Eindhoven University of Technology
HTI Design Track A

Requirements

Stabilight

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Introduction

The main goal of the Stabilight project is to relieve people who suffer from seasickness by creating an artificial horizon with light inside a cabin. Per se, this goal makes the artificial horizon the outcome-product of the sum of all requirements described in this document.

In order to understand the mechanisms behind this artificial horizon, first it is necessary to know that seasickness is a specific case of motion sickness. There are several theories about the causes of motion sickness, but the most accepted one is the sensory rearrangement theory, which states that motion sickness is caused by a difference between the proprioceptive inputs: a is mismatch between the sensed movement by the vestibular and visual systems. When the vestibular system senses the movement of the ship, but the eyes cannot detect that movement because of being inside a cabin, then several symptoms such as dizziness, warmth, headache, stomach awareness, sweating, nausea and vomiting appear.

The uneasiness caused by motion sickness represents loses for ferry companies and discomfortable experiences for passengers. This is especially a problem on ships, because the travel time is long, people cannot get out; this affects both clients and crew.

As Bos et al. (2010) proved it is possible to decrease the seasickness feeling by observing an artificial horizon in which visual motion is presented in the opposite direction of the ship's motion. The following sections of this document will describe the necessary requirements to build and install such artificial horizon in a ship's cabin, so that the people staying there will feel more comfortable when traveling.

Definitions

In order to avoid misunderstandings, the following definitions should be considered:

- Horizon.   According to the sixth edition of the Columbia Electronic Encyclopedia, (2010), "Horizon, in astronomy, is a roughly circular line bounding an observer's view of the surface of the earth where the sky and earth seem to meet. This is the visible horizon. At sea the visible horizon is a perfect circle with the observer at its center, but on land it is irregular due to topographic features". In this document, horizon can also be any elements of an image, which can be used as reference for orientation, in a similar fashion to the real horizon.

- Artificial horizon. The image depicting a horizon that is shown to the users with the purpose of helping them to cope with seasickness. Basically, it is the interface of the system.

- System. In this document, system will refer to the Artificial Horizon, the sensors used to retrieve the information about the movements of a ship, and all the necessary software and hardware to implement all the requirements described in this document.

- Light. According to the Britannica Concise Encyclopedia, 1994-2010, light is "the portion of the electromagnetic spectrum visible to the human eye. It ranges from the red end to the violet end of the spectrum, with wavelengths from 700 to 400 nanometers and frequencies from $4.3 \cdot 10^{14}$ to $7.5 \cdot 10^{14}$ Hz". Light will be used both in the artificial horizon projection and the environment, in order to create the optimal effects.

- Projection.   The projection refers to a mean to show the image of the artificial horizon in the intended scenario described at the end of this document, and complying with all the requirements listed below. Possible synonyms used in the same sense: screen.

- Ship's movements.

  (A) Translate

      1. Heave: moving in and out of the water (up/down)

      2. Sway: moving to the left and right in the water

      3. Surge: moving forwards and backwards in the water

  (B) Rotate

      4. Yaw: moving around the vertical axis (bow turns left and right)

      5. Pitch: moving around the abeam axis (bow goes up and down)

      6. Roll: moving around the longitudinal axis of the ship

- Sensor. The means to sense the relative displacement of the boat. It should be an integrated 3-axis Gyroscope with a 3-axis Accelerometer, to provide the 6 degrees of freedom of the movement of a boat.

- FR. Functional requirement. Define specific behaviors or functions of the system.

- NFR. Non- Functional Requirement. Define qualities or characteristics of the system.

- Real-time. According to the Oxford Dictionary of the US Military, 2001-2002: "Pertaining to the timeliness of data or information that has been delayed only by the time required for electronic communication. This implies that there are no noticeable delays."

- MoSCoW Scale.

    - (M)ust have

    - (S)hould have

    - (C)ould have

- (W)ould have

- Pop-up items. Those elements which are really irregular or outstanding in an image. For example birds, ships, big buildings and big trees.

Key assumptions and constraints

Assumptions

- All kind of motion sickness refers to the same conflict, and seasickness is just a specific case of them.

- The state-of-the-art of the technology that can be used on board (scenario) provides all the means to implement all the Must requirements below. This can be reviewed with the technical staff when implementing the solution.

- There is enough space in the scenario to place the projection described by the must non-functional requirements below.

- Dependencies among requirements should be carefully watched. These dependencies are described in the box "Additional information/references" of each requirement template.

Constraints

- The movement of the boat should be synchronized with the simulated movement of the screen in all six degrees of freedom in real-time. A possible constraint is that due to processing and transmission times there will be a time delay in the movement of the image, however, this delay should be minimized (FR. 2).

- There is no theoretical evidence available on whether the magnitudes of the movements of the ship influence the level of the perceived motion sickness as much as the direction. Because this is not known, FR 4 was defined. However, if the movements of the ship are small they could not be noticeable in the projection. A possible solution for this would be to amplify the depicted movements of the ship on screen, but only if this does not affect the effectiveness of the system.

Functional Requirements

In this section, the functional requirements will be described. The priority will be described in a MoSCoW scale.

FR 1. Sensing the six degrees of freedom of ship movements			
Source	Report page 22, Interview with J. Bos	Priority	Must
Requirement Details			
Description	All degrees of freedom of the movement of a ship induce motion sickness, especially the heave. This means that the Stabilight system must be able to sense the six movements (e.g. with the use of an integrated 3-axis Gyroscope with a 3-axis Accelerometer).		
Measurement criteria	The screen/projection of the Stabilight must have an option to show the numeric position in the x, y, and z axis reference for both, the accelerometer and the gyroscope. These data can be displayed either in a new window or in a rectangle at one side of the horizon image, with toggle options to show/hide it. This option will also be useful as a mean to track errors. It should be labeled with natural language.		
To-be-defined items	NA		
Additional information/references	NA		

FR 2. Real-time translation of the sensed movement into the represented one			
Source	Report page 23, Interview with J. Bos, literature	Priority	Must
Requirement Details			
Description	To be effective, the Stabilight horizon must represent the opposite movements to the ship motion in real-time. This is, the translation of the sensed movement into the represented one should be done as fast as possible.		
Measurement criteria	The delay should not be bigger than 100 ms.		
To-be-defined items	NA		
Additional information/references	Dependent to FR1.		

FR 3. Representation of the artificial horizon			
Source	Report page 19, Interview with J.Bos, Prototype tesing.	Priority	Must
Requirement Details			

Description	The artificial horizon representation must be able to show all degrees of freedom. This means, that the artificial horizon should be a 3D representation and depict depth in anyways, in order to give a sensation of movement.
Measurement criteria	The elements of the image should be able to rotate in three degrees and depict the tree translation movements as well.
To-be-defined items	NA
Additional information/references	Dependent to FR1.

FR 4. Movement-image consistency			
Source	Report page 23, Interview with J. Bos, Prototype testing, Literature	Priority	Should
Requirement Details			
Description	Since moving towards the horizon is useful as reference point as well, the image should match the sensation of motion in the ship. The movements shown in screen should be as similar as possible to the real movements of the ship (direction), and of the same magnitude. This is, if the boat moves 5 meters forward, the displacement seen in the projection should also be equivalent to 5 meters.		
Measurement criteria	The relative changes shown on the projection. The relative size of the elements should change accordingly to the direction and magnitude of the movements of the ship. The nearer the object, the bigger it is, and the other way around.		
To-be-defined items	NA		
Additional information/references	Dependent to FR1.		

FR 5. Inherent illusion of motion matching			
Source	Report page 49, Prototype testing	Priority	Must
Requirement Details			
Description	The images themselves can induce an illusion of motion. For example a bird looking towards the user seems to move in this direction as well. The effect of the movement of the ship on screen should keep consistency and adapt accordingly to these illusions of motion.		
Measurement criteria	No mismatch cues of movement should be perceived.		
To-be-defined items	NA		
Additional information/references	Dependent to FR 1-3.		

FR 6. Ability to obtain attention

Source	Report page 32, 50, Focus group and Prototype testing	Priority	Must
Requirement Details			
Description	The image should be able to draw the user's attention.		
Measurement criteria	It should have pop-up items.		
To-be-defined items	NA		
Additional information/references	NA		

FR 7. Variety of images

Source	Report page 50, Focus groups, Prototype testing	Priority	Should
Requirement Details			
Description	The system should have the option to choose between simple and complex images. Also, by providing several options, the system can maintain people interested on them.		
Measurement criteria	A menu should be available, to switch between at least two images, one complex (around 6 pop-ups) and one simple (one or two pop-ups).		
To-be-defined items	NA		
Additional information/references	Dependency to FR 6.		

FR 8. Interaction with the horizon

Source	Report page 28, Focus group	Priority	Would
Requirement Details			
Description	People should be able to do something with the image, it should be interactive.		
Measurement criteria	Person should be able to interact with the system in a pleasurable way. This should be tested with a questionnaire about interaction experiences.		
To-be-defined items	NA		
Additional information/references	NA		

FR 9. Social aspect

Source	Report page 27, Focus group	Priority	Would
Requirement Details			

Description	The image should have a social aspect, this means, it should let the users interact with other people as well.
Measurement criteria	Person should be able to interact with the system, and it should also let them interact with the people in their surroundings.
To-be-defined items	NA
Additional information/references	NA

Non-Functional Requirements

Now, non-functional requirements will be listed. A MoSCoW scale is also used.

NFR 1. Low image detail			
Source	Report page 37, 50, Literature, Prototype test	Priority	Must
Requirement Details			
Description	The image showed as artificial horizon should not have many pop-ups. Care should be taken about the maximum limit of complexity that a person is able to stand without feeling worse. From the prototype test, we learned that the worse the people feel, the less pop-ups they can tolerate.		
Measurement criteria	A proper quantitative study should be conducted over this topic, in order to stay into the secure range of pop-ups, only between 3 and 6 should be included and the spatial frequency of the background should be kept low.		
To-be-defined items	Maximum acceptable detail frequencies.		
Additional information/references	Dependency to FR6.		

NFR 2. Image Size: 30º of the center of the visual field			
Source	Report page 18, Literature	Priority	Must
Requirement Details			
Description	For the projected image to be perceived as egocentric motion, the projection should cover at least 30º of the visual field. This way, the image can be seen in the central or peripheral parts of the visual field.		
Measurement criteria	Image size: 30º of the center of the visual field.		
To-be-defined items	The typical activities performed in a cabin.		

Additional information/references	Bos et al. 2010. Found that an artificial horizon keeps it effectiveness even if it is saw in the periphery of the eye; however, in order to accomplish this requirement, the suggested high of the projection is at the level of sight of most people in the room (set according to the activities that people perform in that specific room, e.g. sit, stand or sleep) and the image should have as much height as the standard deviation of the height of the typical users (nice to have). In addition should the viewing direction be taken into account; peripheral viewings require larger line sizes.

NFR 3. Luminance Intensity

Source	Report page 20, Literature	Priority	Should
Requirement Details			
Description	The intensity for the artificial horizon depends for the largest parts on the context luminance. To assure a constant perception of intensity the horizon luminance needs to be adjusted when the context luminance changes.		
Measurement criteria	In photopic conditions the relation between the minimum luminance of the horizon (Lh) and the luminance of the background (Lb) is determined by Weber's law ((Lh-Lb)/Lb = k, where k is a constant).		
To-be-defined items	NA		
Additional information/references	NA		

NFR 4. Pop-ups availability

Source	Report page 49, Prototype test	Priority	Should
Requirement Details			
Description	The image should have strong and well defined pop ups, and if they are not available, the depth and direction in the image should be well defined.		
Measurement criteria	At least tree well defined and outstanding elements should be present in the image.		
To-be-defined items	NA		
Additional information/references	Equivalent to FR 6.		

NFR 5. Real vs. abstract consistency

Source	Report page 52, Prototype test	Priority	Must
Requirement Details			

Description	The image should be consistent, this is, the image should have the same level of abstractness.
Measurement criteria	Pictures should not be combined with Photoshop-created images or rendered ones. All elements should have the same source and be consistent among them.
To-be-defined items	NA
Additional information/references	NA

NFR 6. Relevance of the image			
Source	Report page 50, Prototype test	Priority	Should
Requirement Details			
Description	The image should not necessarily be a relevant image for the sea context. In fact, it is recommended to use a non-relevant one, because people prone to motion sickness or the ones that have experienced it before do not want the image to remind them about the sensation.		
Measurement criteria	There should be images available to choose that are not related to a sea view at all.		
To-be-defined items	NA		
Additional information/references	Dependent to FR7.		

NFR 7. Pattern avoidance			
Source	Report page 49, Prototype test	Priority	Should
Requirement Details			
Description	The image should avoid using patterns. From the prototype test, users said that "they are boring and don't help to reduce the feeling of sickness"		
Measurement criteria	No patterns in the images.		
To-be-defined items	NA		
Additional information/references	NA		

NFR 8. Preference for color			
Source	Report page 49, 20, Prototype test, Literature	Priority	Should
Requirement Details			

Description	The image should include colored and uncolored versions, because no specific reference was noticed, however, green-yellow combinations should not be used because this combination reminds the sensation of being sick.
Measurement criteria	Green-yellow combinations should not be used. Besides this exception, colorful images should be available.
To-be-defined items	NA
Additional information/references	Dependent to NFR12.

NFR 9. Consistency across the visual field			
Source	Report page 52, Prototype test	Priority	Should
Requirement Details			
Description	The image should have consistent brightness levels in the entire screen. Also, if the horizon is a line, it should be continuous and consistent.		
Measurement criteria	The projection should consist only of one even image.		
To-be-defined items	NA		
Additional information/references	NA		

NFR 10. Claustrophobia avoidance			
Source	Report page 30, Focus group	Priority	Must
Requirement Details			
Description	The projection should not make the room look smaller.		
Measurement criteria	The projection should not be invasive. A flat screen or a beamed-image is preferred. A user test need to be performed to measure the effect on perceived cabin size.		
To-be-defined items	NA		
Additional information/references	NA		

NFR 11. Bluish color			
Source	Report page 21, Literature	Priority	Would
Requirement Details			
Description	Blue should not be used because of its ability to alter circadian rhythms. Especially, if the intended users are elderly, bluish light should not be used.		

Measurement criteria	Light of 459-485 nm wavelength and 2500 lux would preferably not be used.
To-be-defined items	NA
Additional information/references	"Circadian rhythms are cyclical changes that recur regularly over an approximately 24-hour cycle. They are a type of biological rhythm affecting many aspects of human life and should not be confused with 'biorhythms', a theory which has little scientific support." According to the Oxford Food & Fitness Dictionary, 1997-2003.

NFR 14. Focus points at distant points			
Source	Report page 17, 49 Literature, Prototype test	Priority	Must
Requirement Details			
Description	Pop-ups should be at distant points, because they have the ability to attract most of the attention of the users.		
Measurement criteria	The majority of the pop-ups should be kept in the furthest points in the image perspective, so that the attention is drawn to that point.		
To-be-defined items	NA		
Additional information/references	Dependent to FR6.		

NFR 15. Size of projection			
Source	Report page 39, Literature	Priority	Must
Requirement Details			
Description	The projection should be 2 meters away from the user, and visible.		
Measurement criteria	A user test needs to be performed in which a participants, need to identify projected objects at a distance of two meter. All participants should be able to recognize the objects.		
To-be-defined items	Test required		
Additional information/references	NA		

NFR 16. Repeating movements			
Source	Report 5.3, Interviews in context & report 2.2.5.2, research	Priority	Should
Requirement Details			

Description	The representation could be static or dynamic (i.e. moving imagery). When a dynamic representation is used it should not contain repeating movements of 0.1 to 0.3 Hz due to the potential induction of nausea.
Measurement criteria	Repeating movements of 0.1 to 0.3 Hz should preferably not be used.
To-be-defined items	NA
Additional information/references	NA

Scenario

This system is intended to be implemented in the cabin of a ship where there are no windows available. Two examples are shown below.

Prototype

A simple mid-fi prototype showing several images depicting possible artificial horizons was built. The main aim of building this prototype was to conduct user research that lead to some of the requirements listed above. For further details please refer to the Stabilight Project report.