Playing on AREEF

Evaluation of an Underwater Augmented Reality Game for Kids

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Presented at WaterHCI 9th December 2021

Talk with videos: https://youtu.be/sTiX95DGgTM

Slides at: https://www.slideshare.net/loppermann/underwater-ar-talk-at-waterhci-2021

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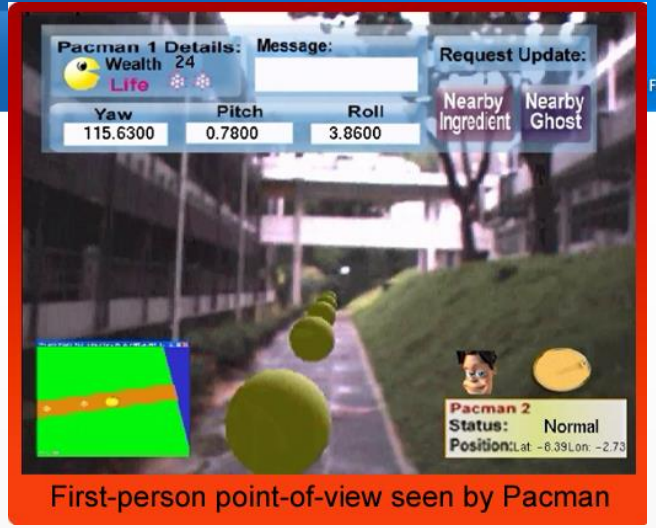
Presented by:
Leif Oppermann

AREEF
Augmented Reality for water-based Entertainment, Education and Fun

Video overview

Video: https://youtu.be/sTiX95DGgTM?t=75

From AR to AReef



First-person point-of-view seen by Pacman

Underwater Augmented Reality: R&D Trends

- **WetPC** - the 1st underwater PC: no tracking, no AR
- **Virtual Oceanarium** - the largest simulated underwater world representing the oceanarium of Lisbon, Portugal
- **SeaSlate** - tablet-PC in waterproof case: GPS-connection for tracking, but no AR
- **Tryton** by VirtualDive - Monitor on swimming pool's wall, PC connected but outside: haptic effect, but no mobility support & no AR
- **FIT Underwater AR** - mobile setup, tracking support

- Tracking objects in a pool
  - Simoncelli et al.: cleaning robot
  - Eskinja et al. Used sonar tracking
  - Carreras et al. Used optical tracking
- HCI examples
  - Blum et al.: UWAR game
  - Pell and Müller: artistic installation
  - Von Lucas et al: improve ROV navigation
  - Raffe et al: Interaction categorisation across six degrees of water contact

- First prototype in a mask by FIT in 2008/2009
  - Tangible aspect of the water changed perception
  - Challenged underlying assumption about AR
  - A game with fish and treasures
  - Student work of Lisa Blum

- Worldwide attention
  - Many dive magazines
  - 3rd prize at Siggraph 2009 student competition for Lisa (out of 625 submissions)
  - Featured by Canadian Discovery Channel
    https://www.fit.fraunhofer.de/en/business-areas/cooperation-systems/projects/underwater-ar.html
    https://www.youtube.com/watch?v=0sQobGBTzhs


AREEf
Augmented Reality for water-based
Entertainment, Education and Fun

AREEF Project Overview

- Title: **AREEF – Augmented Reality for Water-based Entertainment, Education and Fun**
- Goal: **Development of Underwater AR Experiences deployable in Water Parks**

- Duration: **2010.12.1 ~ 2013.11.30 (3 years)**
- Consortium:
  - Lead: Fraunhofer FIT (Germany)
  - Participant: EUMTECH Co., Ltd. (Korea)
  - Subcontract: UD4M (Korea), Trubicon (Germany)

- Funded through Korea Institute for Advancement of Technology (KIAT)
- First KIAT/MKE-funded project with European lead organization

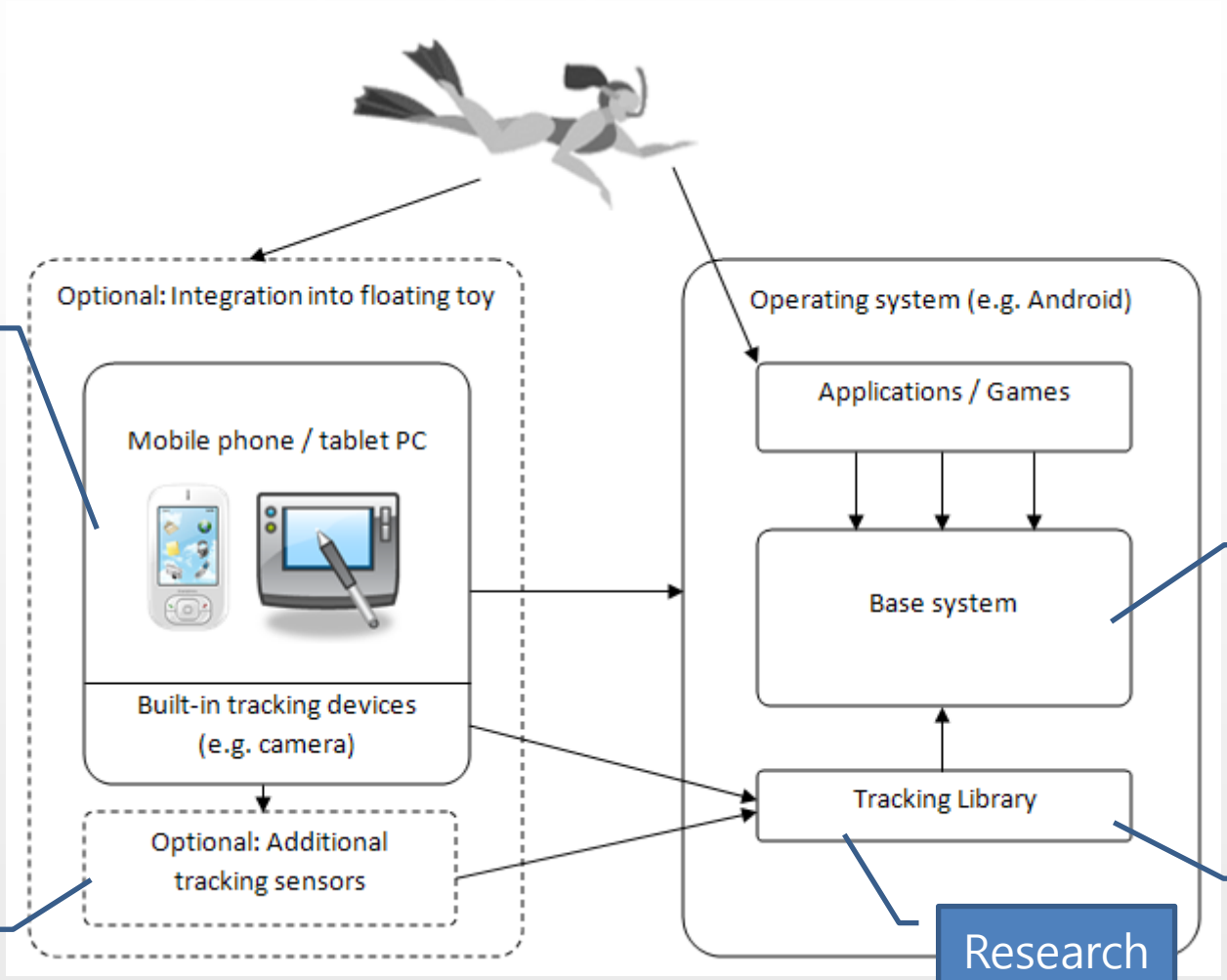
AREEF Fraunhofer FIT EumTech connection technology UD4M United Dimensions For Millennium TRUBICON

AREEF Mission Statement from 2010



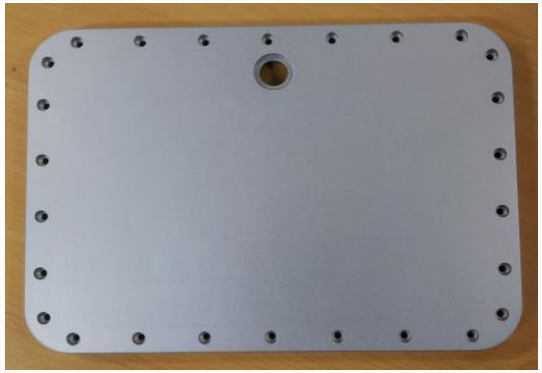

- Water is a fascinating medium
  - Mission: Develop Fascinating Underwater AR Experiences
  - All prior Augmented Reality has been staged in the medium air
  - Bring computer games and entertainment applications from desktop to mobile underwater using augmented reality technology
  - Be the first to do that!

AREEF System Overview from Project Plan



Hardware Development – Waterproof Case

- Year 1: Metal Case, 26 bolts
  - Very robust custom design
  - Touch improvements
  - Single player game
- Year 2: Metal & Plastic
  - Easy lock and unlock
  - Light-weight (60% reduction)
  - Better WiFi reception
- Year 3: Production for user-tests
  - Refined locking
  - Adaptation for changed hardware
  - Multiple units for user-tests
  - Wireless charging prototype

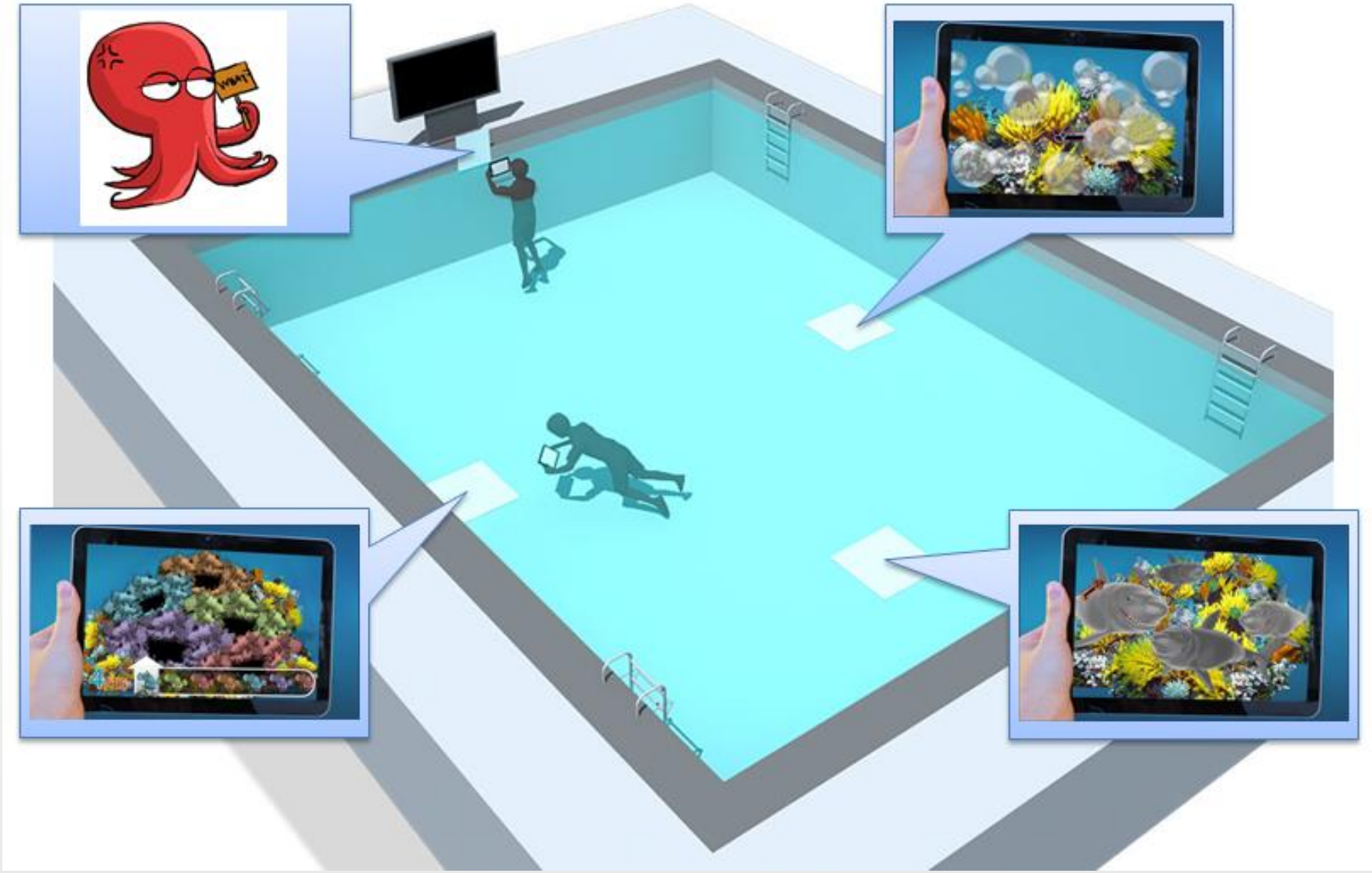


Year 1 case

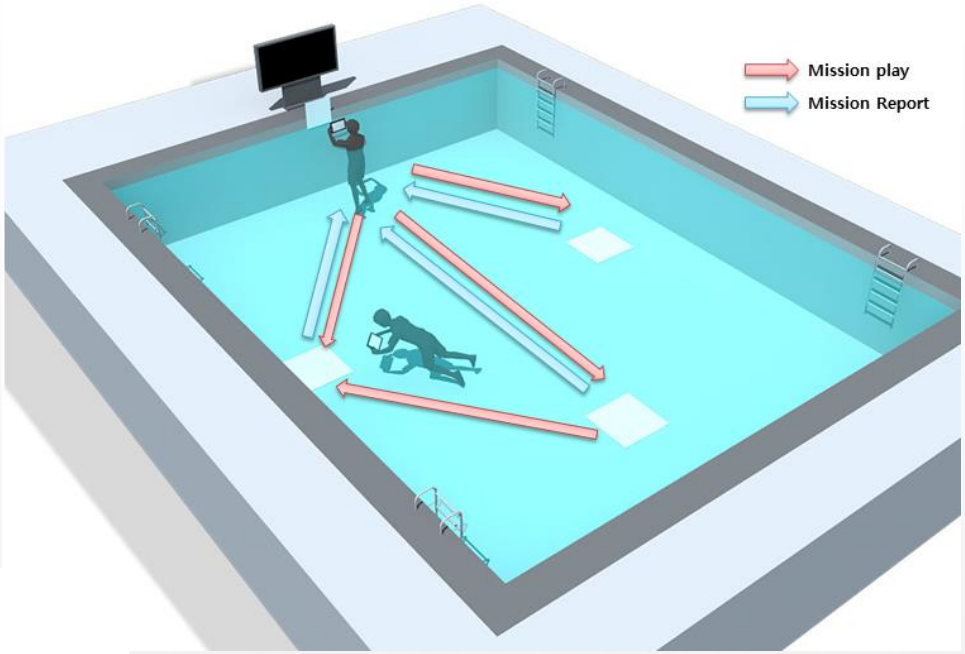
Year 2 case

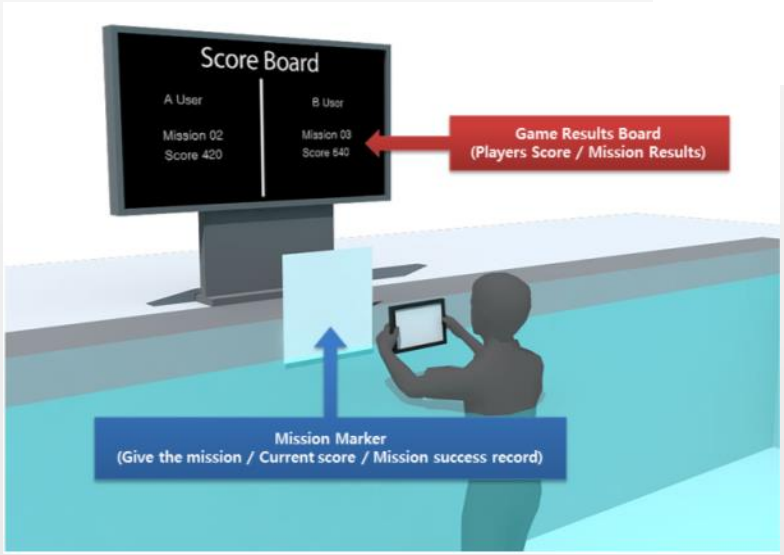
Year 3 case

Experience Design



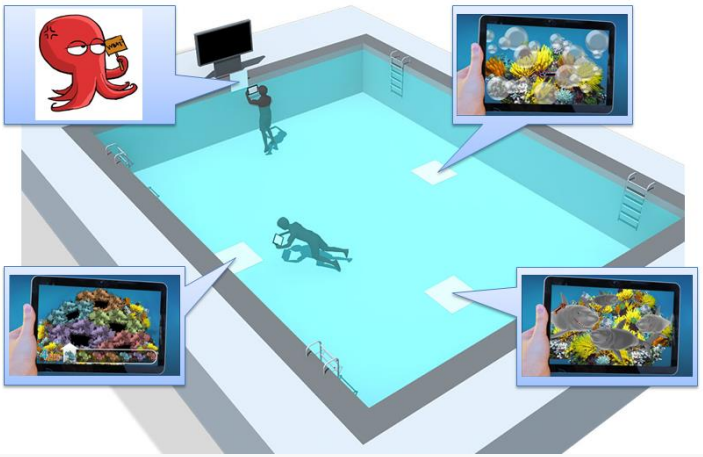
- Interaction
  - Move around
  - Explore the virtual underwater scenery
  - Score at the base station





Base station

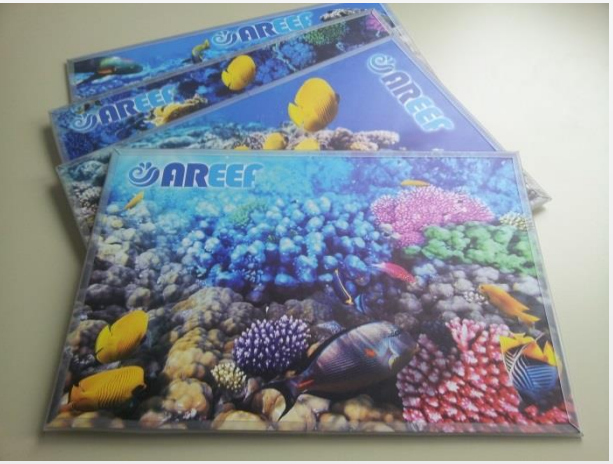
Final AREEF System Overview



Envisioned setup

Actual setup

Base station, Nexus 10



Alu-Dibond markers
105 x 70 cm

Example scenery on
base station and island

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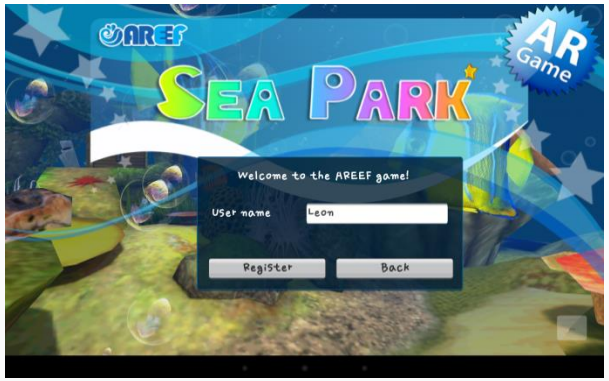
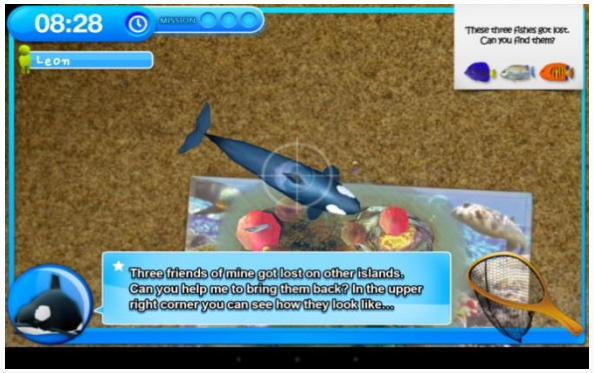
Application Walk-Through



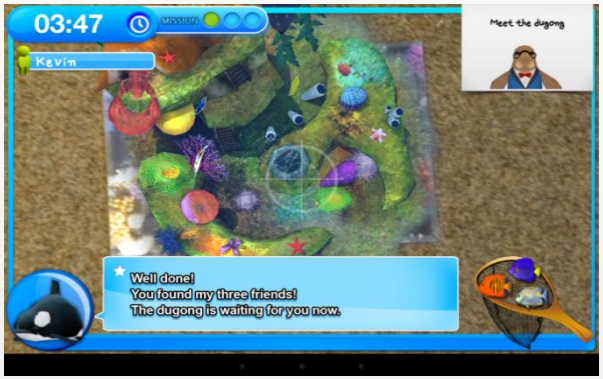
Register player name

Find the Orca



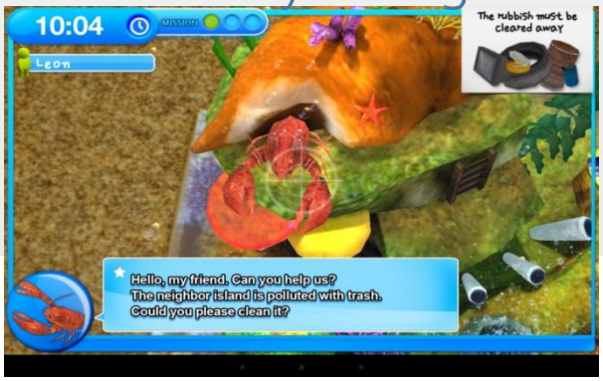
Orca has task: find 3 fish

Catch fish by aiming



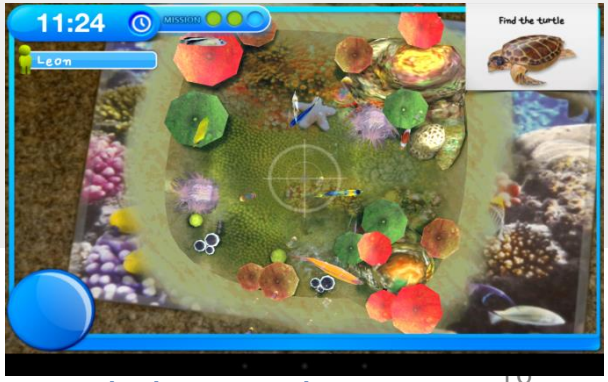
All fish caught

Find the lobster



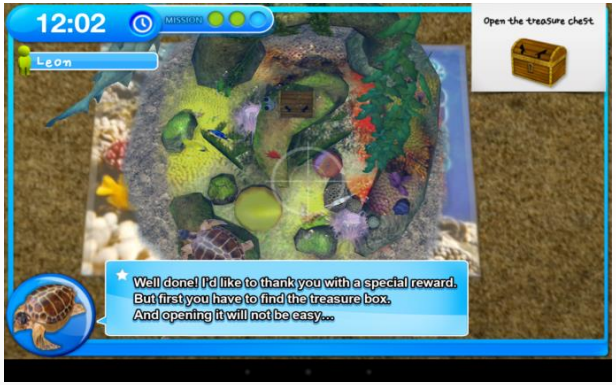
Lobster explains task

Clean trash by sweeping



Find the turtle

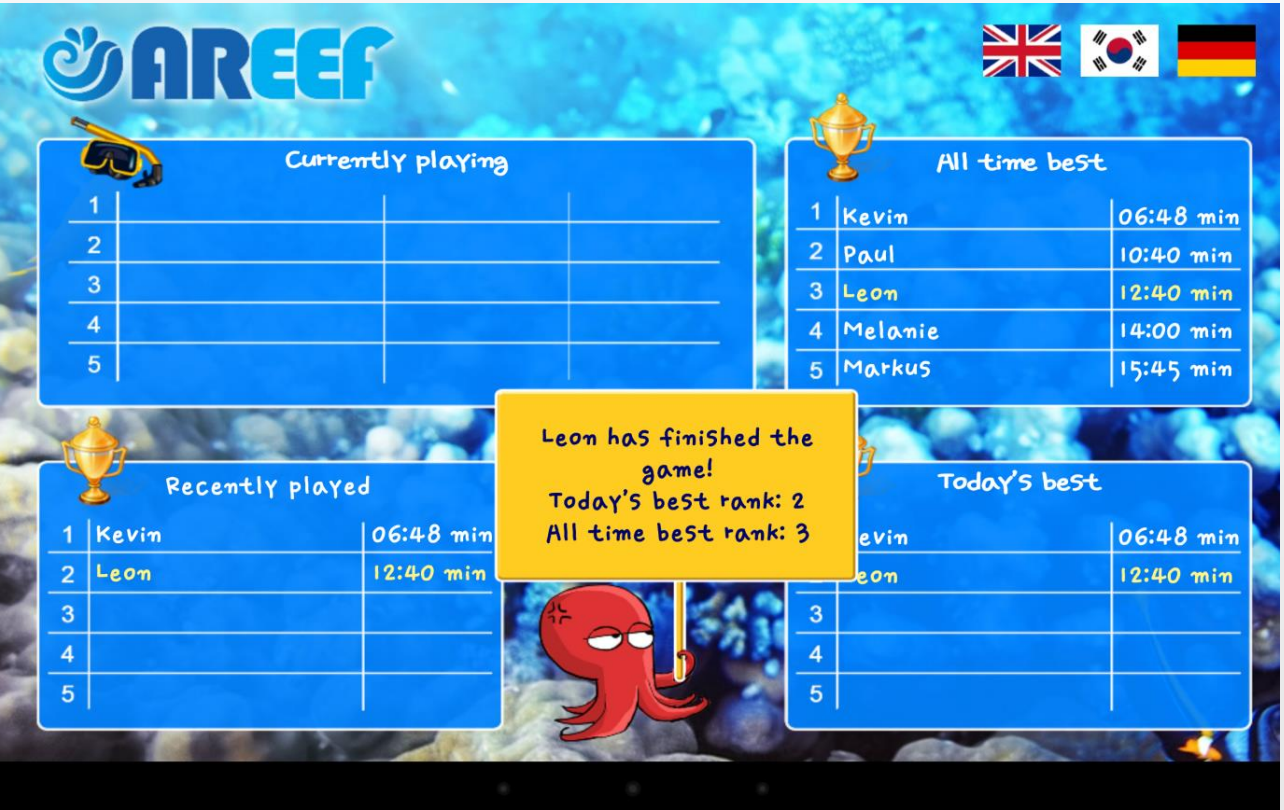
Application Walk-Through



Turtle hints to treasure

Aiming for treasure

Game ends



Scoreboard, Leon finished in 12:40 min

User Evaluation

- (Why) Determine whether the implementation
  - Allows players to successfully and safely finish the game, with a sense of satisfaction
  - Discover problems and challenges that need to be addressed in future versions
- (What) User-centered evaluation: testing and collecting feedback for the game
  - Under real conditions (swimming pool)
  - With real players (children, 7-12 years old)

User Evaluation

- Collect qualitative and quantitative evidence
  - Design evaluation procedure (who does what, when), for team of up to 5 researchers
  - Extend game implementation with logging functionality (data collection)
- Procedure
  - One hour timeslot for 3 children
    - Welcome and introduction
    - Playing game
    - Interview
    - Present
- Chronology
  - Pilot evaluation, Darmstadt/Germany, 3 children
  - Campaign to organize players
  - Main evaluation in Siegburg/Germany, 36 children

User Evaluation Part 1: Pilot Study

- At Bessunger Bad, Darmstadt
  - 30 September 2013
  - Three Children, age 10
  - Pool area ~ 10 x 2 x 1.3m
- Test feasibility
  - Application
  - Evaluation procedure
  - Establish routine
- Led to minor refinements
  - Made cleaning task easier
  - Marker distance

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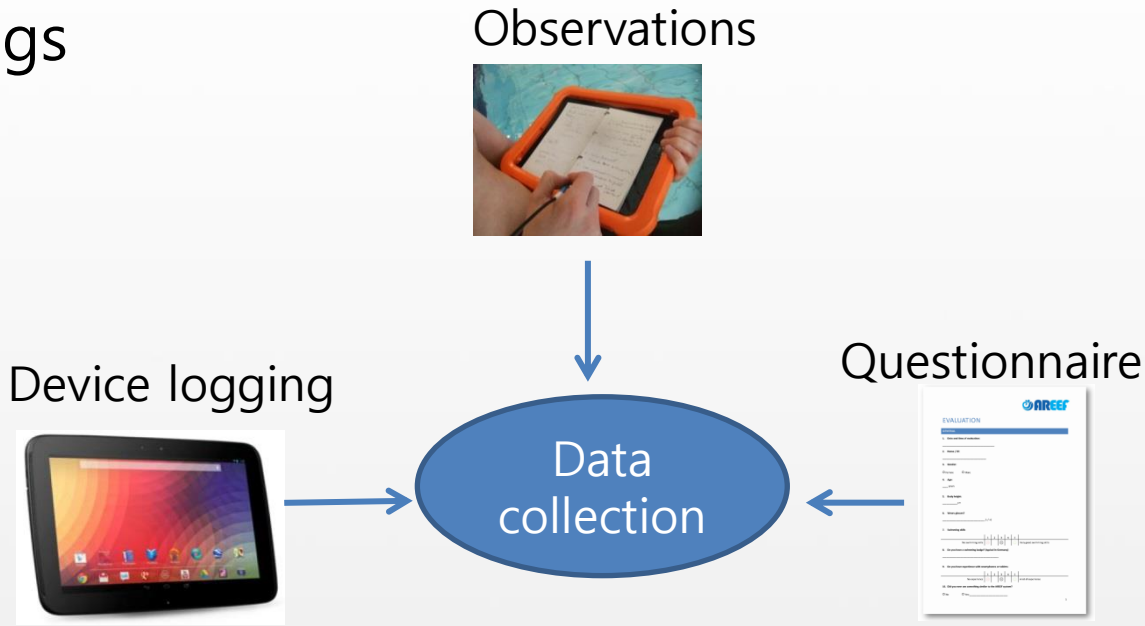
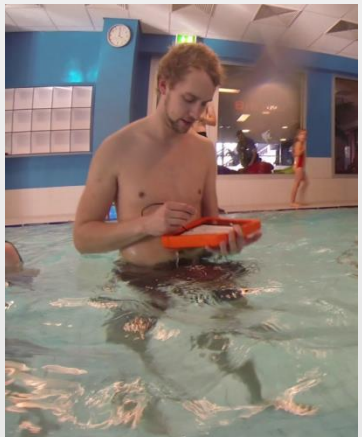
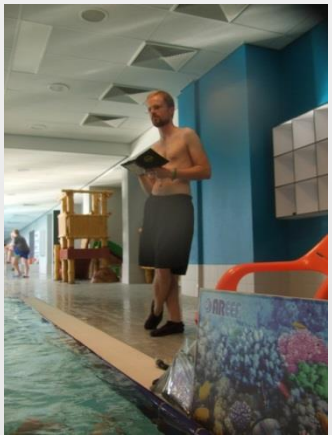
User Evaluation Part 2: Main Study

- At Oktopus, Siegburg
  - 22-31 October 2013
  - 36 children, aged 7-12
  - Pool area ~ 8 x 8 x 1.1m
- Collect evidence on
  - If children like it
  - How they play it
  - Market fitness

- (How) Mixed Approach
  - Observation logs
  - Questionnaire
  - System logs
  - Video




Results

- Novelty Factor
  - Children had not seen anything like this before
- Tracking worked
  - No real issues with standard Vuforia
- Keep the challenges simple
  - Difficulties of tasks were generally well matched
  - The more complicated ones caused more frustration
- Be very obvious
  - If it is not clear, it will cause confusion
    - We only used touch-input for text-entry
    - Game used aiming, still some tried touching

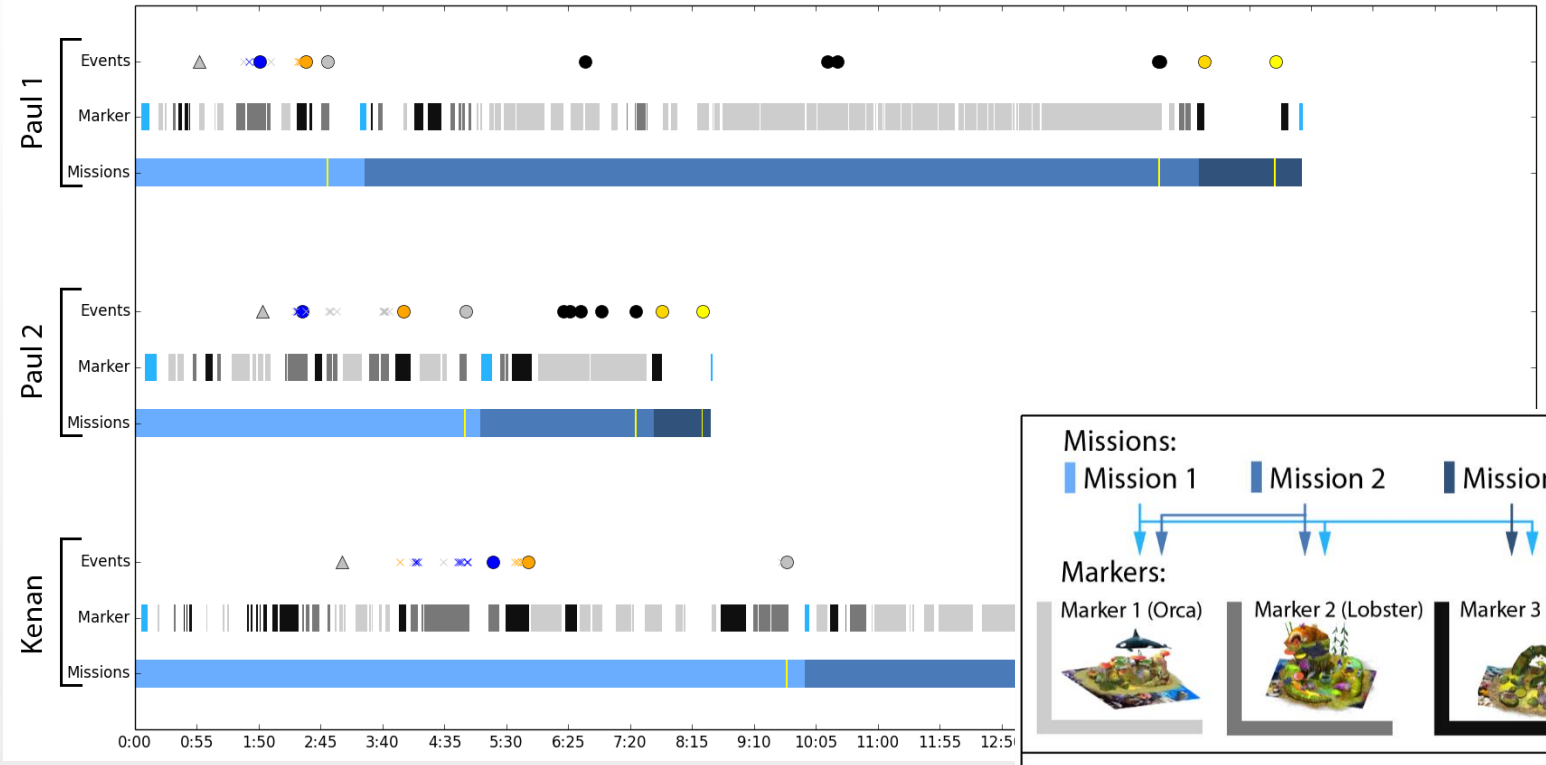
- Marker Distance
  - Marker size and water depth are related
    - 60-70 cm diameter (short side) was good
  - Smaller kids play in shallower water
    - Provide for that (maybe smaller markers)
- Water Current
  - Fountains and vents provide a flow of water
  - Might not be able to turn off
    - Adjacent pool areas might need it
  - Affects small children and markers

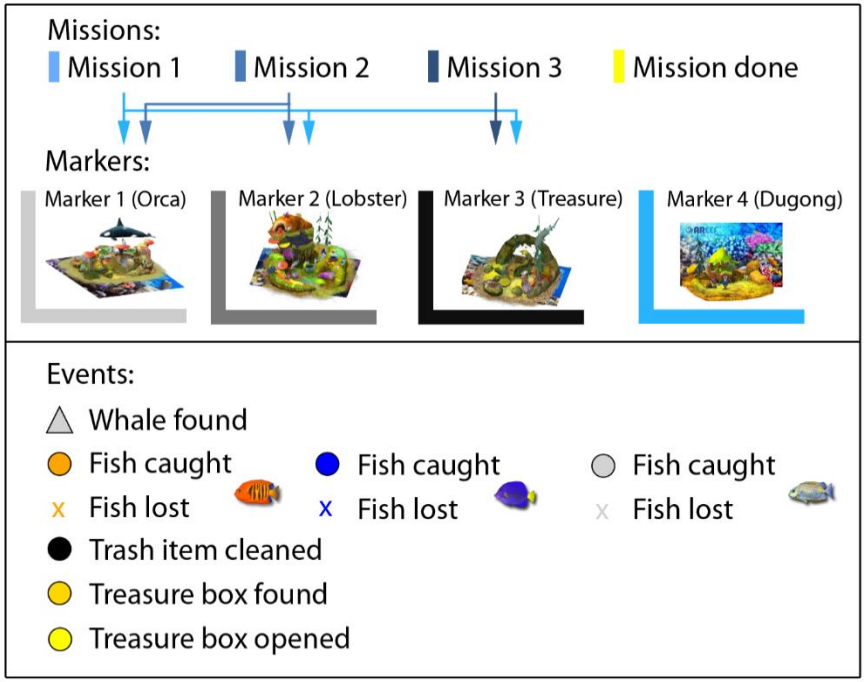
Results

- Game event logging on device
  - All to time-stamped JSON-file
    - Start & end of each mission
    - Completion & cancellation of sub-tasks
    - Tracking of island markers
- Log parsing analysis
  - Automatic creation of diagrams
  - Useful for eye-balling the data
  - Cross-checking with questionaire responses

Results

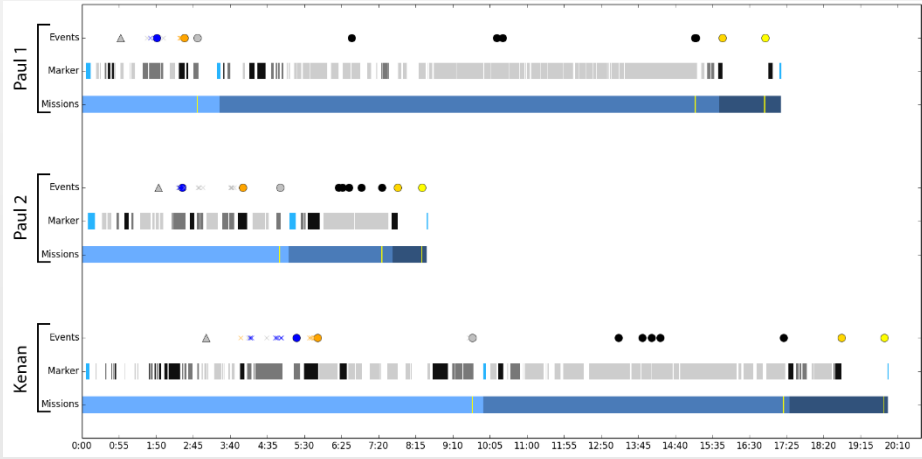
- Example log-diagram for one session





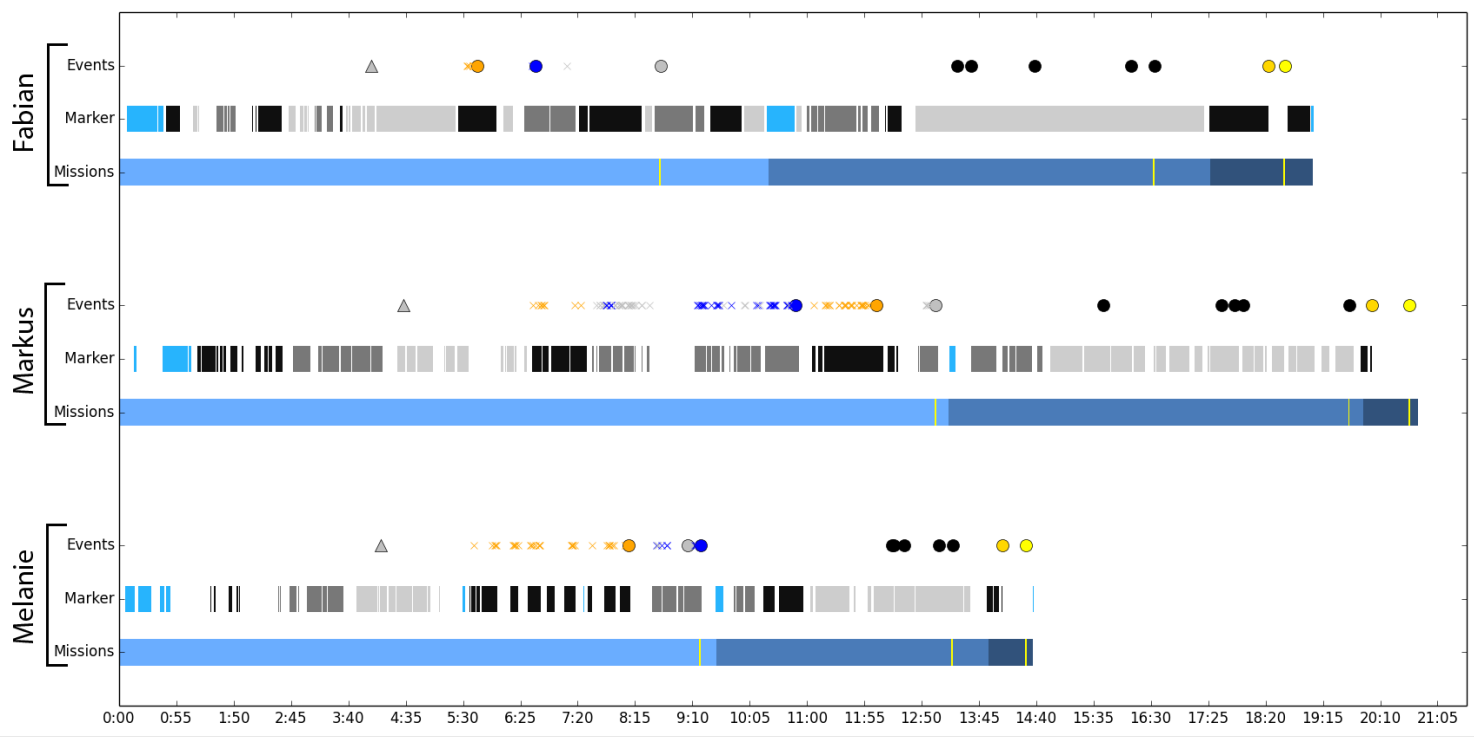
Results

- Speed
  - Paul 1 faster on first mission
  - Paul 2 fastest on second mission (cleaning)
    - Did it in 2 mins
    - Only lost tracking / caught air once
- Clarity
  - Second mission was unclear to Paul 1
    - Pushing trash over the edge of the island
    - Tried again and again
- Breath
  - Cnt. tracking of 2 mins
  - Head above water



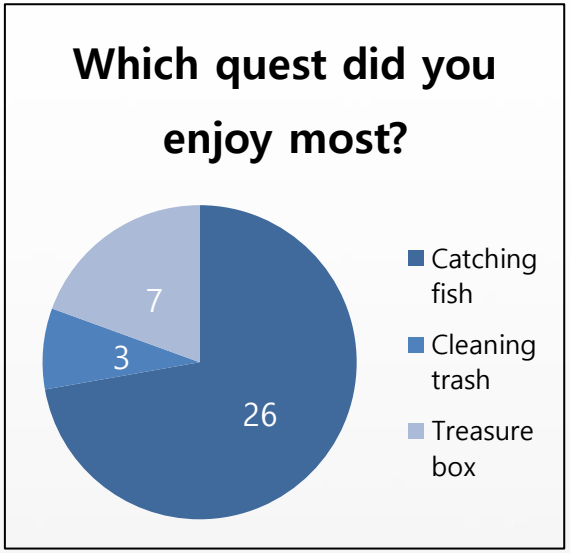
Results

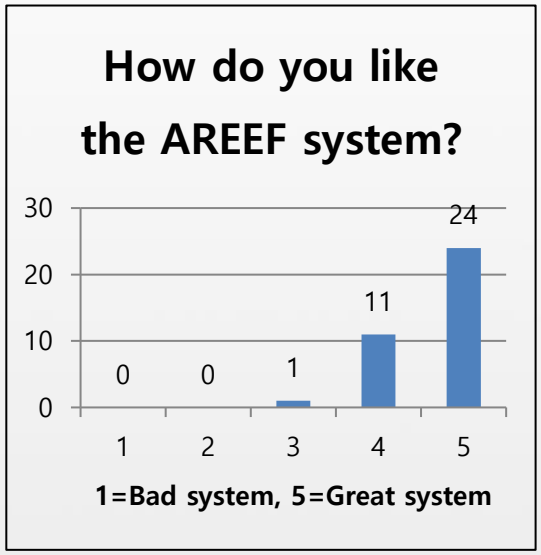
- Graphics well done
  - Fabian just stayed longer (stated in interview)
- Persistence vs. Frustration
  - Markus only caught first fish on 73rd (!) attempt

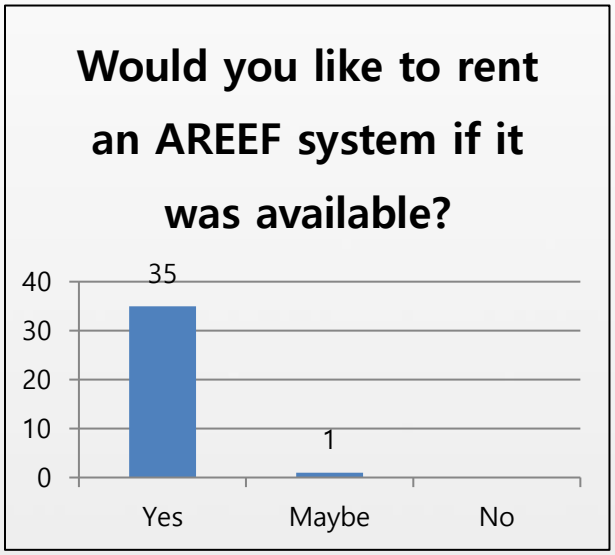


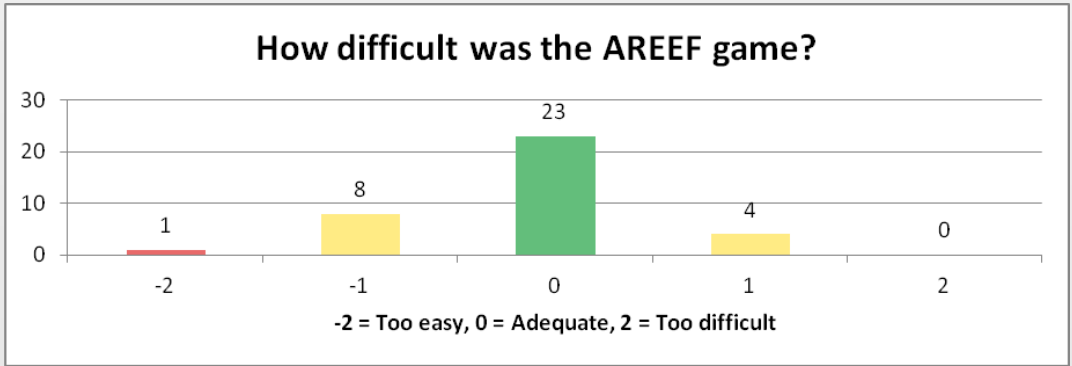
Discussion

- General
  - Overwhelmingly positive feedback
  - Catching fish is favored by most children



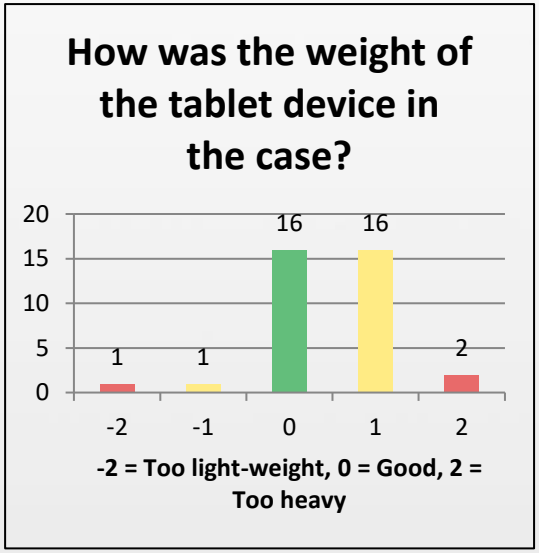


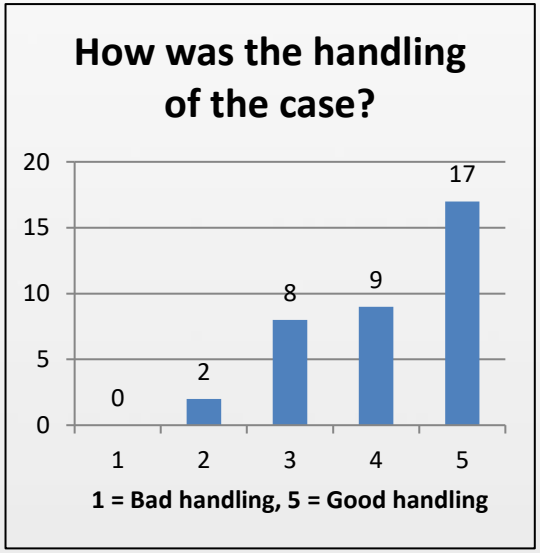




Discussion

- Waterproof case
  - Considered slightly too heavy
  - Improvement: make it floating on water surface
  - Generally worked well





Discussion

- Positive reception by kids, swimming pool director and TV report
- Lessons learned
  - Swimming pool installation needs to consider water depth and water fountains
- Future wishes
  - More virtual scenery (11)
  - Longer play time (5) (30-90 minutes)
  - Other themes (6)
  - Smaller and lighter case (4)

- Anecdote from observing father
  - Son was usually afraid of being under water
  - Not so with the game, dove happily and well
  - The father was very pleased about this
  - Did the game take his anxiety?
  - Could this be designed for, like in VR?

Upshot

- Underwater AR apps can be done
  - Standard tracking is good enough
  - Scenic content was appreciated
  - This is where most of the work is
- Waterproof
  - Waterproof devices are not enough
    - Even if iPhone 7 ;-)
    - Tested also Sony Xperia Tablet Z
      - If touch is required, normal touchscreens need special shielding to not have random presses
    - Casing protects device and environment
    - Should allow wireless charging

Upshot

- Children and pool operators like it
  - Missions should be simple and clear
  - Physical movement not a problem

- Could this be model for spicing up old pools?

www.areef.info

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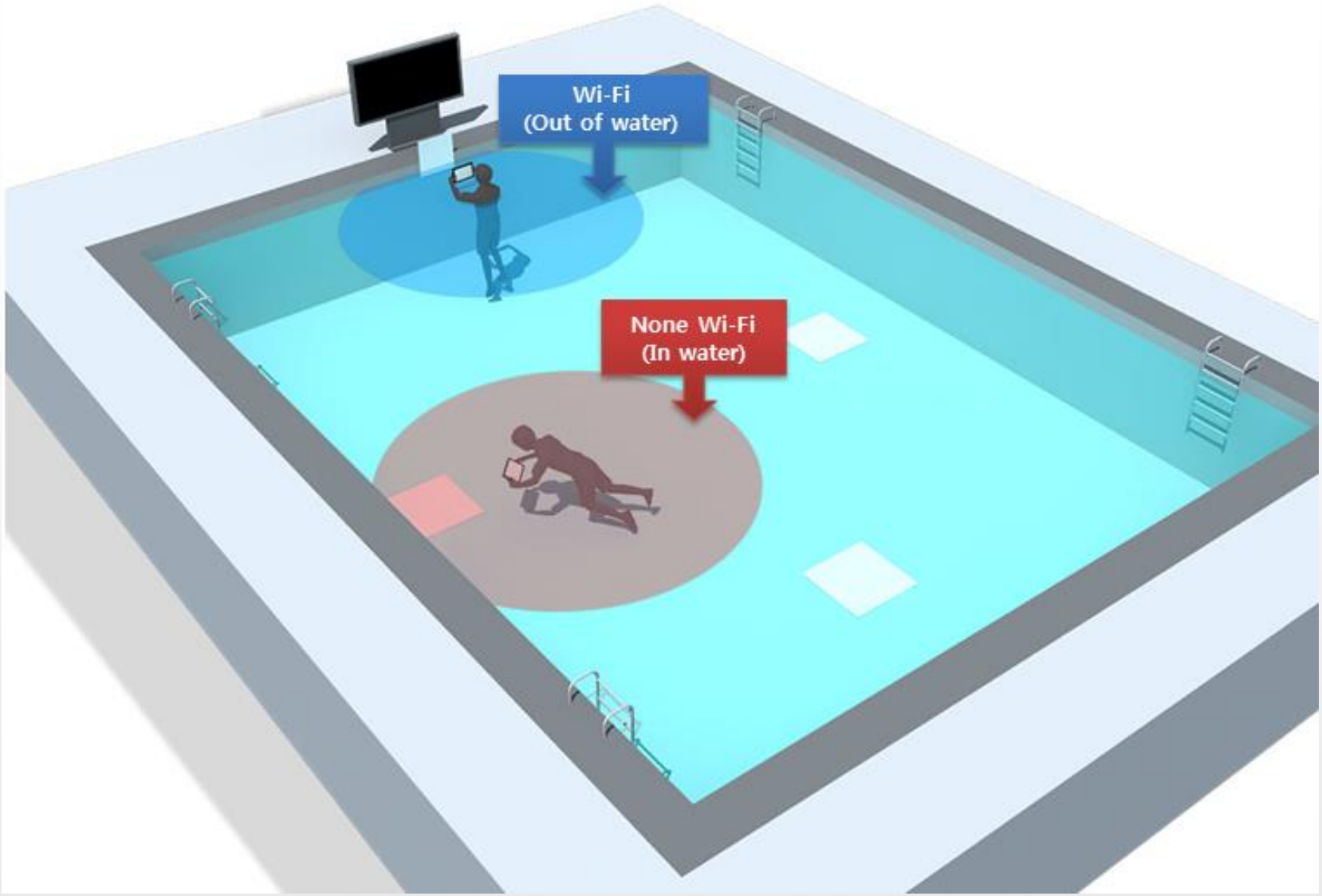
Communication Problem



- Technologies reviewed
  - **WiFi**, Sonar, Infrared, Bluetooth, **NFC**
- Challenges
  - External commercial solutions available but low bandwidth and expensive
  - Built-in WiFi frequently disconnects
- Solutions
  - Appropriate game mechanics
  - Reconnect automatically
  - Sync on reconnect