related to hydrology and highway work, thirty two responded on implementing GIS for mapping and data management.

A DEM data is a digital representation of ground surface topography or terrain. DEM data is significant for environmental studies especially hydrological areas [3]. Another study shows about the potential of LIDAR DEM data in supporting a flood simulation process in urban areas. The study also evaluated the effect of the DEM averaging process, as caused by selected re-sampling procedures on the flood model simulation results. During the research development, they found out that airborne remote sensing data such as LIDAR DEM could provide high quality digital terrain models that could serve as input in the hydraulic flood modeling [4]. Another usage of the LIDAR DEM is for the virtual city development. Lohr, U. described about the various applications used by the LIDAR data, explained on the benefits of using Laser Scan DEM for the development of a 3D virtual city. This paper describes that with 1 meter raster LIDAR DEM data, if overlaid with a scanned aerial photograph, could form an excellent database for the 3D city models used in applications such as simulation of floods and diverse virtual reality applications [5].

#### 2.1.1 Computer Graphic Fluid Simulation

The computer graphics fluid simulation was generated based on the Navier-Stokes equations. The Navier-Stokes equation is the physic-based equations that describes the dynamic of fluid. This equation has enabled more computing techniques for fluid simulation being developed. The initiative started with the introduction of the Computational

Fluid Dynamics (CFD). CFD is one of the fluid mechanic branches that uses mathematical calculations to simulate the interactions of fluids and liquid often used in engineering fields. It started in early 1970's, and it became as an acronym for a combination of physics, numerical mathematics and computer science to simulate fluid flows [6]. Since the introduction of CFD, several more methods and approaches were developed. Among the common ones are Eulerian grid-based method, Smooth Particle Hydrodynamics (SPH) which is derived from Lagrangian method and Lattice Boltzman method.

In computer graphics, the Lagrangian particle-based fluid was introduced to computer graphics by [7] and then extended to the semi- Lagrangian method by Stam [8]. [9] introduced the particle system to model a class of fuzzy objects or fluid objects. Since then, both particle-based Lagrangian approach and the grid-based Eulerian approach have been used to simulate fluids in computer graphic according to Miller [10]. Smoothed Particle Hydrodynamics (SPH) is a Lagrangian approach in the CFD arena, where the flow is modeled as a collection of particles that move under the influence of hydrodynamics and gravitational force. SPH was initially introduced by [11] and [12] to solve astrophysics problems. Because of its advantages over the other techniques to solve complex fluid phenomena, it has been widely used and applied in the fluid dynamics simulations.

### 2.1.2 Smoothed Particle Hydrodynamics (SPH)

The SPH was first tested as the numerical solution for gas flow problems for astronomical interest. SPH is an interpolation method for particle system. In the SPH method, the state of system is represented by a set of particles, which process individual material properties and move according to the governing conservation equations. With SPH, field quantities that are only defined at discrete particle locations can be evaluated anywhere in space. With this purpose, SPH distributes quantities in a local neighborhood of each particle using radial symmetrical smoothing kernels [10].

$$A_S(r) = \sum_j m_j \frac{A_j}{\rho_j} W(r - r_j, h) \quad (1)$$

A scalar  $A$  is interpolated at location  $r$  by a weighted sum of contributions from the particles where  $j$  iterates over all particles in the scene,  $m_j$  is the mass of particle  $j$ ,  $r_j$  the position,  $\rho_j$  the density and  $A_j$  the field quantity at  $r_j$ . The  $W(r, h)$  is called smoothing kernel with core radius  $h$  [13].

[13] applied the modified SPH equation based on [10] for fluid simulations. According to the paper, by using particle-based simulation, it could simplify the solution of Navier-Stoke equations. The research shows about the implementation of SPH-based fluid simulation on a high end 3D animation tool called 'Houdini'. They implemented fluid simulation using 'Houdini' plug-in to create water simulation. The testing applied 30,000 particles to represent fluids (water) movements. [14] presented an interactive technique for physic-based simulation and realistic rendering of rivers using Smoothed Particle Hydrodynamics (SPH). They described a design and implementation of a grid-less data structure to efficiently determine particles in close proximity and to resolve particle collisions. They used a simple linear list that stores the particles. According to them, the proposed method is faster than the Marching Cubes approach, and it constructs an explicit surface representation that well suited for rendering.

## 3 Research Methods

The conceptual idea for research method started with the identification of study area. The development was divided into three steps which were the ground surface modeling, generation of 3D computer graphics fluid simulation and finally the prototype development of a real time simulation system. Ground model involved the use of GIS LIDAR DEM and remote sensing data to model the flood area that had been studied. The river level data and rainfall data were used as an input to create the fluid simulation to represent flood movements. We implemented the SPH method for fluid using GLU3D plug-in for MAYA application. GLU3D is a plug-in for particle creation which was developed using SPH architecture. Figure 1 depicts the full approach use in the development of this research.

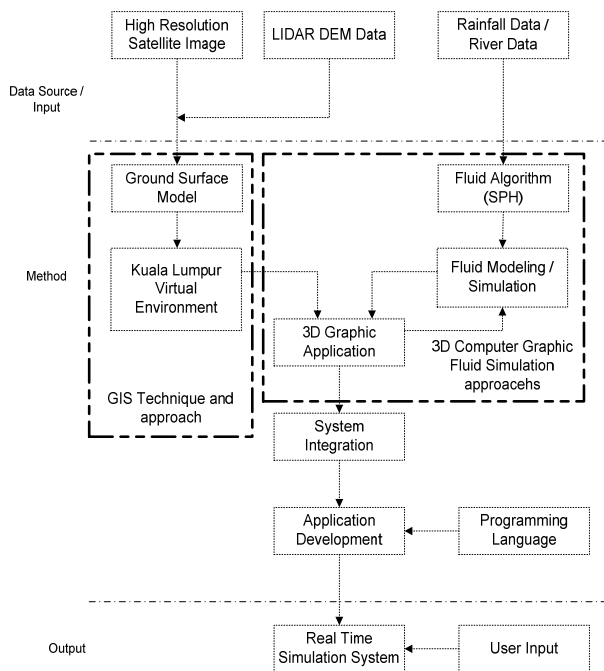


Fig.1. Conceptual Research Methods for the study

### 3.1 Ground Surface Modeling

High resolution satellite data had been acquired for the area of study. Figure 2 illustrates the satellite image for the area of interest. For modeling the elevation of the study area, LIDAR DEM data was used.

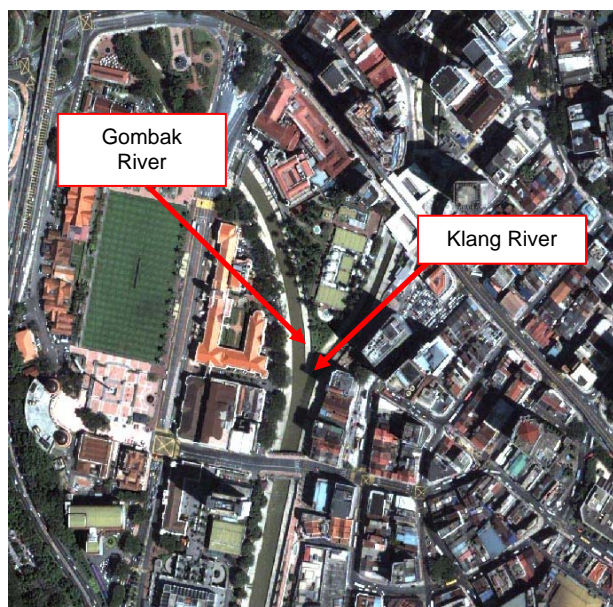


Fig.2. High Resolution Satellite Images for the study area.

Using GIS approaches, we were able to grab both images to create the ground model of the study area. First we utilized the LIDAR DEM to extract the elevation in 3D view which is shown in Figure 3. Then we grabbed the satellite images on top of it for

better object viewing. Figure 4 shows the study area with satellite image grabbed on top of LIDAR data.

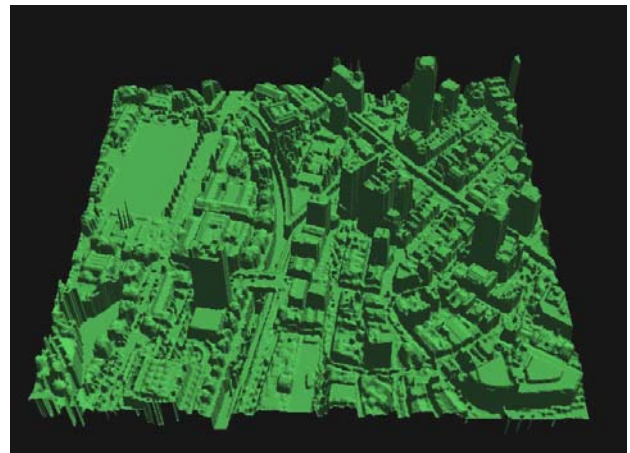


Fig.3. 3D view of the study area generated from LIDAR data

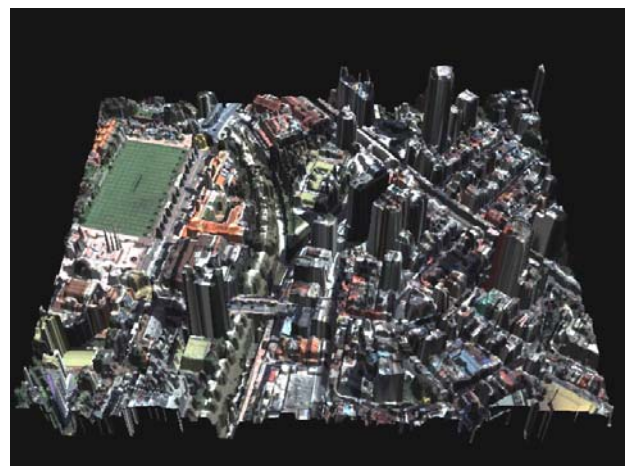


Fig.4 .Satellite image drap onto LIDAR DEM

### 3.2 Modeling Fluid Flow

We used the river level data and rainfall data as a reference point for the generation of fluid movement. It was the objective of this research which was to simulate an actual flash flood incident dated 10 June 2007. Due to that, the data obtained was the same date as the incident. The river level in meter for the area of interest was obtained from Jam. Tun Perak Station. This is the nearest station that holds the data for the study area. The rainfall data and river level for Klang Dam and Batu Dam were also obtained which both Dams are the main reservoirs for Klang River. These data were required for modeling purposes. Table 1 shows the river level for the area of interest while Table 2 illustrates the rainfall movement for the study area.



Time	Jam. Tun Perak Station (m)
6.00 p.m	25.4
7.00 p.m	26.5
8.00 p.m	30.6
9.00 p.m	31.0
10.00 p.m	31.0
11.00 p.m	31.0

Table 1. River Level (m) for Jam. Tun Perak Station on 10 June 2007

Time	Leboh Pasar Station (mm)
6.00 p.m	1.0
7.00 p.m	12.0
8.00 p.m	64.0
9.00 p.m	79.0
10.00 p.m	81.0
11.00 p.m	81.0

Table 2. Total rainfall (mm) for Leboh Pasar Station on 10 June 2007

Before implementing the graphical approach, we evaluated the incident by measuring the water level on top of the ground surface. We created a water layer and compared the water movements using the river level data. This was to show the affected area on hourly basis during the incident. Figure below illustrates the difference.

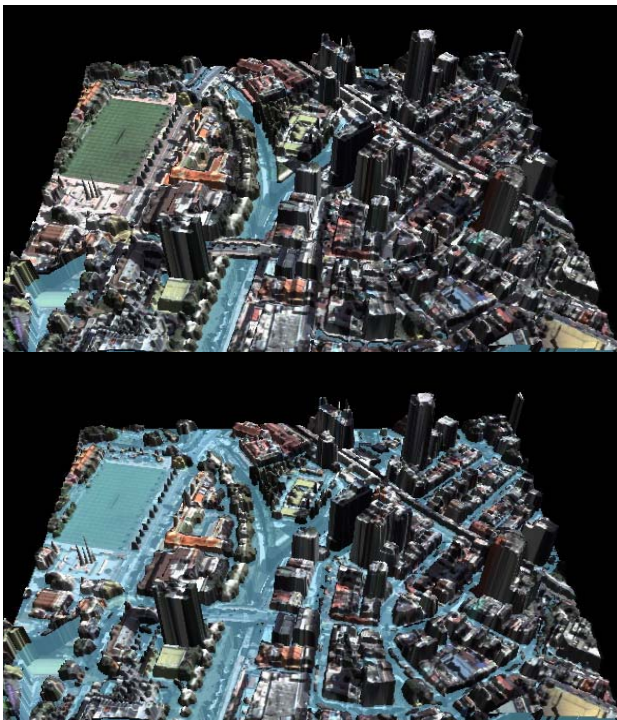


Fig. 5. Water movements during flash flood  
The top image shows water levels as at 6p.m (25.4 meters) while the bottom shows the water levels as at 11

p.m (31.0 meter).

### 3.3 3D Graphical Fluid Simulation

We pinpointed the exact height from the LIDAR DATA to identify water level risk for simulation and compared it with the cross section. The 3D scene was then imported into MAYA to create the water simulation. The water simulation was done using particle-based method showing water movement. The idea was to determine the process in real-time basis.

We implemented the SPH method using GLU3D to create the water flow in MAYA. We simulated the water using 12,000 particles. First we imported the elevation of the study area. The study area was reduced due to memory consumption. First we tested the particle simulation within the river confluence area. The first testing was an inclusive of the first 2 hours of the flash flood incident. We referred to the river level data and compared it with the static water simulation for the study area. The static simulation was based on LIDAR DEM data which we aligned the water level according to time. We created 12000 particles to simulate the water and tested the animation in a real-time of 18fps. The results show that by reducing the particles, less computations were used and accuracy of the simulation can be enhanced. This study proves that by using 12000 particles, it could handle a fluid simulation with a range of 10,000m<sup>2</sup> by using this approach. The simulation step was calculated in 3 seconds showing the water movement from 25.4 meter to 30 meter. The next figure shows the particles created on the ground surface as at 7p.m. with 26.5 meter water level.

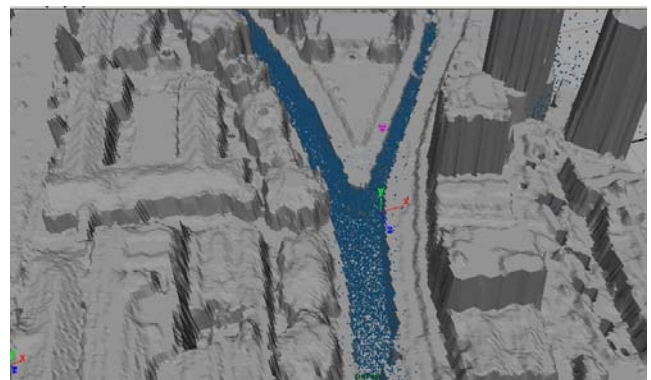


Fig. 6. Water levels at 7 p.m.

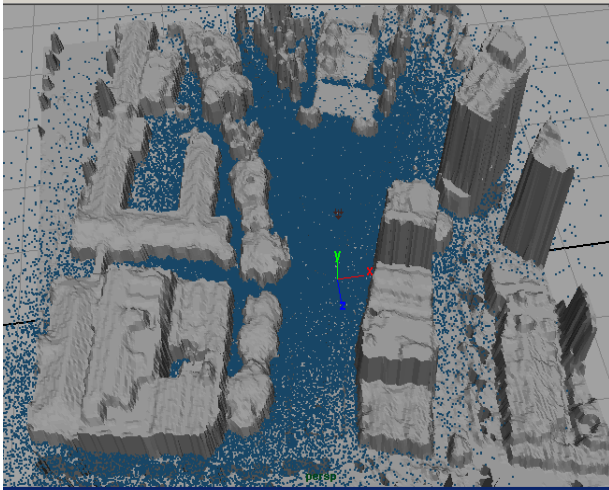


Fig. 7. Water levels at 9.30 p.m.

## 4 Conclusion

We described an attempt to examine the capability of computer graphics techniques to support the environmental studies. With a relevant hardware, larger areas of simulation can be implemented. With the increasing research works in computational fluid simulation areas, higher chances of reducing computation process and real-time computing using computer graphics. The next step is to enhance the simulation process by applying specific algorithm which can simulate a larger amount of particles with enhancement to the real-time simulation. Future test will also include a virtual environment for ground modeling and ultimately to achieve better realism and to optimize the simulation results.

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