[20220628] INFOMMOB - Mobile interaction - 4 - UITHOF

Cursus: Mobile interaction (INFOMMOB)

Exam questions including some comments on the solutions
(not proofread, thus no guarantee for correctness)

1 General aspects of mobile interaction

In the chapter "*Mobile Computing*" of *The Encyclopedia of Human-Computer Interaction*, J. Kjeldskov describes the history of mobile computing by discussing seven waves or trends. In the following, we want to look at them with a concrete example: **mobile handheld gaming**, which can be done on your smartphone or via a dedicated device (such as the Nintendo Game Boy).

1 pt. **a.** [max. 1 pt] One of the waves described by Kjeldskov is **divergence**. Shortly describe in your own words what this means.

See article.

1 pt. **b.** [max. 1 pt] Give one convincing example in relation to mobile handheld gaming that would speak for divergence.

Some examples for good answers (in key phrases):

Interface, i.e., hard buttons (more precise, haptic feedback, don't use screen estate).

Performance (although this is a bit debatable given the hardware in today's phones).

Dedicated or optimized hardware for gaming (e.g., cartridge offering extensibility).

1 pt. **c.** [max. 1 pt] Another wave is **convergence**. Shortly describe in your own words what this means.

See article.

1 pt. **d.** [max. 1 pt] Give one convincing example in relation to mobile handheld gaming that would speak for convergence.

Some examples for good answers (in key phrases):

Always with you / no second device.

Additional technology / hardware offering new opportunities.

1 pt. **e.** [max. 1 pt] Kjeldskov also talks about the wave of **connectivity**. Shortly explain in your own words what this means.

See article.

1 pt. **f.** [max. 1 pt] Give one convincing example how mobile handheld gaming can benefit from this wave and the resulting opportunities.

Some examples for good answers (in key phrases):

Downloading games on the go.

Connect with others / multiplayer gaming.

Allows you to put work-intensive parts on server (e.g., high-end rendering).

Enables location-based gaming (e.g., by using GPS signals).

Later in the article, Kjeldskov also discusses **the role of context** for mobile interaction. Context can make mobile interaction harder and more challenging, but also provides new opportunities for it.

1 pt. **g.** [max. 1 pt] Give one convincing example related to mobile handheld gaming where context makes the interaction harder or more difficult and thus must be considered in the interaction design.

One example for a good answer:

The environment and state of the user can vary and change even during the playing the same game. E.g., sitting comfortably on a bench while waiting for a bus vs. sitting in a bus driving over a bumpy road, or sitting in a bus vs. standing in more crowded bus (with one hand needed to hold yourself), etc.

Another one:

Crowded space / public => some interactions not possible or socially awkward.

1 pt. **h.** [max. 1 pt] Give one convincing example related to mobile handheld gaming where context provides new opportunities, that is, where context is used as part of the game design in a way that is impossible without it or that significantly improves the game.

Some examples for good answers (in key phrases):

Location-based games obviously rely on context (i.e., where you are).
Connecting to other people via small-area networks (e.g., Bluetooth) opens opportunities for multiplayer gaming. (Here: context = other people around you.)
AR games obviously take the environment into account.

Today, many people do not use dedicated mobile handheld devices anymore, but instead play games on their smartphones. This also opens new opportunities, because smartphones contain various technologies and sensors that were not part of traditional dedicated mobile gaming devices. Although integrated in smartphones for a non-gaming-related purpose, they can be used in the context of gaming as well, thus offering new possibilities for mobile game design.

2 pt. **i.** [max. 2 pts] Give one example for such a technology or sensor and a convincing usage in mobile gaming. That is, name this technology or sensor and its original main purpose, and shortly explain with a concrete example how it can be used nowadays in the context of mobile handheld gaming.

Basically everything from above (but others exist, too):
GPS => used to get location (e.g., for map apps) => can be used for location-based games
Bluetooth => used to connect to other devices (e.g., for data transfer) => can be used for multiplayer games
Camera => used to take pictures => can be used to make AR games
Other examples:
Accelerometer => used to adjust screen orientation (portrait/landscape) => can be used for tilt-based gaming

Magnetometer => used to get location for navigation and map apps => can be used for 3D interaction where it is relevant to know in which direction a device is pointing.

2 Sensors for interaction

Today's smartphones contain many technologies and sensors that relate to the human senses, that is, they can be used (to some degree) to simulate how we as humans experience our environment (which is why they can be used for input in interaction design) and also provide related sensory information to us (which is why they can be used for output in interaction design).

1 pt. **a.** [max. 1 pt] Name a technology in mobile phones that relates to the human sense of **sight** and is used for **input** in mobile interaction design.
Camera

1 pt. **b.** [max. 1 pt] Name a technology in mobile phones that relates to the human sense of **sight** and is used for **output** in mobile interaction design.
Screen/display

1 pt. **c.** [max. 1 pt] Name a technology in mobile phones that relates to the human sense of **hearing** and is used for **input** in mobile interaction design.
Microphone

1 pt. **d.** [max. 1 pt] Name a technology in mobile phones that relates to the human sense of **hearing** and is used for **output** in mobile interaction design.
Speakers

1 pt. **e.** [max. 1 pt] Name a technology in mobile phones that relates to the human sense of **touch** and is used for **input** in mobile interaction design.
Touch screen

1 pt. **f.** [max. 1 pt] Name a technology in mobile phones that relates to the human sense of **touch** and is used for **output** in mobile interaction design.
Vibration units (tactors)

(Note: Any phrasing related to "vibration" got full credits.)

Other examples exist that gave full credits, too. This question was intended to be about the used hardware (see slides in lecture 2), but some people also brought software examples (or apps and/or concrete usages). If these can be considered a "technology" (even in the broadest sense), these answers are correct, too. A good example is "speech recognition" (or "Siri") for c.

The location and orientation of a smartphone can be used for mobile interaction design as well. Various sensors are used for that.
Many examples exist here, but the simplest ones (listed below) are probably related to maps and navigation.

1 pt. **g.** [max. 1 pt] What data do we get via **GPS** that can be used for mobile interaction? Shortly explain and give a convincing example of its usage in mobile interaction.
Data: our absolute location on earth.
Example usage: Automatically center a map around your location.

1 pt. **h.** [max. 1 pt] What data do we get from a **magentometer/compass** that can be used for mobile interaction? Shortly explain and give a convincing example of its usage in mobile interaction.
Data: Direction of the North pole.
Example usage: Automatically rotate a map so it matches the direction in which the device is pointing at.
(Note: An informal answer for the first, such as "Where the device is pointing at" or "heading of the device" also gave full credits)

1 pt. **i.** [max. 1 pt] What data do we get from a **gyroscope and accelerometer** that can be used for mobile interaction? Shortly explain and give a convincing example of its usage in mobile interaction.

Data: Orientation of the device with respect to itself.

Example usage: Show content, e.g., a map, on the screen in portrait or landscape mode depending on how the device is held.

One example that we saw in the lecture that uses the orientation of a smartphone for interaction is called **SWiM** (Shape Writing in Motion).

2 pt. **j.** [max. 2 pts] The SWiM approach solves two problems. What are these?

- Accidental touch (when typing with one hand)
- Fat finger problem (difficult to type precisely)

These are the two mentioned in the video. Stating "reachability" or something the like instead of "accidental touch" is correct, too, because the accidental touch does in fact happen because parts of the screen are hard to reach. Likewise, "occlusion" or "accuracy" are terms that gave full credits as well when used instead of "fat finger problem."

1 pt. **k.** [max. 1 pt] Shortly describe how SWiM solves these problems.

See video shown in lecture

You also read a paper by Corsten et al. where they introduced a technique called **ForceRay**, which addresses one of the problems that SWiM resolves, too.

1 pt. **l.** [max. 1 pt] What kind of sensor does ForceRay use for that?

Force/pressure-sensitive touch screen

1 pt. **m.** [max. 1 pt] Shortly explain how ForceRay solves this problem.

See paper.

You also read a paper by Voelker et al. where they introduce a technique called **HeadReach**, which addresses this problem as well.

1 pt. **n.** [max. 1 pt] What kind of sensor does HeadReach use for that?

Camera(s)

(Technically also the touch screen, but 'camera' was sufficient for full credits.)

1 pt. **o.** [max. 1 pt] Shortly explain how HeadReach solves this problem.

See paper.

3 Mobile evaluation

For user studies, we often distinguish between internal validity and external validity.

1 pt. **a.** [max. 1 pt] Shortly describe what is meant by **internal validity**.

1 pt. **b.** [max. 1 pt] Shortly describe what is meant by **external validity**.

From the slides:

Internal validity: to what degree can we assume that the effect does indeed result from the change of the independent variables?

External validity: to what degree can we generalize our results to general conditions other than the ones under which we tested?

In the paper *Understanding user strategies when touching arbitrary shaped objects*, Q. Roy et al. (2021) present "a quantitative controlled experiment to empirically verify which model is the most representative of touch behavior on arbitrary shapes" (quote from paper).

If you need to refresh your memory, here some relevant quotes from the paper: They "used a computational approach to automatically extract 15 arbitrary shapes out of a set of icons" and picked "two sizes of shapes relative to the finger size, more precisely 25% larger than the participants' fingertips or 25% smaller." Then they gathered touch data from 12 participants with different finger sizes and compared "this data with our models' predictions to identify the one best able to predict pointing behavior."

3 pt. **c.** [max. 3 pts] Shortly discuss the experimental design of their controlled experiment (i.e., not the pre-study) with respect to internal and external validity. That is, explain if it has a high or low internal validity and external validity and why.

Internal validity
Should be relatively high, because very controlled experiment and setup.

People are known and carefully selected.
Finger size is measured and thus eliminated as confounding variable if experiment is repeated (assuming subjects of repeated study have same finger sizes).
Icons chosen with a structured approach (thus also eliminating subjective selection bias) although containing some randomness and thus harder to reproduce by others.

External validity
Lower, due to low number of subjects (12).
Controlled environment does not necessarily represent the real world very well (also doesn't accommodate for different context, e.g., walking vs. sitting).
Yet, because finger size is eliminated as confounding variable, results should be generalizable to random people (although 12 participants might not cover huge ranges of sizes).

Note: Some of these things are debatable and other aspects may exist. Thus, not all the aspects listed above needed to be addressed or stated similarly to get full credits. The important criterium was that both are addressed well and arguments were correct and reasonable

.

3 pt. **d.** [max. 3 pts] Internal and external validity often behave opposed to each other (i.e., a high internal validity often comes at the price of a low external validity and vice versa). What are the major changes that you would make in the experiment design above to increase the lower of the two (but still keeping the other one high)?

To keep the internal validity high (in general), we must make sure that the test environment is as controlled as possible or make up for it by having larger test and sample sizes (because with larger numbers, differences due to confounding variables are more likely to "even out").

Actions to achieve the first are: good instructions and tutorials, integrate measures into the test, targeted recruitment of participants, etc.

Actions to achieve the second are: large user numbers, etc.

Other aspects may apply (but not all were needed to address to get full credits). E.g., context of the user, such as sitting, walking, etc. (randomness here increases external validity / possibilities to minimize impact on internal validity include measuring this context and analyzing the results with respect to it).

4 Touch screens

The so-called **Gorilla arm** is an ergonomic problem that can happen when touch screens are used on desktop PCs and laptops.

1 pt. **a.** [max. 1 pt] Shortly explain what it is and why it happens in this context.

From the slides:

*"**Gorilla arm**" was a side-effect of vertically-oriented touch-screen or light-pen use. In periods of prolonged use, users' arms began to feel fatigue and/or discomfort.*

1 pt. **b.** [max. 1pt] The Gorilla arm is generally not a problem when touch screens are used on mobile phones. Shortly explain why.

Screens are smaller, handheld and not mounted vertically.

1 pt. **c.** [max. 1 pt] Even if the Gorilla arm is not an issue for touch interaction on mobile phones, there are other ergonomic problems with touch interaction on mobiles. Give one example.

Reachability during one-handed usage.
(others exist that were not discussed in the lecture or only shortly mentioned (e.g., neck issues due to bad body posture) but still gave full credits if correct)

1 pt. **d.** [max. 1 pt] While the Gorilla arm is generally not a problem for touch interaction on mobile phones, there are mobile interaction approaches where it can be an issue. Give an example for one and shortly explain why it can happen there.

Basically, any kind of interaction where the phone must be held in a way resulting in an arm location like the non-ergonomic one caused by a vertically mounted monitor.
Examples include some kinetic gestures (e.g., around body interaction) or some AR applications or AR use cases.

Optical touch screens use cameras and sensors to "see" where and how they are touched.

1 pt. **e.** [max. 1 pt] Give an example of a use case or functionality that could be achieved because of that but is not possible with the capacitive touch screens that are currently used in most mobile devices.

Examples include but are not limited to:

Creating a hovering state.

Identifying users and/or objects.

5 Human aspects & UI design

Some mobile interaction designs use the so-called **Gestalt laws**.

1 pt. **a.** [max. 1 pt] Shortly explain that the Gestalt laws are. (A short, high-level description is sufficient.)

Various ways exist to explain this. Here just one example:

Shapes that are only partly shown are still perceived as a whole (e.g., our brain may still interpret a shape as a full circle even if only one or a few arcs of the circle are shown).

2 pt. **b.** [max. 2 pts] Give one example where Gestalt laws are used in a beneficial way in mobile interaction design and shortly explain how. (You can give a concrete example or a high-level description of a concrete issue that can be addressed with them. A short explanation is sufficient.)

A possible example for a correct solution:
To illustrate the location of something off-screen. E.g., showing the arc of a circle on the screen borders, assuming people associate the center of the complete circle with the related off-screen location.

Overview+Detail and **Focus+Context** are two well-known visualization approaches. Yet, we hardly find them in mobile interaction design anymore (or at least to a much lesser degree than we used to).

1 pt. **c.** [max. 1 pt] What is the reason for this, that is, why don't we see them in mobile interaction design that much anymore?

Multi-touch and high-resolution displays.

Surprisingly, many people forgot the latter (both items were listed on the related slide though).

1 pt. **d.** [max. 1 pt] Give a convincing example where either of these visualization concepts is or could still be used beneficially in today's mobile interaction design.

Several examples exist here. Basically, everything where switching between different zoom levels via multi-touch would be too cumbersome or inefficient and screen is not large enough (despite high resolution) to show some relevant content at the necessary level of detail.

Many people brought examples that motivated switching between two views (e.g., overview and detail) but the essential part here is that both are displayed simultaneously.

6 Gestures and touch interaction

In the lecture, we saw a video where they introduced so-called **MicroRolls**, which are a special kind of small touch gestures done with your thumb. A use case that they demonstrated were "Copy&Paste" actions. You also saw a video where the authors introduced the so-called **Force Picker**, where pressure sensitive touch input is used for interaction. A use case that they demonstrated was the selection of an input value.

1 pt. **a.** [max. 1 pt] Give one potential advantage that the Force Picker approach could have compared to the MicroRolls approach.

…

1 pt. **b.** [max. 1 pt] Give one potential advantage that the MicroRolls approach could have compared to the Force Picker approach.

…

In addition to **touch gestures**, we can also use **kinetic gestures** when interacting with our mobile phones. Let's look at them in relation to **navigation apps** and use cases with geospatial data.

1 pt. **c.** [max. 1 pt] Give one good example for a touch gesture in this context. It should be convincing, that is, there should be a clear benefit or reason why one would use a touch gesture in this example and not a kinetic gesture.

Multi-touch / pinch-to-zoom, because … (see slides)

1 pt. **d.** [max. 1 pt] Give one good example for the usage of a kinetic gesture in this context. Explain the advantage of using this gesture in this context compared to a touch gesture.

Dynamic keyhole, because … (see slides)

Exploring environment around you (AR apps), or StreetView / Google's compass mode

When touch would be too distracting (e.g., for simple interactions in cars)

Assume you have perfect hand tracking implemented on your mobile phone, that is, your hand and fingers can accurately be tracked at various levels of granularity in the 3D space covered by the range of the phone's cameras.

1 pt. **e.** [max. 1 pt] There are several obvious problems when such a method is used for mobile interaction. Name one of them.

See slides for examples / reasons. E.g.:

Examples include but are not limited to:

Ergonomics.

No haptic feedback.

Hard to distinguish between hovering and pressing.

Limited range covered by the camera (also, borders of that range not visible / clear to user).

1 pt. **f.** [max. 1 pt] Yet, there are also good use cases and examples where such hand tracking would be useful as input. Provide one of them.

See slides for examples / reasons. E.g.:

Hands occupied otherwise (driving, eating) but allowing for quick mid-air gestures.

Hands dirty.

Experience (e.g., can be nice in gaming or for leisure apps).

No occlusion as with direct touch (fat finger problem).

1 pt. **g.** [max. 1 pt] In the lecture, I also shortly mentioned Google Soli, which is a "miniature radar-based interaction enabling motion understanding at various scales" (quote from slides). Give one advantage that such an approach has compared to the hand tracking approach described above.

Possible correct answers include but are not limited to:

"Radar-based" thus independent of a camera's FOV (works everywhere within a certain range).

Allows for micro gestures not recognizable by visual approaches.

7 Mobile gaming

A common interaction design for mobile games that is inspired by controllers from video game consoles are **twin stick shooter** buttons. One design option when implementing them on a touch screen is to realize them as static controls or as dynamic controls.

2 pt. **a.** [max. 2 pts] Explain what that means, that is, what is a static control design, and what is a dynamic control design?

See slides or blog post

Implementations of such twin sticks on touch screens leads to several problems that do not exist for hard buttons on controllers. One of them is the fat finger problem. Another one is the drift problem.

4 pt. **b.** [max. 4 pts] Discuss the **fat finger** problem in this context. First, explain what is meant by that, that is, what kind of problem(s) occur because of this in the context of twin sticks. Then, discuss it with respect to static and dynamic controls, that is, shortly describe if the problem appears in either of these implementations and how (or why not, if it doesn't).

Fat finger:

- *Bigger contact surfaces can lead to inaccuracies / unintended contact points (Was the input really registered at the position that I intended to touch?)*
- *Big size of finger leads to occlusion of content (Where is the location that I want to touch?)*

Problems in this context for static:

- *Inaccuracy when hitting them (due to occlusion and large finger size / contact area)*
- *Harder to accurately change the direction (e.g., where is up when I don't see it?)*

Problems in this context for dynamic:

- *As above for changing directions, but not a problem for first hit since button always appears centered around the contact point*

3 pt. **c.** [max. 3 pts] Discuss the **drift problem** in this context. First, explain what is meant by that, that is, what it is and why it happens. Then, discuss it with respect to static and dynamic controls, that is, shortly describe if the problem appears in either of these implementations and how (or why not, if it doesn't).

Drift problem = due to the lack of haptic feedback (like we have it with hard buttons on controller for consoles), users may not notice when they move too far away from the button or in an unintended direction while continuously holding it.

Especially problematic for static designs, because of the fixed location of the center.

Less of a problem for dynamic ones, because they can be recentered by releasing the finger and touching again. It is still a problem if you want to change direction without releasing your finger though.

In the paper *Investigating on-screen gamepad designs for smartphone-controlled video games*, M. Baldauf et al. (2015) used a similar implementation of on-screen controller elements to control a video game on a distant screen.

1 pt. **d.** [max. 1 pt] Name one problem that does <u>not</u> exist for on-screen controllers in this context compared to mobile games played on your phone.

Using up screen estate / covering content with the on-screen buttons

8 **3D and around body interaction**

In their design paper Way Out: A Multi-Layer Panorama Mobile Game Using Around-Body Interactions, S.-Y. Teng et al. (2017) propose a game where you can "navigate an omnidirectional panorama by moving the device around the body, as if the display is a peephole to another world" (quote from paper).

2 pt. **a.** [max. 2 pts] Describe what kind of sensors they used to implement this and why (i.e., what kind of data was needed from them to achieve this).

For such around body interaction, the following sensors are needed:

- Magnetometer to get the heading of the device (where it is pointing at).
  This is needed to change the view when the device is moved left or right.
- Camera to get the distance of the user's face to the screen.
  This is needed to switch between different layers.

Note that the first one is not mentioned in the paper, but it is clear from the description and accompanying video that this is needed. Technically, you could also do this with the camera that is facing away from the user (e.g., by measuring optical flow), so that would be an equally correct answer, although it seems easier and thus more likely that they just used the magnetometer.

Because only left/right and closer/further-away movements are considered in the game, you do not need an accelerometer/gyroscope (which would measure the relative orientation of a device with respect to itself). For example, there is no evidence in the paper or video that tilting the device up or down or rotating it would cause any change in the visuals.

The text only mentions "motion sensors" but not which ones. A magnetometer is clearly needed. One could argue though that accelerometer/gyroscope support could be used to make the motion mapping more accurate. (Some did and got full credits for it.)

Because their paper was a design paper and not a research paper, they did not compare it with other approaches to navigate 3D spaces on mobiles. Yet, we can make educated guesses. Assume you want to set up an experiment comparing this approach with 3D navigation by tilting of the device around its own axes (we discussed this latter approach in various contexts including mobile gaming).

2 pt. **b.** [max. 2 pts] Phrase a hypothesis highlighting one aspect where the authors' approach might be better than tilting and explain why you make this assumption.

A short answer can be sufficient. For example, something like this (different context, just to illustrate a possible phrasing): I expect that walking is better for losing weight than cycling because it is considered a weight-bearing activity, while cycling isn't.

Various correct answers exist here. Some nice and interesting examples that people came up with (just key phrases here, not formulated as hypothesis):

Better spatial orientation (3D world places correspond to 3D locations in real world).

More intuitive (same as above, i.e., 3D world places match to real world locations – with tilting, you often have the same problem as mentioned under d. below).

More immersive (you are surrounded by the virtual world and thus more likely to feel like you are there / inside the scene).

It nicely integrates interaction in the third dimension (closer/further-away) (how to do this with tilting?)

2 pt. **c.** [max. 2 pts] Phrase a hypothesis highlighting one aspect where tilting might be better than the authors' approach and explain why you make this assumption.

As above, a short answer can be sufficient.

Various correct answers exist here. Some nice and interesting examples that people came up with (just key phrases here, not formulated as hypothesis):

Better ergonomics (no gorilla arm effect).

Requires less space (e.g., tilting can also be used when standing in a crowded space, the other approach can't).

It may be more accurate (magnetometers, which are needed for the authors' approach, often have more sensor noise than accelerometers/gyroscopes used for tilting).

If focused on the closer/further-away dimension (and not the left/right motions), having a bigger range is a good answer, too, because the motion range of your arm is limited, but with tilting, you could, e.g., also continuously pan the environment back and forth and thus in theory have an unlimited range. (In theory, you could use panning with the authors' approach, too, but that's not what they did in the paper. They clearly did a direct mapping of different locations in the real world to fixed location in the virtual one.)

Better in non-standing situations (e.g., when sitting on a non-rotating chair, this 360-degree around body interaction is difficult if not impossible to do).

Around body interaction has various advantages (e.g., it might benefit from spatial memory). Yet, there are sometimes situations where the implemented behavior that is evoked by certain motions of the device feels counterintuitive.

1 pt. **d.** [max. 1 pt] Give one example for this where the output on the screen may feel obvious to some users but counterintuitive to others.

Various good answers exist here. For example, in the lecture, we discussed "map zooming via moving the device closer or further away" and saw that this could be interpreted differently due to a different mental model (map held in your two hands vs. map mounted on a wall).

9 Mobile augmented reality (AR)

AR can be achieved in various ways, for example, via head-worn AR glasses, but also via handheld devices such as mobile phones and tablets.

2 pt. **a.** [max. 2 pts] Give one convincing example, use case, or situation where a handheld AR solution would be sufficient if not better than one with head-worn AR glasses. Shortly explain why.

Various good answers exist here.

2 pt. **b.** [max. 2 pts] Give one convincing example, use case, or situation that can be achieved with head-worn AR glasses but not or much worse with mobile handheld AR. Shortly explain why.

Various good answers exist here.

2 pt. **c.** [max. 2 pts] Give one convincing example for handheld mobile AR where full registration in 3D is <u>not</u> necessary but it could still be considered AR.

Various good answers exist here.

Ray picking selects the first object that is hit by a ray "shot" from the device towards the AR scene shown in the device's display.

1 pt. **d.** [max. 1 pt] Explain how you can select an object with ray picking that is placed behind the first one hit by the ray.

Text from the slides (the non-italic one would be sufficient here to get full credits):

How to select objects behind the first one?

We can move the device to avoid occlusions.

1 pt. **e.** [max. 1 pt] Explain how you can rotate or move an object in 3D using ray picking

Text from the slides (the non-italic one would be sufficient here to get full credits):

How to manipulate objects in 3D?

We can "attach" them to the device and move it along with the device."
(*Should actually be "move them along", typo on the slides*)