Game Design Document

Earthquake Game

Introduction

Pitch:

The game features the fun aspects of a casual puzzle game and in addition functions as an educational tool to inform the player about earthquakes and their destructive force. In a 2D perspective the player can see the layers of soil and tectonic plates from the surface to the mantle of the earth. It is able to build and destroy cities in different levels based on actual earthquake-ridden regions. Through the different gameplay modes the player learns about the effect of different soil types and the resilience of certain building materials.

In short:

There are two game modes in this game. The first is to build a city as safe as possible and the second is to create an earthquake as destructive as possible. The player progresses through sets of levels for different countries, with increasing variety and complexity to solve the ‘puzzle’ and progress to the next level.
For the first mode, the player has the ability to decide what types of buildings should be built. These buildings have different properties, such as their building material, foundation and its placement on the surface of the terrain. The goal in the game is to keep as many people safe as possible. The player learns about the techniques and innovations used to protect buildings from earthquakes.
For the second mode, the player has the ability to create earthquakes and has control over the position and strength of the vibrations. The goal in the game is to damage certain buildings at much as possible. The player learns about the forming of earthquakes and which variables have what effect on its destruction.

General Information

The game will be played at an exhibit about earthquakes in the Science Center in Delft. It should be playable in a browser it is not necessary to save the gamers progress as their are only a limited amount of levels. The target audience is children from 10 to 16 years old which make up the majority of the visitors to the Delft Science Centre.
As an advisor about the scientific content in the game, we contacted Marion Tuijp, who was suggested to us by our commissioner. She is an Civil Engineering student who studied the effect of soils in the human induced earthquakes in Groningen.

Gameplay description

The player is presented with a globe that it can see to review the different levels. The more advanced levels are shown but not accessable. They will be unlocked as the player progresses through the game. Each level consists of a 2D view of a landscape with the cross section of the underlying soil.

Building Mode
The player is expected to build enough buildings to facilitate a certain size population and do that within a given budget. The player can choose from different building types which vary in size and material each will have a different price. As the placement on a soil type and the building materials influence how well the buildings can withstand the earthquake so the player has to go about this strategically. When the player is content with its design, an earthquake will be simulated. The player sees the seismic waves move through the soil and the destruction that is being done to its city. To warn people player can click on buildings as soon as the earthquake starts. These will leave the building as soon as possible. It is taken into account that large buildings will have more people and will take longer to evacuate. A maximum of a three star rating is given to the player depending on the amount of financial damage and casualties.

Earthquake mode
When the players completes a level with at least two stars in the building mode it is rewarded with the option to be the earthquake. It is then presented with the same level including a prebuild city. The epicenter of the earthquake is located at a realistic position along a faultline. The player can then produce seismic waves by hitting the spacebar. To create the most destructive earthquakes the player should follow a magnitude bar that indicates the right moments to hit the spacebar. The player is now scored on the amount of damage it has done. This is based on the Damage Ratio; the ratio of the earthquake damage repair compared to the total value of the building. When it is sufficient, they can continue to the next level.

Level design

General level variables:

- Building materials/structures: Wood, concrete, steel and skyscrapers vs. small houses
- Soil build-up: Soft soils are more dangerous than solid soils
- Prevention methods/technical innovations: e.g. buildings absorbing shockwaves
- The minigame that defines the magnitude of the earthquake can be made faster or slower

1. Serious game (purpose and reality)

The game serves the purpose as an educational tool about earthquakes, the influence of different soil types on the destructive power of the earthquakes and an insight in building types and materials that can withstand earthquakes.

For the insight in different soil types we have included soil types based on the actual soil compositions at the various locations around the globe. The exact depths of different layers have been simplified for enhancing playability.

The influence of the different soil types on the magnitude of the earthquake is simulated and will be visualized in the waves. Then the player can see that when a waves enters another soil type, it influences that magnitude and/or speed of the wave.

Finally a distinction will be made for the building types. These buildings collapse under different circumstances, teaching the player that certain types are better at withstanding earthquakes than others. The player will be given a budget to build a city in every level by selecting from a building library, with the aim of housing a minimum amount of people for the least amount of money whilst keeping them safe to get the most points.

2. Serious game (play)

The game concept has already been discussed in the gameplay description and the introduction. The main elements in the game are building cities in different locations whilst balancing budget, safety and population. Hereafter the player can try to be the earthquake and destroy other players' cities to get points. The player is given feedback in the amount of points they receive for the choices they have made, but also the visual feedback of earthquake waves traveling at different speeds and intensities in different soil layers. The balancing of budget, safety and population is the main dilemma for the player. The actions and types of choices the player gets to make are already described in the gameplay description

Soils

Soil buildup of countries

For the purpose of our game idea that you can travel the world during the game we have looked at several soil types where earthquakes regularly occur. In the table below the different soil compositions are shown, which will be used to design the terrain for each level:

Location	Soil composition (top to bottom)
Central Italy (Luzi et al., 2005) Population umbria 2015 ±900.000 GDP Umbria ±€25.000.000.000	1. Limestones 50m (v=200m/s) 2. Marly limestones 50m (v=300m/s) 3. Marls 50m (v=650m/s) 4. Flysch (mixture between marls and sandstones) 50m (v=750m/s) 5. Bedrock (v=1000m/s)

Groningen (Human induced) (Meijles, 2015) Population 600.000 GDP groningen €28.000.000.000	1. Clay 2. Clay & Sand 3. Sand 4. Sandstone
Japan (Fukishima (Moore & Karig, 1976) Population 2 million GDP €78.000.000.000	1. Mud 2. Mud & Mudstones 3. Sand 4. Sand & Sandstones 5. Sandstone
San Fransisco (Borcherdt, 1970) Population 850.000 GDP €250.000.000.000	1. Peat 2. Clay 3. Glacial till
New Zealand (Christchurch) (Cooper et al., 2011) Population 400.000 GDP: 30.000.000.000	1. Sand 2. Sandy gravel 3. Silt 4. Peat mixed
Haiti (Saint Fleur et al., 2015) Population port au prince: 2.500.000 GDP: 13.000.000.000	1. Chalky limestones 2. Marly limestones
Nepal (Dahal, 2006) Population: 1.000.000 GDP: 6.500.000.000	1. Granite 2. Grained rocks

Properties of soil types

- A: Bedrock/hard rock:
    - Speeds up waves if on the surface
    - If present below other soil type, it dampens waves
- B: Rock (Volcanic, soft bedrock)
    - Small amount of amplification
- C: Dense soil/soft rock (sandstone)
    - Slows down the waves but increases intensity
- D: Stiff soil (mud)
    - Significant amplification of shaking
- E: Soft (water saturated) soil
    - Liquefaction happens the ground will start to act like a liquid, heavy object like buildings and cars start sinking.

Reference: https://earthquake.usgs.gov/regional/nca/soiltype/

The ground types have different elasticities. There is a very small impact for the hard soils and more impact for the soft soils, however this impact is not big enough to be incorporated

into the game (Source: http://www.rcsolver.com/en/eurocode-8-ground-types) We can improve the velocity formula of the earthquake with this source. http://ascelibrary.org/doi/abs/10.1061/%28ASCE%290733-9410%281986%29112%3A11%281016%29#aHR0cDovL2FzY2VsaWJyYXJ5Lm9yZy9kb2kvcGRmLzEwLjEwNjEvKEFTQ0UpMDczMy05NDEwKDE5ODYpMTEyOjExKDEwMTYpQEBAMA==

Soil type calculations:

$$v_s\left(\frac{m}{s}\right) = 69N_j^{0.17}D^{0.2}(m) \times F_1 \times F_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

F1 = Alluvial-diluvial. Respectively sediment of a river or of a flood. 1 and 1.3
F2 = Nature of the soil:

Clay	(E)	1.0
Fine Sand	(D)	1.09
Medium Sand	(D)	1.07
Coarse Sand	(C)	1.14
Sandy gravel	(B)	1.15
Gravel	(A)	1.45

D = depth beneath the soil
N is neglectable
F1, probably also.
So the formula for us will be v=F2*D^0.2

The amplitude is not easy to quantify with our parameters. Therefore a certain difference should be used that works for our game, having the most effect in the softest soils and lowest in the hard soils.

The angle is also important

Buildings

To generalise, we describe a few specific types of buildings. In the game, these can be used to define schools, hospitals, town halls and others.

Building types

- Small wooden building
  - Building materials: Wood
  - Foundations: None (Wooden poles)
- Small brick building
  - Building materials: (Un)reinforced masonry
  - Foundations: None, Concrete
- Apartment complex
  - Building materials: Concrete
  - Foundations: Concrete, Reinforced concrete

- Skyscraper
    - Building materials: Reinforced concrete, metal beams
    - Foundations: Base isolation, concrete
    - Earthquake resistance: Counterweights
- Other: Symbolic buildings/structures for each country

Properties of building materials

- Wood: Can collapse to medium earthquakes
- Brick: Can collapse to strong earthquakes
- Concrete: Can collapse to medium earthquakes (cannot bend)
- Reinforced concrete: Can collapse to strong earthquakes
- Metal beams: Can collapse to strong earthquakes

https://en.wikipedia.org/wiki/Earthquake_engineering
http://timelines.latimes.com/l-quake-danger-which-buildings-are-risk/
https://en.wikipedia.org/wiki/Seismic_retrofit

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