(INFOMMOB) Mobile Interaction - 24 june 2019

Course: Mobile interaction (INFOMMOB)

The exam contains 9 problems, each covering content from one of the nine lectures.
Note that some problems contain many sub-questions. Thus, plan your time accordingly.

Good luck!

Number of questions: 9

You can score a total of 63 points for this exam, you need 31.5 points to pass the exam.

Note that text in italics was just added to explain the answers or comment on them, but not needed. Regular text generally indicates short answers that were sufficient to get full credits.

Comments on the grading:

- Given the text-focused style of the exam questions, it can always happen that people misinterpret the question or understand it a bit differently. If your answer clearly reflected that and is correct with respect to this alternative interpretation, you did get full or at least partial credits.
- In some cases quotes from the papers are given below; correct phrasing was not needed though. Questions were made in a way that they test if you understood the content, not just remembered it. Therefore, various different phrasings were acceptable as correct answers. Likewise, in some cases other answers than the one presented in the papers (or in the notes here) were also correct and gave full credit, even if they are not listed here and/or were not discussed directly in the lecture.

1 General context

Note: in the following, short answers are sufficient. In most cases, you don't even have to write full sentences, but some phrases or words could be enough to get full credits.

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. The first wave was ***portability***, and the second was ***miniaturiztation***. Both of these waves were mostly driven by the desire to develop mobile computers (e.g., laptops). Yet, the resulting technological improvements had relevance for the development of today's smartphones as well.

1 pt. **a.** [max. 1 pt] Name one technological improvement related to either of these two waves that was motivated by the need to create portable computers, but had a relevance for today's smartphones as well.

Multiple options exist, including (each single one of them is sufficient to get full credits):

- Batteries
- Processing power
- Storage

These were all technologies that improved significantly due to the need for mobile computing (e.g., laptops), but obviously smartphone technology benefited from these improvements later as well.

1 pt. **b.** [max. 1 pt] Name one technology-related characteristic of today's smartphones that did not just happen because of general technology improvements in mobile computing, but was clearly motivated by the needs and demands of smartphone users.

Again, multiple options exist:

- High-resolution displays
  (*This is probably the most obvious one. We discussed them in detail in lecture 2 and I also referred to it in relation to VR in the 3D/VR lecture. While there were high-resolution displays before, the massive adoption by them was clearly triggered by smartphones; e.g., Apple first introduced their Retina displays into iPhones, several times later into their iPads, and much later then finally into laptops and even later into their desktop computers*)
- Touch screen technology
  (*Again, there were touchscreens before, even ones that did multitouch. But the introduction of touch-operated smartphones caused a massive boost in the development and improvement of touch technology*)

*We didn't discuss networks and connectivity in this context, but it would have been perfectly correct to also state "*WiFi network technology*" under a. and "*Cellular network technology (e.g., GSM) *under b. Several people wrote something like "*sensor technology*" or "*Finger print sensors,*" which both are indeed a good answer as well.*

In the following, we want to look at four of the other waves in the context of **digital cameras.**

1 pt. **c.** [max. 1 pt] One of the other waves was ***convergence***. Give one advantage of convergence in relation to digital cameras; that is, state an improvement of digital cameras and/or their usage that is due to this trend.

Multiple correct answers exist but probably the most obvious one is:

- If a camera is integrated into a device with multiple functionalities, you do not have to carry two (or more) devices with you but just one.

1 pt. **d.** [max. 1 pt] Another wave was ***divergence.*** Give <u>one advantage</u> of divergence in relation to digital cameras; that is, state an improvement of digital cameras and/or their usage that is due to this trend.

Again, multiple ways to answer this correctly, with probably the most obvious one being:

- If a device only contains a camera, it can be optimized for the purpose of photo taking, e.g., with respect to performance (optical lenses, …) and ergonomics (better grip, …)

Note that much shorter answers would have been sufficient (e.g., just stating 'ergonomics' *is perfectly fine).*

1 pt. **e.** [max. 1 pt] Another wave was ***connectivity.*** Shortly describe what is meant by that.

Mobile devices became connected to networks.

This is the version that I used in the answers to last year's exam. The one used in the paper:

Connectivity was about developing devices and applications that allowed users to be online and communicate via wireless data networks while on the move.

1 pt. **f.** [max. 1 pt] Give <u>one advantage</u> of connectivity in relation to digital cameras; that is, state an improvement of digital cameras and/or their usage that is due to this trend.

Various examples exist, including (each singles one gives full credits):

- Uploading photos
- Sharing photos with friends, posting them on social media
- Updates of the camera software without the need to connect the camera to a computer

1 pt. **g.** [max. 1 pt] Another wave is ***apps***. Shortly describe what is meant by that.

From the paper:

Apps is about developing matte and substance for use an consumption on mobile devices, and making access to this fun or functional interactive application content easy and enjoyable.

Other, shorter descriptions were fine, too. (E.g., it is not essential to mention that apps are 'fun or functional interactive' but, e.g., easy access to large amounts of different apps is more important.)

1 pt. **h.** [max. 1 pt] Give <u>one advantage</u> of apps in relation to digital cameras; that is, state an improvement of digital cameras and/or their usage that is due to this trend.

You could answer this question with a concrete example or a more general description. A possible phrasing for the latter including two concrete examples:

Apps enable users to use the camera for other purposes than photo taking (e.g., scanner apps) and can be used to extend the functionality of the camera by software (e.g., adding filter effects).

4 pt. **i.** [max. 4 pts] If we look at today's situation, many people still use stand-alone digital cameras to take pictures. But many others use mostly or exclusively cameras integrated into their mobile phone to take photos. **Shortly discuss this in relation to the four advantages that you described above for the waves of *convergence, divergence, connectivity,* and *apps.*** That is, explain why today's situation happened with respect to the advantages that you listed above.

The answer to this depends on the advantages specified above. Thus, here only some general comments with respect to the ones given here:

Using your phone as camera is clearly related to the trend of convergence (phone and camera combined in one device). Using stand-alone cameras relates to the trend of divergence.

The advantages given above for either of these approaches is clearly a disadvantage of the other approach. If it is more important for someone to just have one device or to have better performance and ergonomics is a very personal aspect, which is why we still see both; people using only phones or people using also or exclusively stand-alone cameras to take photos.

The same goes for apps and connectivity. People who take photos to mostly post them on social media might prefer a device that has network capabilities and a flat rate for data upload, whereas for hobby or professional photographers, being constantly online might not be as important, and some of the advanced features of smartphone cameras (e.g., upload via WiFi) have been added to these cameras, too. (Side notes: some of this functionality is also integrated in stand-alone cams these days, but generally less sophisticated; e.g., solely WiFi or Blutooth, but not GSM networks. A nice observation mentioned by some is also that the respective additional features match the user's needs; e.g., people mostly interested in social media sharing are not necessarily interested in highest resolution images and sophisticated photo taking options, whereas professionals or photo enthusiasts but more emphasis on picture quality and control during the photo taking rather than quick filter adding and social sharing.)

2 Sensor technology for interaction

Accelerometers were originally introduced into mobile phones to improve usability by automatically changing the screen orientation between landscape and portrait when a user rotates the phone accordingly. Then people realized that they can use it for various other types of user interaction as well (e.g., tilting the phone as input for games).

Name **one other sensor or technology** that we find in today's mobile phones, which was introduced for a specific purpose and is now used for interaction. Give its name, shortly state its original purpose, and then give a short example of a scenario or context where it is used for interaction and how.

0 pt. **a.** [0 pts; this is just needed for the following questions] Name of the sensor or technology:

1 pt. **b.** [max. 1 pt] Original purpose why this sensor was integrated into the phone:

1 pt. **c.** [max. 1 pt] Example illustrating how this sensor is now used for interaction *(note: your example must be different from the original usage that you mentioned above):*

Good examples include:

- Camera -> taking pictures -> scan barcodes / … (any non-picture taking camera usage)
- GPS -> navigation / map usage -> AR or stargazing apps (*same for compass/magnetometer*)
- Microphone -> make phone calls -> classify songs that are playing (e.g., Shazam app)

Today's smartphones contain **vibration motors** that can be used to provide haptic feedback via small vibrations. These are sometimes used **to improve interaction** by complementing other types of input, such as ***touch***. For example, some soft-keyboards on touch screens do not only give visual feedback, but also vibrate when a key is pressed.

1 pt. **d.** [max. 1 pt] Give one reason why this is done, i.e., a problem that interface designers are trying to resolve by adding vibration feedback to on-screen keyboards. *(Note: be specific; "lack of haptic feedback" is not sufficient.)*

*This is related to the issue of "**Response**, e.g., confirmation of button press" discussed in the lecture, i.e., here: "Did I hit the button or not?" Adding haptic to, e.g., visual feedback gives a stronger confirmation that your key press was actually registered by the device.*

1 pt. **e.** [max. 1 pt] Give one common problem in this situation (i.e., entering text with a soft-keyboard) that is not resolved by adding such vibration feedback.

*This is related to the issue of "**Notification**, e.g., support or replacement of ring tones" discussed in the lecture, i.e. here: "What button did I hit?" or "Did I hit the right button?" Because keys are very close to each other and small, you can easily hit the wrong one. The pure notification that you hit one, does not help you in assuring you that you hit the right one.*

Now we want to look into how **vibration** could be added **to improve interaction** via ***tilting*** your phone.

Assume you want to implement a car racing game, where players steer a car along a race track by tilting the device left or right. On the screen, the player sees the race track as if he/she is sitting in the car and looking out of the windshield (so basically a first person view of someone driving a car).

Give two examples of how one could use vibration motors in this context to potentially improve interaction; your examples must illustrate when you would use them and why (i.e., what is the purpose of the vibration or how does it improve interaction).

1 pt. **f.** [max. 1 pt] Example 1 and purpose:

1 pt. **g.** [max. 1 pt] Example 2 and purpose:

I mentioned three in the lecture on gaming, but if you remember the usage of vibrations discussed in lecture 2, you could easily come with the first two as well (and some came up with even others that were also very good):

*An example related to **notification**: vibration to indicate that you are, e.g., running out of gas. While this is often done via a visual element on the screen, a vibration might be easier or more likely to get noticed.*

*An example related to **response:** vibration to indicate when you hit a car or go slightly off the track. While this is often done via visuals (e.g., sparks when you scratch a guarding rail at the side of the road), adding haptics can make it clearer (similarly to the confirmation of a button press with visual and haptic feedback above).*

*An example related to **experience**: vibration when bumping into a car or hitting the guarding rail does not only provide a better response, but could also add to the game play experience, since it simulates the rattling of a car that would happen in reality.*

Interaction via touch screen as well as interaction via tilting can both result in **visibility problems**.

1 pt. **h.** [max. 1 pt] Give one common visibility problem that can appear when using <u>touch</u> as input.

An obvious answer here is occlusion *with your fingers during interaction*

1 pt. **i.** [max. 1 pt] Give one common visibility problem that can appear when using <u>tilting</u> as input.

Examples include: bad viewing angle when tilting, light reflections at certain tilting angles, motion of the device during usage

3 Touch screens

In the lecture, we discussed different **touch screen technologies**. One of them was ***pneumatic displays*** (we saw an example of a research prototype of this approach), another one was ***electrostatic touch screens*** (we saw a video of a prototype built by Disney Research). Both of them address the same basic problem that standard touch screens have. But they do this in different ways. Therefore, they only solve parts of this problem, but not everything.

1 pt. **a.** [max. 1 pt] What is the general basic problem of standard touchscreens (e.g., the ones in your phone) that these two technologies both address?

Lack of haptic feedback

1 pt. **b.** Give one issue that is part of this problem but can not be resolved with *pneumatic displays.*

Creating texture feedback

1 pt. **c.** [max. 1 pt] Given one issue that is part of this problem but can not be resolved with *electrostatic touch screens.*

Simulating hard / physical buttons

(Other correct answers or phrasings exist, esp. for the last one)

One problem with touch screens is that objects at the top of the screen are hard to click when interacting with just one hand, because your thumb is not long enough to reach them comfortably. We saw three ideas how to deal with this: One that uses a software solution ("***ExtendedThumb***" described in the paper by Lai and Zhang (2014)), one that uses pressure sensitive input ("***ForceRay***" described in the paper by Corsten et al. (2019)), and one that uses another sensor, i.e., the accelerometer for tilting-based input (see "***SWiM***" described in a paper by Yeo et al. (2017) and illustrated in the video that we watched in the lecture).

1 pt. **d.** [max. 1 pt] Give one advantage that the ***ForceRay*** approach could have compared to tilting-based approaches, such as ***SWiM.***

"… they use tilt, which is prone to overshooting and makes reading the screen difficult at certain angles"

(Quote from the ForceRay paper; other correct answers or phrasings exist)

1 pt. **e.** [max . 1 pt] Give one advantage that the ***ForceRay*** approach could have compared to the ***ExtendedThumb*** approach.

"… the swiping that these techniques require, can lead to grip instability when the thumb is moved beyond its comfort region."

(Quote from the ForceRay paper; other correct answers or phrasings exist)

1 pt. **f.** [max. 1 pt] Give one potential disadvantage of ***ForceRay***.

- "FR is affected by handedness"
- "distance targets require more precise movement the smaller such targets are"
- "sacrifices the benefit of direct manipulation"
- "interferes with existing force input techniques"
- "only designed for targets responding to taps"

(quotes from the paper; other disadvantages exist; e.g., the paper mentions also a learning curve, which suggests that some training is needed to get good performances)

In all of these three techniques, you are not touching targets that are out of reach directly, but select them indirectly using a cursor or other indication to select them. Give two advantages that such **cursor-based touch interaction** could have compared to directly touching the objects with your fingers or thumbs.

1 pt. **g.** [max. 1 pt] First advantage:

Visibility / no occlusion with finger

1 pt. **h.** [max. 1 pt] Second advantage:

Potentially higher accuracy due to ‘snap to target’ / ‘bubble cursor’ like targeting / “virtual cursor enlargement” (quote from paper)

Several people also referred to the “fat finger problem”, which is correct, too. Because the cursor can be made smaller than your finger, it seems fair to claim that cursors might be more accurate. Note though that the fat finger problem is also related to occlusion. Thus, two points are only given if both issues are clearly stated.

4 Human aspects & perception

In the lecture, we talked about a technique called **Rapid Serial Visual Presentation (RSVP)** that allows people to grasp content faster by showing it to them rapidly. We saw an example of this in the context of speed reading (remember the fast reader shown in the video by a company called Spritz), and we talked about how this could be applied to access larger image databases.

Now assume you are an interface designer who works on creating interfaces for tiny screens, such as the ones found on smartwatches.

1 pt. **a.** [max. 1 pt] Give one concrete example where applying RSVP in this context (tiny screens) might work and provide a convincing reason why.

Searching for information (e.g., in text or a particular image)
Humans are very good at spotting visual information even if presented rapidly. Fast presentation of the content will therefore reduce search time.

1 pt. **b.** [max. 1 pt] Give one concrete example where applying RSVP in this context (tiny screens) might <u>not</u> be a good idea and provide a convincing reason why.

Learning or memorizing information (e.g., reading a text book for learning)
RSVP overloads short-term memory and is therefore not good for achieving long-term memory (which is usually what you want then reading a text book)

We also discussed that **audio** content can be **played faster** (to some degree) and people are still able to understand or at least classify what they hear (if the playback is modified in a way that the pitch is preserved).

1 pt. **c.** [max. 1 pt] Give one concrete example where such a faster audio playback makes sense and thus adding this option to the interface could be a good idea.

Possible answers (others may exist):

- Searching for information in speech recording
- Quick recap of a speech recording (e.g., a recorded lecture)

1 pt. **d.** [max. 1 pt] Give one concrete example where such a faster audio playback does <u>not</u> make sense.

Basically everything where people are not interested in quick information gain, but want to enjoy or hear the audio in its original form, e.g., when listening to music *(which is also why it is not integrated in common music players)*

5 Touch interaction design

In the lecture and one of the papers, we addressed **callouts**, i.e., enlarged visualizations of an area covered by your finger or thumb that is displayed in a non-occluded area. The one discussed in the lecture was applied to target selection on a map and called *Shift.*

1 pt. **a.** [max. 1 pt] Give one example or issue with touch interaction that is relevant in this context (i.e., target selection on maps) that such callouts might resolve.

Precision/accuracy problems due to occlusion of objects by your finger

(*The callouts allow you to see "what's under your finger" and a cursor shows you where you are currently touching.*)

1 pt. **b.** [max. 1 pt] Give one example or issue with touch interaction that is relevant in this context (i.e., target selection on maps) that this approach might not resolve.

Precision/accuracy problems due to objects being too close to each other or overlapping

(*If objects are too close to each other, it is still too hard to hit them. The enlargement only shows where you are touching, but if your finger is too big to make an accurate selection, the callouts won't help. In the lecture, we discussed another approach right after the Shift callouts that deals with this issue via gestures (small icons that indicate the direction in which you have to move your finger to select them).*)

If we look at today's apps, callouts are rarely used in target selection tasks for maps. Yet, they are sometimes used for text entry via on-screen keyboards (e.g., in iOS, the key that is hit with your finger is shown as an enlargement on top of it).

1 pt. **c.** [max. 1 pt] Give a convincing reason why callouts are hardly ever used in target selection tasks for maps anymore.

Today we have multi-touch and pinch and zoom gestures, which are very intuitive and quick. It resolves both of the problem mentioned above.

1 pt. **d.** [max. 1 pt] Give a convincing reason why they are still used for text entry with on-screen keyboards.

Enlarging the keyboard via multi-touch gestures solves these problems when hitting one key, but it is not efficient to constantly zoom in and out to type a full word. Thus, other techniques such as callouts are still useful here.

General note (mostly for people who will follow the course next year): This is actually a nice example for a question type that verifies the different 'levels of learning' that I'm often referring to in the lecture (i.e., knowing – understanding – applying).
Several people mentioned the 'occlusion' problem or the 'fat finger' problem in relation to the first question. Thus, they clearly learned something and had knowledge about it. Yet, the fat finger problem has two aspects: you are hiding content with your fingers, which makes it harder to select. But the size of your finger (compared to, e.g., the tiny tip of a pen) makes it also harder to give a precise input. People who answered correctly to the second question demonstrated that they did not just learn or memorize the problem but also had a good understanding of it. The maps versus keyboard question tested if you are able to apply this understanding to different contexts; e.g., if you know when and when not to use it and why. (E.g., several people just repeated the advantaged and benefits of callouts, thus not clearly demonstrating that they get a full understanding of all the characteristics (incl. pros and cons) of this approach to be able to apply it in a slightly different context.)

If interface designers want to use a technique such as callouts, they also need to decide how to implement them. In the paper *Evaluation of Callout Design for Ultra-small Touch Screen Devices,* Ishii et al. evaluated three design options for callout designs. In the paper, they call these options design "factors".

State what these are and shortly explain what each means. (*Note: the meaning is more important; there will be no deduction if you do not remember the correct name but give a correct description. Stating the correct name without explanation gives 0.5 credits. Stating the name with a wrong explanation will give 0 credits.*)

Quotes from the paper (note: giving the levels was not needed for full credit):

1 pt. **e.** [max. 1 pt] Factor 1:

"Presentation method is the factor that determines how the content of a callout changes in response to a user operation" (*levels: continuous and discrete*)

1 pt. **f.** [max. 1 pt] Factor 2:

"Presentation position is the factor that determines how the position of a callout changes in response to a user operation" (*levels: fixed and following*)

1 pt. **g.** [max. 1 pt] Factor 3:

"Pointer existence is the factor that determines whether the actual touch point of the user is displayed on a callout as a pointer (Existing) or not (NotExisting)

6 Mobile gaming

In the lecture we discussed the use of **on-screen joysticks** for games. You also read two articles about them. The paper by Teather et al. ("Tilt-Touch synergy") calls them *dual-analog controllers*. The article by G. McAllister refers to them as *twin stick shooters*. McAllister discusses also different design options, including *static* and *dynamic controls*.

1 pt. **a.** [max. 1 pt] Shortly explain what is meant by *static controls.*

From the article:
Static Controls. This approach fixes the location of the touch controls, typically they'll be within easy thumb reach of the corners of the iOS device.

1 pt. **b.** [max. 1 pt] Shortly explain what is meant by *dynamic controls.*

From the article:
Dynamic Controls. This approach centers the controls at the point where the player touches the screen, i.e. the controls can change spatial location depending on where the player's thumb makes contact.

1 pt. **c.** [max. 1 pt] Give one example or reason why a game designer might decide to use static controls instead of dynamic ones.

- No discovery problems / visual aid
- No accidental occlusion of relevant game content
- Less ambiguous or unclear behavior when touching too close to borders

Several other correct solutions exist (in fact, many students came up with some pretty good ones)

1 pt. **d.** [max. 1 pt] Give one example or reason why a game designer might decide to use dynamic controls instead of static ones.

- No need for exact targeting
- Less problems with drift of fingers during longer interaction

As above, many other good answers exist here.

In their paper *Tilt-touch synergy: Input control for 'dual-analog' style mobile games"* (2017) Theather et al. describe three deficiencies that virtual controls have compared to their physical counterparts know from game console controllers. List three of such disadvantages. (*You do not necessarily have to list the three mentioned in the paper. There might be others and any convincing answer will give full credits.*)

1 pt. **e.** [max. 1pt] 1st deficiency:
"The absence of tactile feedback yields a noticeable performance cost …"

1 pt. **f.** [max. 1pt] 2nd deficiency:

"… do not include shoulder buttons to circumvent that virtual face buttons are inaccessible while using the virtual joystick."

1 pt. **g.** [max. 1pt] 3rd deficiency:

"… occlude portions of the screen …"

These are all slightly adapted quotes from the paper. Other correct answers do exist.

In their paper, Teather et al. compare touch with tilt input and combinations thereof. Name two problems of touch controls that do not appear for tilting (*again, it is not necessary to name exactly the two stated in the paper, but any correct one will give you credits*). Also, name one additional potential benefit that tilt input might have, i.e., a unique characteristic of tilt that might be beneficial for interaction (*and again, there is one mentioned in the paper, but there might be others; it also does not necessarily* *have to be related to a deficiency of touch*).

1 pt. **h.** [max. 1pt] 1st problem with touch control that does not appear with tilt:
"… tilt does not occlude the view …"

1 pt. **i.** [max. 1pt] 2nd problem with touch control that does not appear with tilt:
"… and (tilt) can be used to tandem with virtual face buttons."

1 pt. **j.** [max. 1pt] Another general advantage that tilt might have for interaction:
"… it may … leverage proprioception."

*These are quotes from the paper. Several other correct answers exist. In fact, some of the deficiencies listed above could be repeated here (similar to "occlusion", which does indeed appear here under "h." and under "g."). **A general comment in this context**: There were actually several places in the exam where you could re-use previous answers. This was done on purpose as it can show if people really understood the matter, for example, by recognizing that this is actually the same issue (although phrased slightly different or in a different context). Likewise, some people did not get full credits because they phrased a generic characteristic again without realizing that there are actually small, but important differences in the two scenarios that would not allow to use the same answer (or require a slight modification). Thus, although it seems simple or even stupid to have questions with the same answer, it was actually a good way to test if people really understood things or just had some vague knowledge of the matter.*

In their paper, Teather et al. note that the standard implementation of dual-analog controls (both physical and virtual) conforms to Guiard's model of bimanual control, which states that "bimanual tasks often use the non-dominant hand to coarsely set the frame of reference within which the dominant hand operates, performing fine control" (quote from the paper).

Based solely on this information, which mode (*tilt* or *touch*) would you assign to which action (*orientation* or *navigation*) if you want to implement a combined approach (i.e., use tilt for one and touch for the other action)? Keep in mind that the majority of people is right-handed. (*Note: the answer is given in the paper, but if you don't remember it, you should still be able to figure it out based on things we discussed in the lecture.*)

2 pt. **k.** [max. 3pts] Complete the following sentence by writing down either *orientation* or *navigation* and then add a short justification of your answer: *(Note that one can argue in different ways. Any answer that provides a convincing reason will give full credits. Thus, answers without justification will get no credits.)*

I would match tilting to ... because ...

Generally, we can consider "orientation" to be a task that requires less accuracy than "navigation". "Tilting" is generally considered harder to control more accurately than "touch" interaction. Thus, according to this theory, it would make sense to map "tilting" to the task of "orientation" to 'coarsely set the frame of reference' and "touch" to the task of "navigation" to 'perform fine control'.

(Note that you can also argue the other way around; it doesn't really matter as long as you provide a convincing argument and match the pairs accordingly. The paper actually proved that this is not the case, so this question was more about testing if you can make a good and justified statement and put the characteristics learned about certain interaction types (tilt and touch) in context to other knowledge. Some people provided other reasons that were also correct, but in this context irrelevant (the question clearly stated that you have to base your arguments on Guiard's model ("Based solely on this information, …"). Thus, these comments did not get any credits, even if they were generally correct. The answer above is actually sufficient, which is why it was not required to address the dominant-hand issue; the paper discusses it in way more detail, which is why this comment was included, but it is actually not necessary to address it here (but also didn't hurt your credits if you did).)

7 Mobile evaluation

In the paper *Tilt-Touch synergy: Input control for "dual-analog" style mobile games* (2017) Teather et al. present an experiment where they use “a custom-developed game” that is “reasonably complex and potentially more representative of ‘real’ games than relatively simple games used in previous work” (quotes from the paper). They justify these two experiment design decisions with higher internal and external validity.

1 pt. **a.** [max. 1 pt] Which of these two experiment design decisions should result in higher internal validity and why?

Quote from the paper:

… we used a custom-developed game. This offers high internal validity, as it enables precise measurements.

1 pt. **b.** [max. 1 pt] Which of these two experiment design decisions should result in higher external validity and why?

Quote from the paper:

Recreating the experience of a real game increases external validity by decreasing participant boredom or distraction during repeated testing. Hence, we expect that the external validity of our work is also high – the game is challenging, engaging, and should generalize to real games.

They also used only “regular gamers” who “reported weekly use of games using either dual-analog physical game controllers of mobile virtual dual-analog controls” in their study (quotes from the paper).

1 pt. **c.** [max. 1 pt] Why did they only use experienced participants?

Quote from the paper:

Experienced participants were chosen to reduce result variability.

General note*: you did not have to quote the paper directly, but general descriptions of the issues were sufficient to get full credits. It was more important that you understood the issues than that you remembered them by heart (that holds for other questions as well).*

In this case though, quite some people lost credits because they were basically just summarizing what generally leads to high internal or external validity by stating that simple games generally achieve the first (e.g., due to being more controlled) and more realistic ones to the second (e.g., to being more similar to real-world games and thus achieving comparable results). But they missed that the authors tried to achieve both with one game implementation! (I.e., the question here was not “what do you do to achieve high internal or external validity”, but “what did the authors do to achieve both”.)

8 Mobile 3D interaction

In the lecture, we talked about different **3D visualization concepts**. One of them was called ***Shoebox VR*** (or ***Fishtank VR***; in the context of this question there is no need to distinguish between them). The other was called ***Fixed world VR***. The latter follows the same principle as the implementations in Xiang A. Chen's papers on *Body-Centric Interaction* and *Around-Body Interaction*.

Assume the following ***scenario***: You have three screens filled with icons of apps on your phone (the home screen and two other ones). You can switch between them by swiping (as it is done on almost all current smartphones). Now you want to replace swiping by a Shoebox VR-like implementation or a Fixed world VR-like implementation. (We actually saw an example for the first case in a video in the lecture. The second is illustrated in Chen's papers.)

1 pt. **a.** [max. 1 pt] Give one *advantage* that such a Shoebox VR implementation could have compared to the Fixed world VR implementation.

Various correct answers exist, e.g.:

- Shoebox only requires sideways tilting, whereas for Fixed world VR the device has to be moved left and right, which might not be practical in real-world situations (*or …* which might be more ergonomically challenging)
- The 3D visualization might be more intuitive and locations of the additional pages might be easier to access. (*E.g., how far do you have to move for Fixed world solutions to get to the next page? Due to the 3D visualization, this is very clear for Shoebox VR*).

1 pt. **b.** [max. 1 pt] Give one *advantage* that such a Fixed world VR implementation could have compared to a Shoebox VR implementation.

And again, various correct answers exist, e.g.:

- Fixed world VR can be implemented that the user does not have to look at the device sideways, which reduces some visibility problems.
- Fixed world VR might benefit more from spatial memory. (*We addressed this shortly in relation to the dynamic keyhole concept*.)
- Fixed world VR scales to more than three screens. (Shoebox VR is limited to left and right tilts, but for Fixed world VR, you could easily add a few more screens to the left and right.)
- The perspective change of the content on the screen for Shoebox VR might cause problems (motion might decrease visibility, targets might be harder to hit). With Fixed world VR, you have a flat, 2D visualization similar to the standard screens.

1 pt. **c.** [max. 1 pt] Give one *advantage* that the standard approach (swiping between home screens) could have compared to both of these two VR implementations.

And again, various correct answers exist, e.g.:

- No sensor noise from motion sensors. (Touch gestures are generally easier to recognize than motions of the device; esp. simple ones like swiping.)
- No accidental change due to unwanted motions of the device (e.g., during a bumpy bus ride).
- Less visibility problems, e.g., due to no changes in light reflection because the device is moved or tilted.

9 Mobile AR

In relation to augmented reality (AR), we often distinguish between so-called *immersive* installations and *non-immersive* approaches. Shortly explain what this means in this context.

1 pt. **a.** [max. 1 pt] Immersive AR: Immersive: no other view than that of the mixed environment *(quote from the slides; other phrasings are possible)*

1 pt. **b.** [max. 1 pt] Non-immersive AR: Non-immersive: mixed environment takes up only portion of field of view *(quote from slides; other phrasing are possible)*

Give a convincing **example of an AR app** for mobile AR (i.e., AR done with your smartphone or tablet) that only utilizes accelerometer / gyroscope and magnetometer and no other sensor, but could still be considered a useful AR app (even if it may not fulfil all the criteria of an AR system defined by Azuma).

1 pt. **c.** [max. 1 pt] Example:(*Note: if you use one from the lecture, a short statement that identifies it is sufficient; for others, make sure that your explanation clearly illustrates why only these two sensors are necessary.*)

UFO shooter game "AR Invaders"
(Basically everything that places objects at a fixed location around you, but not at a fixed place in the world is correct here. There was still some confusion about the camera here, although I tried to phrase this very clearly in the lecture and on the slides this time, since we had this problem last year, too. The camera is needed to create the video image, but that is just its 'normal' usage as a camera. If you analyze the image's content, the camera serves as a sensor. Thus, approaches that need CV are not really correct here, since they cannot be implemented by just using accelerometer and magnetometer.)

Give a convincing **example of an AR app** for mobile AR that needs one additional sensor (that is, in addition to accelerometer / gyroscope and magnetometer).

1 pt. **d.** [max. 1 pt] Example:(*Again, giving the name and/or a short description of one mentioned in the lecture is sufficient; if you come up with your own idea, make sure to clearly describe it. In both cases, don't forget to mention the name or type of the additional sensor.*)

GPS is required for, e.g., information browsers (e.g., Layar Browser), Stargazing apps, PokemonGo-like location-based AR games, …
(Basically everything that places objects at a fixed location in the real world is correct here. Accelerometer and magnetometer are still needed to get the orientation of the device with respect to the user. If you wrote 'camera' as sensor here, you could have actually used the same example as in f. below.)

In the context of AR, what is meant by **3D registration**?

1 pt. **e.** [max. 1 pt] Shortly explain it.
Virtual objects are presented at a fixed location in the real world
(which means at a fixed location in 3D, not just superimposed on a flat 2D screen)

Give a convincing **example of an AR app** that would need perfect or at least a very good 3D registration.

1 pt. **f.** [max. 1 pt] Example:

- *Anything that needs to be on a fixed position on a flat surface, e.g., the tower defense game that we saw in the lecture or the AR Minecraft version from Apple's last keynote that we also discussed in the lecture.*
- *Anything that needs a perfect integration into the 3-dimensional real world, e.g., the IKEA app that we mentioned where virtual models of furniture should be placed into your living room as realistically as possible.*

Thank you for participating in the course.
I hope you enjoyed it.
Now have a nice summer vacation.

PS: If you haven't done so already, please fill out the Caracal evaluation to help me improve the course. Thanks!