Find my bike

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Abstract

Finding an object in an object-rich environment is sometimes difficult and requires good orientation skills. With the rapid development of AR technologies, there are many more options as a support to navigate in an environment using AR. In our case, we developed an application that helps the user find his bike in a bike-rich environment using AR technology. The results showed that in most cases users preferred to use this approach over regular GPS map navigation. The main advantages were that it was much more accurate and intuitive to use and also that it took much less time for users to find the bike.

1 Project idea

1.1 Problem

There are a large number of students using the Metrovélo bikes nowadays in Grenoble. Metrovélos are bikes for renting and they always have a yellow color and a similar shape; the only difference is a small serial number in front, which is hard to see from a greater distance. The similar appearance leads to difficulties to recognize the bike when returning back from classes or lunch and the bike is located in a cluster of bikes where most of them are Metrovélos similar in color and shape. This creates a space to develop an app that would help the user to find his bike using AR technology.

1.2 Objective

The main objective of our project was to determine whether an approach using AR technology would be better than other methods that are used more frequently. Our main focus was whether the AR app can reduce the time required to find the user's bike, but also the user's behavior and experience. As an example of an approach that does not use AR, we chose Google Maps with GPS localization.

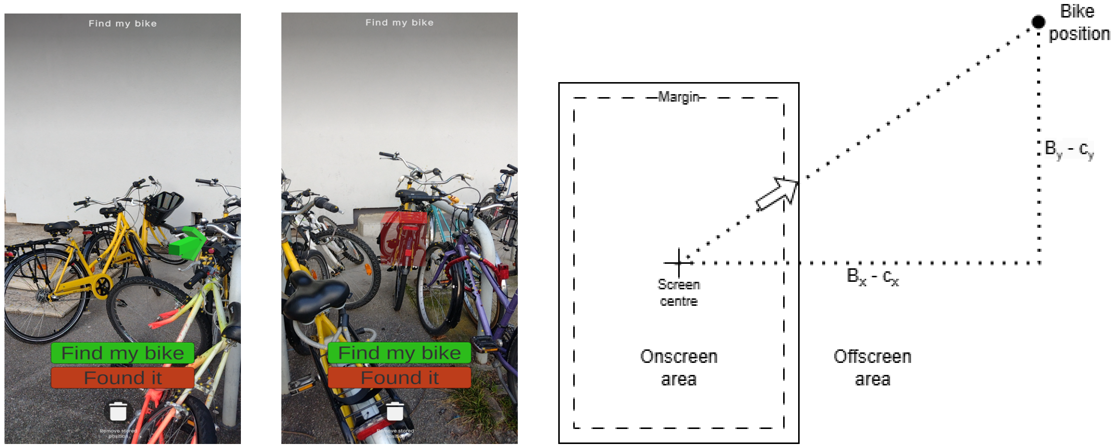
2 State of the art

There are already existing approaches to help the user navigate to the objects that are located off the narrow mobile screen field of view. Perea et al. introduced Halo [1] and later Halo 3D [5], which represent off-screen objects' locations by surrounding them with circles that are made just large enough to reach into the border region of the display window creating arches on the screen edge.
EdgeRadar [3] and Aroundplot [4] use a small portion on each edge of the screen to display the off-screen point of interest locations. The distant ones are indicated with square icons or dots in the edge area. The main benefit is that it provides information on the spatial relationship between the points of interest and the current work zone. On top of that, Aroundplot is also able to magnify part of the context (indicators on the edges) in the direction of the view movement, making navigation easier with a lot of off-screen points of interest that could otherwise make an indistinguishable cluster.
There are also multiple studies that compare the mentioned methods with regular 2D arrows [6] [2]. Most of the results proved the Halo [1] [5] approach to be the most effective. In Aroundplot [4] the authors also compare their method to a top-down 2D radar, which is similar to the 2D map approach we used in our experiments.

3 Prototype

We programmed our project in Unity using the anchors part of the AR Foundation Samples package. Our project can be found on a GitHub repository here.

To our knowledge, there is no approach that would use 3D arrows for user orientation. We tried to implement 3D arrows and test their performance. Unfortunately, due to time limitations we were not able to compare this to any other state-of-the-art methods that use AR, but we compared it to the top-down 2D map which is used for orientation by most of the users nowadays and therefore can be also considered as state-of-the-art. Our idea was then to compare if the users would prefer our approach over the state-of-the-art 2D map. In our approach, same as the 2D arrows in [2] we put the 3D arrow on the side of the screen indicating the direction to the off-screen object and show the user in which direction the device should be turned. In [2] to indicate the distance or amount of rotation required the arrows are scaled. We used a different approach of keeping the arrow at the same size but since the arrow model is 3D, we can use its rotation to indicate the direction to the bike in the world. We used only vertical-axis rotation, since the bike is mostly on the same level as the user while exploring the area. Later in the experiments 10a, it was shown that a few participants were missing this characteristic.



(a) App arrow (b) App target (c) Geometry of the arrow position

Figure 1: Application arrow

We compute the position of the arrow (figure 1c) to be at the intersection of screen margin and the line between the center of the screen and the off-screen position of the bike projection in the screen plane. The computation is described in equations 1 and 2. We denote the horizontal and vertical margin distance from the screen edge as m_x and m_y. The screen center is computed as $c_x = \frac{width}{2}$, $c_y = \frac{height}{2}$. We denote the bike offscreen position by B_x and B_y. We also restrict the resulting arrow position coordinates A_x and A_y not to get outside of the screen margin. When the object is inside the screen we do not display the arrows.

$$A_x = c_x + \left| \frac{c_y - m_y}{B_y - c_y} \right| (B_x - c_x) \tag{1}$$

$$A_y = c_y + \left| \frac{c_x - m_x}{B_x - c_x} \right| (B_y - c_y) \tag{2}$$

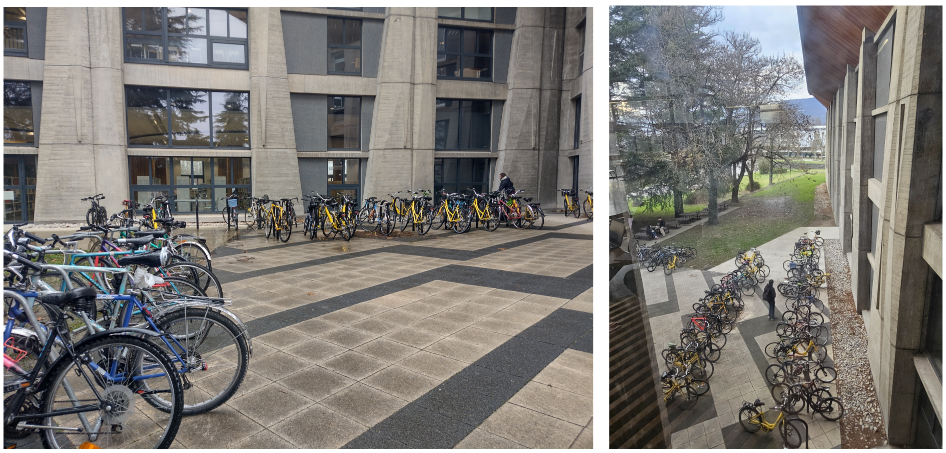
We encountered difficulties with the arrow orientations because during development we forgot to continuously update the relative orientation of the object to the user. However, while testing it before the experiment, we were not moving around the targets, and if so, we were only approaching them on a rather straight line. Therefore, we did not experience any strange behavior of the arrows.
This led to inevitable errors during the experiment because the relative orientations when we set up the experiment and when we gave the device to the user were different leading to wrong arrow orientations and even though the arrow position on the screen was correct, the wrong rotation confused the user.

We were not able to solve the issue on-site, because at the start of the experiments it was working perfectly, because we were not moving much around the bikes, so the relative position even thought not continually updated was more or less correct, but to the end of the experiment we started walking more around the bikes and therefore initializing more different relative position than it was later on the start. After we encountered theses problems we fixed this issue in our prototype.

4 Experiment

4.1 Environment

For the experiment, we chose an area near the campus library with a bike parking space (figure 2), which was approximately 8 m x 10 m with around 30 bikes. The area was perfect for testing real world conditions as there were also other people walking and sometimes changing the scene by taking their bikes.



(a) (b)

Figure 2: Location of the experiment

4.2 Experimental plan

We tested each user in a sequence of 6 turns. Each time a random bike was chosen in the area for the user to find. Each turn we also switched between the two tested methods: the 2D map state-of-the-art approach and our implemented AR application. The participants in the experiment were divided into two equally large research groups: one starting the sequence with the 2D map and one starting with the AR application. With the 2D map part, participants were given a phone with a map zoomed in on the area. The bike position was marked by a red pin. The users could orient themselves using the edge of the library roof in the map or a GPS position estimate. We let the users choose freely whether they will use the GPS or just the map landmarks, since due to the impreciseness of the GPS position it was sometimes more confusing to use it than not.
The participants started from a position in the center of the area that was fixed for the whole experiment. We measured the time between giving them the application and when they signaled that they found the bike with a separate timing device. After that we noted whether the bike guess was correct. At the end, we asked the users some questions for a qualitative evaluation:

- Which method did they find more comfortable to use and what was their personal opinion on if they would use our app in their daily life.
- Which possible changes they would like to see in our app.
- How did they evaluate the idea of using arrows on the screen to show the direction to turn

We collected all the data properly and kept as well potentially biased data, for which analysis of the bias was included in evaluation as well.

4.3 Results

We have put the results of our experiments into tables. For better clarity of the document, we decided to put it in the appendix chapter 7.

5 Evaluation of the results

Parameter to evaluate

To evaluate the effectiveness of the app, we focused on several key parameters. First, we measured the time taken to make the correct guess and the overall time spent across all guesses for each navigation method. Additionally, we analyzed the correlation between time and the accuracy of the choices, examining whether longer or shorter decision times were associated with correct or incorrect guesses. We also calculated the relation between correct and wrong guesses to assess the reliability of the methods. Finally, we evaluated the improvement in user performance when utilizing the app compared to other approaches, highlighting its potential advantages in a real-world, object-rich environment.

5.1 Experimental biases

There were several biases, which influenced the results of the experiments.
At first it was raining the day during the experiments, which lead to difficulties with the sensitivity of the phone screen for touching. For example the slower scroll interaction caused by the raindrops during the map method led for some participants to higher time results. Also other distraction like people passing by or putting off your gloves effected the results.
The reaction time for stopping the time is as well included in the numbers, though it is included in every single time the comparison is still fair.
There were some technical difficulties with the prototype during the experiments, which led to wrong guesses for the app method and a strongly increasing. The technical problems, which we encountered during the experiment, are explained in detail in the section 3. The reason for the wrong guesses was, because the technical difficulties lead to assuming wrong bikes, where as our app shows with the corrected version an almost 100% accuracy for finding the bike. Due to time management, we could not repeat the experiment with our new version, which would have been the normal case, but we have decided to include this bias in the evaluation and tried to handle this influence the best way possible. That is why we made the decision to evaluate some of the results both times, one with the wrong guesses and one with only the correct guesses. The reasons are that in a second run with the new version of the prototype the location misinterpretation would have been almost eliminated automatically. The more, the outliers were not produced by the participants themselves or their interaction with the prototype, but by the prototype itself. A third reason is that the differentiation between wrong and right is less relevant than the comparison of the needed times because it only shows the accuracy, which can also be just underlined by the correct guesses alone without wrong guesses next to it.
For the map method it was difficult to use the GPS correctly due to its inaccuracy, so a rely on the map was necessary, which some participants learned through the experiments, but did not figure out at first. The background of our participants was not very diverse. All of them are students of nearly the same age and studying in the field of science. Most of them are male. This should not strongly effect the results, although the technical background helped the participant with the usage of the device and the technical context.
We have decided to tell the participant after their guess, which bike the chosen bike was. This should help them reflect on their decisions and learn with it. A potential learning curve through the experiment for each participant includes reflection of the correctness of the guess, as well as getting more used to the method.

5.2 Experimental time

As a remark in advance, the results show mainly an absolute amount of time, because the equal amount of experiments (6 in total, 3 per app method, 3 per map method) performed by a person for both methods leads to a valid comparison, although the absolute numbers. The results with wrong guesses excluded, show mean values over the time to preserve a relation between the values.

The following figure 3 shows for both methods the app and the map, the amount of time needed for all correct guesses and for all wrong guesses. It is visible that for correct guesses the time for finding the bike in our app is much less than the amount of time needed for all correct guesses using the map. That means that our app is more effective in helping the user to orientate and therefore find the bike's position faster than the map/GPS method.
Nevertheless, the total time of the incorrect guesses for our app is very high compared to the time for correct guesses due to mentioned outliers.
For the map method, the figure underlines that no matter which result it takes more time to guess the bike's position. Compared to the app, for correct guesses it needs more than three times the amount of time. One reason is the behavior of the participant 2, which shows that they take a longer time to guess their bike position due to the uncertainty of the position. For the app, the deciding process was faster, especially after realizing how the target bike is visualized.

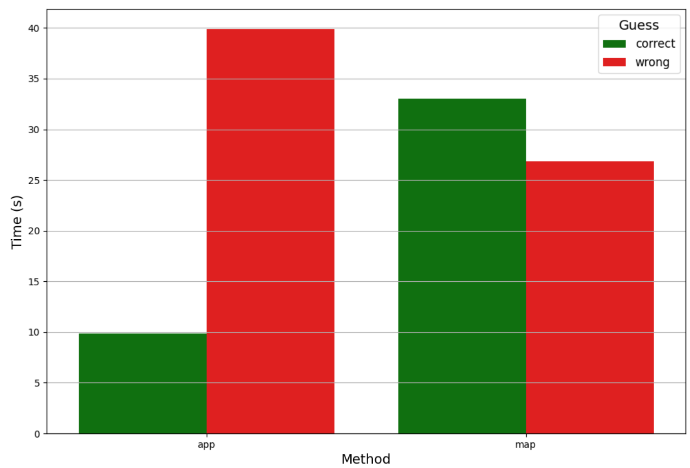
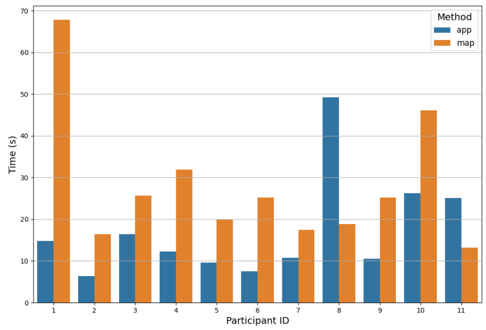
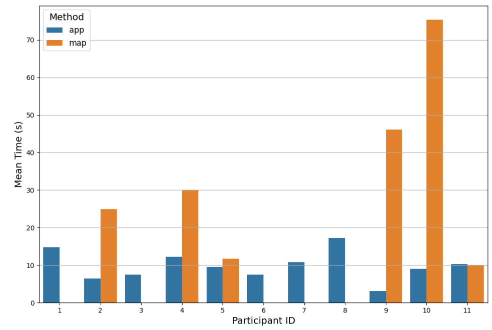


Figure 3: Time by method and correctness

Analyzing the results of figure 4a, which show the absolute experimental time for each participant for the app method and the map method, leads to the validation of the hypothesis. For all participants except of participants with id=8 and id=11 it can be seen that the times needed for the app method are lower than for the map method. The exceptions are caused by the previous described outliers. The values of the map method are in more than 2/3 of the participants twice times or more higher as the values of the app.
The figure 4b without outliers states the intuitive understandable interaction of the app method by showing that all participants after understanding the bike's recognition performed very fast. To find the correct bike with the map it takes time to compare the map with the environment, where as looking through the camera directly at the environment and seeing the bike projected is fastens the process.



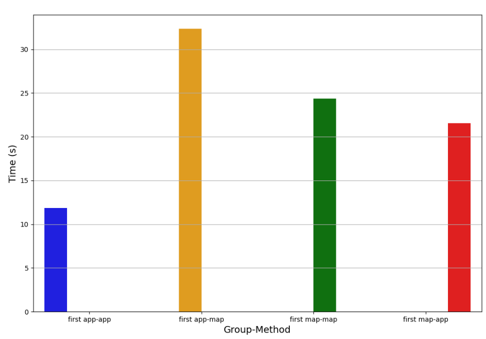
(a) Time for each participant by method



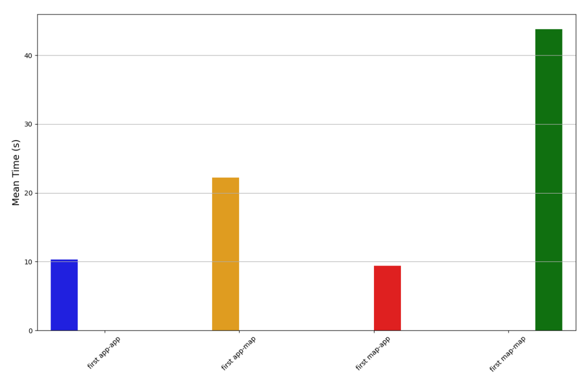
(b) Mean times without wrong results

Figure 4: Time for each participant comparing the method app and map

The figure 5a compares for each group method combination the amount of time needed. The reason behind dividing the participants into research groups was to find out if it matters to start getting to know about the app method in the first place or using the map method for the first time.
The given data at first hints away that first diving into the other method extends the time needed for the other method after that (first app-map, first map-app) comparing to starting with the same method (first app-app, first map-map). The differences can be explained, that getting used at first to another method, can extends the time to switch to a complete other method before starting to really use it. Anyways it is still a not yet validated hypothesis and the appearance can be caused by outliers.
In 5b there is no difference of starting method for the app shown. So the participants are not struggling with switching from one method to another. The time gap we assumed before has its origin in the influence of the outliers on the data.



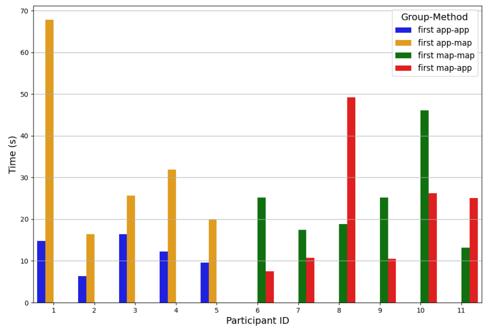
(a) Time for each method and group



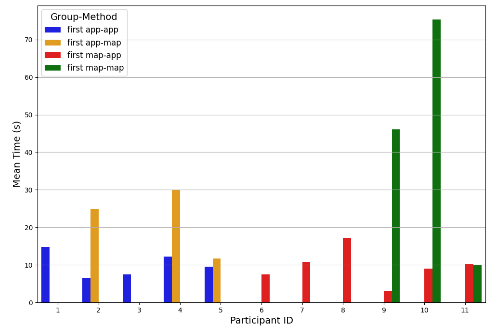
(b) Mean times without wrong results

Figure 5: Time for each group and method combination

To see how participants individually performing in their research groups first app or first map there is figure 6a. It reinforced that the results of the different research group did not differ a lot because of any influence on the order of the experiments. All the blue bars of group method combination first app-app seems to be nearly equally high than the red bars of first map-app (no counting outliers). The same impression gives the comparison between first map-map and first app-map. In figure 6b it can be seen even more that the order of the app's usage is irrelevant concerning an influence on the results.
Again both figures state the faster bike localization time for almost all participants with the app method by looking at the blue and red bars. As a remark, no shown bars for a participant in 6b means that they have no successful experiment for the method, which was quite common with the map method.



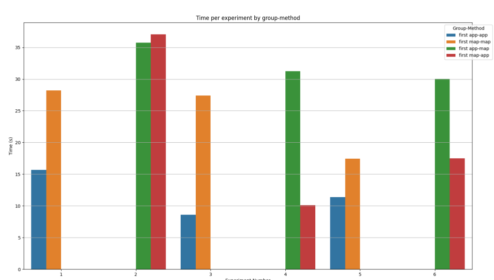
(a) Time for each participant by method and group



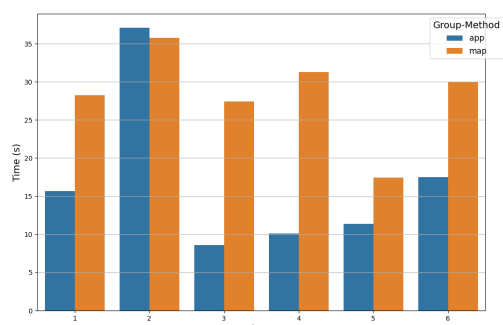
(b) Mean times without wrong results

Figure 6: Time for each participant in group and method combination

We evaluate as well the different amount of times for each experiment number, which is shown by the figures 7, to draw a connection between the method and the number of the experiment. In 7b the orange bars do not show a pattern saying that it does not matter in which order the map method is used. This could reason in the already existing knowledge how to use the map method, which presents our state of the art method to find the bike. Participants did not encounter usage problems or were not loosing time to understand how the interaction works.
For the app method we can figure out a trend of taking more time to behave as we expected. The new way of feedback through the arrow-pointed directions took for each participant some time before starting to resolve the given task of finding the bike.
In 7a it gets even clearer that for the first contact with app, both combination first app-app and first-map app the first of the three bars is the highest, which points out that in this case the first contact with the method consumes more time for finding the bike. Especially not knowing in advance, how to indicate on the screen, when a bike is found, led to higher time and confusion, seen as well in 2.
For the map method there is a slightly tendance downwards during the experiment, but this can be caused as well by not being completely sure of the whole experimental process and not because of the new encounter with the map method.



(a) Time for each exp. no. by group and method



(b) Time for each experiment no. by method

Figure 7: Time for each experiment

5.3 Relation of correct and wrong guesses

We do not want to dive very deep into this section, because we prioritized the amount of time as a more relevant objective. Nevertheless here are some comparisons we mentioned in the section before. The figure 8 shows the correlation between the used methods and the correctness of the guess. We can figure out that the app is more accurate with 25 (out of 33) correct guesses over all participants and experiments against 6 for the map. Because the app is visually showing the bikes position by marking it with a red box, the participant does not have to translate the 2D position into the real world scene and cannot make guessing errors. For the map as the behavior trackings recall as well the participants were really unsure, which bike to chose, shown as well in table 2. In 5.1 we mentioned that the GPS was inaccurate leading to more mistakes, because participants relied on it more than on the map.

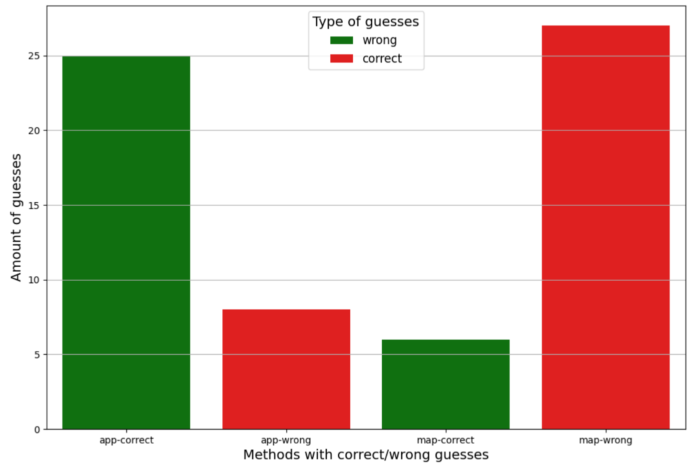


Figure 8: Relation for guesses

The relation for the correctness of a guess by each participant can be pulled off the figure 9. In here we can clearly see, that each participant struggled with using the map method successfully. For the app method it is diverse. Half of the participants have a 100% success rate, with a remark that every of the just tried it three times. On a larger scale this rate would not be realistic, but it shows the tendance towards high accuracy. Though the other half, especially the first-map research group, struggled a little bit with the new method, with successful guesses of 2/3 or even less. A reason behind it is underlined as well with the behavior in the table 2 showing the confusion about the new method and the outliers due to technical issues played their part as well.

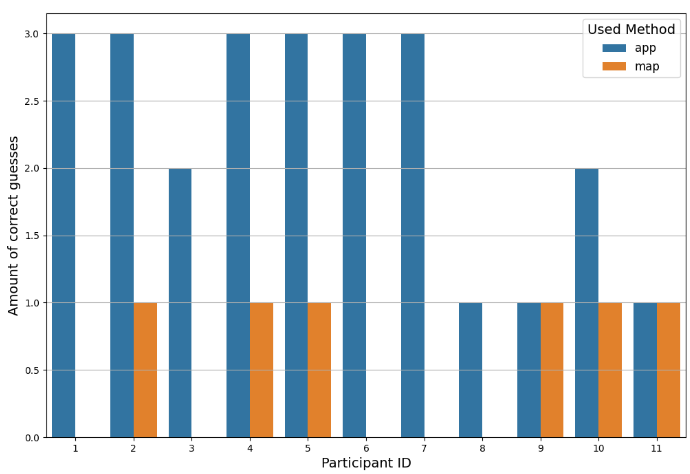
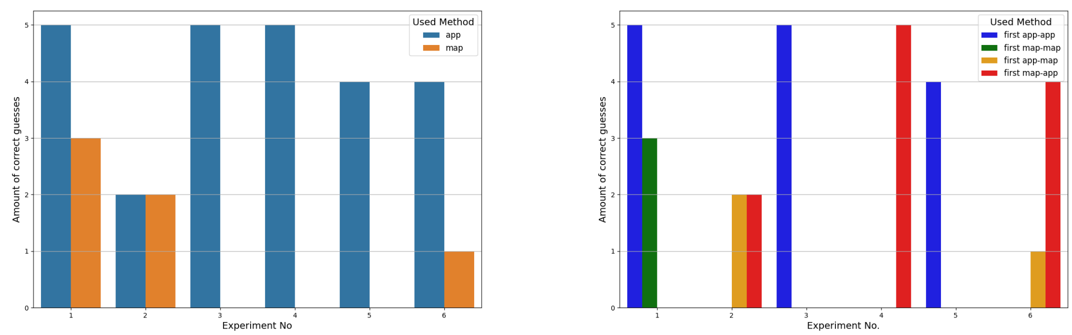


Figure 9: Relation for guesses by participants

The figure 10 creates a link between the development of the experiment and the correctness of guesses. In 10a participants succeed for the map method more at first. This is maybe because they

do not experienced the strong difference in interaction between the two methods. For the app method participants find the correct bike throughout the experiment with a little struggle at first, when using it for the first time after getting used to the other method, shown by the green bar (first map-app) lacking in height. This is supported by the behavior in table 2 like the confusion and uncertainty of localizing the bike.
Through the experiment one can see that participants tend to rely on the inaccurate GPS rather than the position placed on the map like described in 2. Comparing the position on the map with potential real time positions was hard and inaccurate as well.



(a) Guess for each experiment no. by method

(b) Guess for each exp. no. by method and group

Figure 10: Correctness of guesses for each experiment

5.4 Qualitative evaluation

5.4.1 Behavior

This section is to provide detailed descriptions of user behavior during each trial. It offers critical insights into how participants engage with the app and respond to challenges.
The first aspect is the learning curve among the participants throughout the experiment. Many participants start cautiously, struggle initially, and improve over time. For example participant 1, who starts with holding the phone like a map and cautiously approaches the bike but improves significantly in later experiments. Where as participant 2 initially has difficulties but later moves directly toward the correct location. Turning the phone upright (to use AR) is a recurring initial challenge, but once learned, participants quickly improve (e.g., Participants 1, 2, 4).
The environmental distractions bias, which we mentioned before in 5.1 is another influence on the behavior. Rain, people passing by, and umbrella usage hindered some participants (e.g., Participants 1, 10). This highlights the importance of designing an app resilient to environmental factors.
Like mentioned in 5.1 some issues with arrows and GPS lead to misbehavior of arrows is a common issue. Participant 9 repeatedly experiences confusion due to imprecise arrow guidance, resulting in wrong decisions. Participant 10 faces confusion from arrows and imprecise GPS directions. GPS inaccuracies also contributed to incorrect navigation (e.g., Participants 7, 8, and 10).
The most interesting behavior to watch was the process of developing different strategies to solve the task. Some participants primarily rely on maps or external environmental features rather than the app's directional features (e.g., Participants 3, 11). Participant 5 demonstrates a blend of approaches, using environmental comparisons to orient and ensure accuracy.
The personality of the people could make an effect as well like the confidence level. Participants like 4 and 2 exhibit calm and confident behavior after familiarizing themselves with the app, moving directly toward their goal. Others, such as Participants 7 and 9, struggle to gain confidence due to persistent app issues.
Mentioned as well before the decision time had an impact on the experimental time. Long decision times are noted in participants who are cautious or struggle with app functionality (e.g., Participants 4, 5). Conversely, participants who adapt quickly (e.g., Participant 3) make faster decisions.
To conclude these all were challenges the participants need to face during the experiment and influenced the results in some points.

5.4.2 Comfort

All participants agreed that our app was the most comfortable to use. This is related to the preconditions that we built up the scene with choosing the bike and giving them the phone in advance. The comfort includes only the usage itself.
This aligns with the study's conclusion that the app is intuitive and easier to use than traditional methods like GPS or maps. Participant 6, however, noted they didn't need the app, indicating that prior knowledge of their bike's location could impact app adoption.

5.4.3 Daily usage

This question should explore whether users would integrate the app into their daily routines.
Participants who preferred the app (e.g., IDs 2, 7, 8) found it particularly useful for large-scale or bike-dense environments. Several participants (e.g., IDs 3, 5) expressed conditional use of the app if the interface was improved or the app better implemented. There is a general divide, where as some users (e.g., IDs 8, 9) preferred traditional map-based approaches in certain scenarios, while others (e.g., ID 7) found GPS challenging with many bikes present. Participant 10, who does not own a bike, highlighted a niche issue for app adoption, where its utility depends on the user's specific context.

5.4.4 Further wished improvements in the app

The answers to the question reflect the feedback on improvements or additions to satisfy the participants.
There were some interface-related improvements with common suggestions as a cleaner interface (ID 3), clearer graphics (ID 10), and better organization (ID 5). Several participants (e.g., IDs 2, 4, 8, 10) suggested integrating traditional map views with AR for enhanced orientation and usability for combining AR and map functionalities. Improvements such as a bigger bounding box for bikes (ID 5) or 2D map view alongside AR (ID 9) were mentioned. There were as well some participants, which wished for no improvement. These responses point to the potential for hybrid solutions combining the intuitive aspects of AR with the broader contextual information offered by maps.

5.4.5 Evaluation of the direction showing arrows

The results of this question evaluate the usability of the directional arrow feature.
Most participants found the arrow helpful (e.g., IDs 3, 5, 6, 7). It was noted as intuitive and beneficial for localization and navigation. Several users identified issues or areas for improvement: Arrows should be more fluent (ID 3) or less buggy (ID 5). Some users (e.g., ID 8) found it inconvenient in dense environments with small spacing between bikes. Additional suggestions included better accuracy, such as displaying distances (ID 3, ID 10), or adding complementary elements like a "box bike" marker (ID 10).

5.5 Conclusion of the evaluation

The conclusion of the evaluation of the experimental time is that our app let the participant perform its task faster than with the state of the art method. A perspective for our app is that the time to find the bike is going to reduce, when the participants are familiar with the interaction and its feedback.
So in comparison to the map method is the app an accurate and fast choice to pick. Our method of using the arrows in augmented reality lead to quick orientation in space with finding the direction to head towards fast.
The evaluation of the correctness of the guesses shows that the participant has to get used to the new method by experiencing the localization of the bike and the feedback gained, when the bike is found. Surprisingly many of the participants struggled with the map method and the orientation in space with it.
In general the qualitative results show a preference for our AR app. Most participants found the app intuitive and useful, particularly in environments with numerous bikes. Their feedback indicates that users want better UI/UX design, a combination of AR and traditional maps, and more accurate or robust features.
The app is not universally preferred, with some users leaning toward maps or not needing navigation

aids due to strong memory or infrequent use cases. A strong bias is the attachment to already existing knowledge in usage for the map method. For some participants it is hard to rely on a new unknown method, although the experiment succeeded in showing them the great improvement from map method to app method.

6 Conclusion

The big improvement in speed and accuracy with the app towards the map method can clearly be seen in the evaluation.
Nevertheless to achieve a better interaction, there are some issues one can look more in detail onto. For a next human interaction experiment a perspective would be to compare our app to an hybrid version of our app and the method method or improving the app method with a distance visualizer to perfect the localization.

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7 Appendix

Warning, big tables incoming!

Participant ID	experiment no.	group	method	time (s)	correct/wrong guess
1	1	first app	app	31.97	correct
	2		map	76.03	wrong
	3		app	8.16	correct
	4		map	65.5	wrong
	5		app	4.25	correct
	6		map	61.87	wrong
2	1	first app	app	14.81	correct
	2		map	24.95	correct
	3		app	2.68	correct
	4		map	16.24	wrong
	5		app	1.73	correct
	6		map	8.05	wrong
3	1	first app	app	7.69	correct
	2		map	15.91	wrong
	3		app	7.21	correct
	4		map	21.87	wrong
	5		app	34.29	wrong
	6		map	39.17	wrong
4	1	first app	app	12.71	correct
	2		map	30.07	correct
	3		app	15.52	correct
	4		map	36.30	wrong
	5		app	8.49	correct
	6		map	29.37	wrong
5	1	first app	app	11.09	correct
	2		map	31.76	wrong
	3		app	9.52	correct
	4		map	16.32	wrong
	5		app	8.01	correct
	6		map	11.65	correct
6	1	first map	map	7.44	wrong
	2		app	9.55	correct
	3		map	53.53	wrong
	4		app	7.93	correct
	5		map	14.78	wrong
	6		app	4.95	correct
7	1	first map	map	5.44	wrong
	2		app	9.87	correct
	3		map	38.36	wrong
	4		app	11.02	correct
	5		map	8.41	wrong
	6		app	11.43	correct
8	1	first map	map	25.12	wrong
	2		app	81,32	wrong
	3		map	18.82	wrong
	4		app	17.23	correct
	5		map	12.63	wrong
	6		app	49.08	wrong
9	1	first map	map	46.07	correct
	2		app	20.21	wrong
	3		map	15.89	wrong

Participant ID	experiment no.	group	method	time (s)	correct/wrong guess
	4		app	8.24	wrong
	5		map	13.72	wrong
	6		app	3.10	correct
10	1	first map	map	75.32	correct
	2		app	60.73	wrong
	3		map	22.68	wrong
	4		app	6.06	correct
	5		map	40.47	wrong
	6		app	11.92	correct
11	1	first map	map	9.93	correct
	2		app	40.73	wrong
	3		map	15.11	wrong
	4		app	10.26	correct
	5		map	14.63	wrong
	6		app	24.36	wrong

Table 1: Quantitative results of the experiment

Participant ID	experiment no.	behavior during experiment
1		comment: cautious and carefully behavior
	1	holding phone down like a map, directly goes to bigger group, approaching cautiously, orientating only with arrows
	2	turns around seeing direction of map location, carefully, goes in wrong direction
	3	realize turning up phone is possible, directly finds the bike
	4	distracted shortly from people passing by, localization time on map, directly walks somewhere, struggles with deciding for bike
	5	no remark
	6	rain delays the time to scroll, stands longer and indecisive in front of bikes, aimed the direction good
2		comment: after understanding function, straight forward and fast
	1	first difficulties with function, figures out how to turn up phone, slowly looking around to localize, moving directly toward position
	2	turning around immediately in direction of bike, long decision process
	3	turning around immediately, directly finds bike
	4	no remark
	5	bike was already near him
	6	no remark
3		comment: turns less, trusts only on GPS, not map
	1	first thinking time, walks fast in right direction
	2	struggles with deciding

Participant ID	experiment no.	behavior during experiment
	3	holding phone down towards botton, realise turning it up, fastly finds bike
	4	directly walking, long decision process
	5	application problems with arrows showing false direction
	6	turns in right direction, walks directly
4		comment: calm participant
	1	realization to turn up phone, walking in correct direction
	2	carefully walking towards location, slowly approaching
	3	first confused, after calibration correct way
	4	slowly walking, decision process long
	5	immediately in direction to bike
	6	orientation in situation with the help of the map
5		comment:
	1	orientation in new system, turned a couple of times to check if bike is insight correctly, walking straight after marked bike is showing on screen
	2	orientation on map took a long time, confused, just guessing
	3	almost directly sees it, turning to make sure of recognition
	4	no remark
	5	larger turns to scan for environment
	6	orientation with environment-map comparision, finds it fast with this
6		comment: struggles strongly with the maps method
	1	turns in wrong direction, turns more, fastly deciding
	2	turning up the phone, walks in correct direction
	3	tries to use augmented vision in Maps
	4	turning left and right, directly walking
	5	walks in opposite direction
	6	no remark
7		comment: at first not moving at all
	1	just looking on map, pointing immediately at random bike, confused with usage
	2	no moving
	3	GPS is totally offset, but decides for right direction
	4	no turning, directly moving towards correct bike
	5	can only guess direction
	6	confused between some near bikes, arrows behave incorrectly
8		comment:

Participant ID	experiment no.	behavior during experiment
	1	carefully turning, right direction, then GPS distracts from right path, bike was taken in the mean time
	2	wrong direction confused, long time, because of arrow misbehavior
	3	orientates himself with map, not GPS
	4	quick orientation
	5	decision made very fast
	6	holds phone wrong, arrows point to wrong direction
9		comment: confusion about arrow pointing
	1	right direction, imprecise GPS, standing in front of right bike, then wrong decision
	2	walking straight, failed arrows, following in wrong direction
	3	no remark
	4	walks in wrong direction, not following arrows correctly
	5	after orientation directly guessing
	6	turning directly right
10		comment: rain and umbrella disturbed fluent process
	1	walking a lot, turning around a lot, going forth and back
	2	phone pointed to the ground, failing arrows lead to confusion
	3	GPS leads in wrong direction
	4	turns phone up directly, right direction
	5	scrolling a lot, looking around, walking in a decided direction, long time to decide
	6	right direction immediately
11		comment: good with map orientation
	1	orientates himself with environment features on map
	2	false arrow pointing leads to nowhere
	3	no remark
	4	turning to assure that bike is on screen, directly walking towards bike
	5	right direction
	6	confused, opposite direction

Table 2: Behavior during the experiment

ID	comfortable	use in daily life	changes in app
1	our app	used to digital maps	no improvements
2	our app	combination of both, big parking lot map is better to orientate, then area scan	combine both
3	our app	ours, if better implemented	clean interface
4	our app	map: knows how his bike looks, less work to prepare	combination of both
5	our app	less preparation work then app, with cleaner interface	bigger box around bikes
6	our app	neither, remembers where the bike was parked	no improvements
7	our app	our app, a lot of bikes, then GPS is hard to use	no improvements
8	our app	google maps, because in real time scenario f.e. useful information about buildings in the map, but for some scenarios app practical, because it gives you the direction perfectly	adding map with information
9	our app	app for direction towards object is helpful, but maps is more diverse, likes 2D look more	instead of augmented reality to 2D view
10	our app	tends to use the app more, but in general not use case for them, because owns no bike	maps with app feature, nicer graphics, cleaner interface
11	our app	our app with better interface	would add arrow scaling and 2D minimap

Table 3: Qualitative results of comfort, usage in life and changes

ID	idea of direction arrow
1	helps to find the right direction
2	intuitive
3	good, maybe more fluently, showing the distance towards object
4	helpful, stopped too early and flipped too fast
5	helpful, but still a little buggy, helps to find direction
6	useful, intuitive
7	helps how to localize yourself in the scene
8	useful for direction, inconvenient, believes that with smaller range between each bike, it can be hard to distinguish just with arrows
9	easy, ”supercool” to track objects
10	helpful, as direction identifier, plus box bike for accuracy
11	needs some time to understand, then very fast to handle

Table 4: Qualitative results of the new way of interaction with arrows pointing the direction