Geomorphology study in relation to ground subsidence on urban area with sandbox simulation

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Abstract. Ground subsidence on urban area are one of the major factors of disaster. in urban area such as Jakarta, ground subsidence is frequently occurred on main road and densely populated building. Study of surface elevation changes due to influence of groundwater movement have broadly discussed. In Many areas of subsidence caused by groundwater pumping have been identified and monitored. To understand more advance in subsidence process through direct experiment. The sandbox simulation of surface structure changes due to material movement. The simulation projects the surface elevation changes due to loss of mass.

Keywords: Ground subsidence, elevation, sandbox, simulation, depth camera

1. Introduction
Mass transfer of has been major problem in urban city since the beginning of the population. Land subsidence is the form of mass transfer from the ground in responds of underground development, utilisation and evolution [1]. Subsidence is geological activity due to ground elevation loss [2]. There are more than 150 cities around the world encounter land subsidence at rates of centimetres [1], for instance in Indonesia, Jakarta have a subsidence rate about 2 until 17 cm/year and ground density changes up to 41 μgal/year [3]. Ground subsidence has become global and multidisciplinary subject. Groundwater sustainability is often defined through a water budget approach, as the balance between inputs and outputs of an aquifer system [4]. Although study about subsidence has been going on since 1969 [5], study of this subject has not been thoroughly investigated. To profound the relation subsidence and mass transfer can be directly approached with the application of sandbox. There are several researches to evaluate physical changes in real world with sandbox simulation [6, 7].

Some application of sandbox are used for fault growth [8], compaction and deformation [9] and stress distribution [10]. Other application of sandbox in subsidence detection is applied for subsidence on volcanic area to analogue modelling of crater [11]. But there is no study on subsidence in urban area from sandbox simulation perspective. New approach to study subsidence are combination of sandbox simulation and Augmented Reality Sandbox (ARS) to detect deformation of surface more accurate through depth sensor detection. ARS has been developed by UC Davis [12]. The ARS works by emitting infrared light to sand and record depth, and the data recorded from depth sensor proceed by computer to be project on projector as topographic map. ARS also used to teach topographic maps and Surficial Processes in introductory geology labs [13].
2. Experimental

University California (UC-Davis pioneered ARS in collaboration by LakeViz3D and funded by the National Science Foundation [14]. The project primary objective is to increase understanding and stewardship of freshwater lake ecosystems using 3D visualization [13]. Sandbox origin developed to create topographic models by shaping real sand on which an elevation colour map, contour map and water flow simulation that projected Realtime. As the user change the shape of sand, depth sensor camera detects the shift of elevation, and the projected colours change accordingly. Sea level can be manipulated to give an insight of shore projection.

2.1. Sandbox set up

The setup of sandbox for the ARS is 4:3 aspect ratio. In this experiment we are using 100 cm by 75 cm wide and 30 cm tall for the sandbox. The size of sandbox limited by the depth sensor camera. The depth sensor camera approximately 90° field of view and need to be mounted high above the sand surface as shown in the figure 1. The sandbox field with white sand for best displaying projector image.

Sandbox equipped with depth sensor camera (Kinect), Short throw projector and a PC that runs AR Sandbox software as shown in figure 2.

2.2. Software and installation

The basic process of installation using Vrui, Kinect (as depth sensor) SARnbox software on the Linux operating system. The software is opensource and can be downloaded and use under GNU general public license. Installation process divided into four steps. Software installation, system integration, running ARS software and fine tuning.

![Figure 1](image1.png)

**Figure 1.** (a) Arrangement of projector and camera [14] arrangement of projector, and (b) Kinect camera above Sandbox. The short-throw projector is mounted at the same height as the Kinect camera.
3. Results and discussion

Initial model is made from flat surface that later sustain mass removal as shown in figure 3. The condition is analogue of subsidence over groundwater movement. This initial condition using sandbox analogue with size 100 cm × 75 cm with ratio 4:3. On this first initial condition we applied as datum level to be identify by the depth sensor. Datum level coloured by light brown. Qualitative approach for colour scale defines as red for high ground level and blue to low ground level. The analogue situation of ground subsidence generated using vacuum suction to represent as extraction of underground water. The reason from using vacuum suction is to accelerate the simulation in order to image the ground level change.

The result of analogy subsidence experiment representing different surface condition relative to material transport as shown in figure 4. Our goal is to illustrate how subsidence form and the deformation. We identified four different surface condition over short period of time. We utilize depth sensor to detect the surface change and displayed it in colour scale. This experiment is pilot program for next to be utilizing depth sensor in quantitative experiment such as flume tank.

4. Experiment limitation

Analog experiment enable us to simulate geological process at the laboratory scale. But it is important to understand the limitation of these experiment to avoid over interpretation. There are scaling factor that must be calculated, and many other factors that need to be account.

![Figure 2](image1.png)  
(a) Projector for projecting image and (b) Kinect 360 as depth sensor.

![Figure 3](image2.png)  
(a) Sand on initial condition, and (b) Sand on initial condition with projection of level from ARS.
Figure 4. Surface level change due to extraction of sand material, (a) initial condition, (b) second condition, (c) third condition, and (d) fourth condition.

5. Conclusion
Analog experiment of subsidence demonstrate that the presence and position successfully to be pilot project for future experiment. The reason of this experiment is to simulate real conditions with parameters that approach the original conditions. Sandbox simulation is live simulation that including all interaction between particles that might not be included during computer simulation, such as interparticle force attraction, friction of movement etc. Although it is possible to include all the parameter to computer simulation, but there is another factor need to be concern such as computer limitation and there is a change of false simulation. From this experiment we can digitized surface level using depth sensor to be qualitatively illustrate the surface change due to mass extraction with colour indicator. Although there are several important parameters that have not been considered in this experiment such as scaling factor. Therefore, the future work should investigate quantitatively subsidence from scaling and volumetric point of view.

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