AI'M BOULDERING
shareAIble Interface

Short description

Bouldering is a form of rock climbing on small rocks or artificial walls. On the way to the top one has to solve more or less complex so called bouldering problems. Good technique allows climbing with more ease and efficiency, consuming less energy and reducing the risk of injury. Therefore we want to develop an AI-powered system, which analyzes the technique of a climber and helps to improve it.

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About Artificial intelligence

Definition according to Wikipedia[1] : „Artificial intelligence (AI) is intelligence—perceiving, synthesizing, and inferring information—demonstrated by machines, as opposed to intelligence displayed by animals and humans. Example tasks in which this is done include speech recognition, computer vision, translation between (natural) languages, as well as other mappings of inputs."

About Human-AI teams

Human-AI teams are increasingly being used to tackle complex tasks and address challenging problems. Human-AI teams are teams in which one or more humans work together with one or more AI supported systems, to achieve a common goal.

This trend is gaining momentum, especially in crucial fields such as healthcare, criminal justice, and finance. But as with any collaborative work, team performance does not depend solely on the performance of an individual team member, e.g., the accuracy of the AI system. The best team performance is often achieved when all team members know their own strengths and weaknesses, as well as those of the other team members. Distributing the tasks in a way that the individual team members complement each other well enables good collaboration and performance. [Bansal et al. 2019]

Strengths and weaknesses of AI and humans

Cognition, i.e., receiving sensory input, encoding and processing it, and finally deriving meaning from it, can be viewed as a hierarchy. At the bottom of this hierarchy is data, from which information can be obtained, which is why information is one level higher. Through the interpretation of the information knowledge can be derived, and knowledge leads to wisdom, which is at the top of the hierarchy. AI is capable of processing large amounts of data and information, and is thereby usually faster and more accurate than a human could ever be. What AI cannot do, however, is interpret information to generate knowledge and thus gain wisdom - that's what we humans are good at. [Carter 2021] Therefore, a good collaboration between humans and AI is often characterized by the AI providing advice to the human based on data and information, while the human is responsible for making the final decision. [Kamar et al. 2013] Ideally, talented, compassionate, and moral humans should focus on the area of knowledge and wisdom where they can add the most value, and leave the rest to AI (wherever possible). [Carter 2021]

[1] https://en.wikipedia.org/wiki/Artificial_intelligence, accessed December 2022

How could Human-AI teams work

Collaboration between humans and AI in a team can impact, among others, the following areas [Lenox et al. 1999]:

- Reducing the time to make a decision
- Allowing teams to consider a broader range of alternatives
- Allowing teams to manage contingencies flexibly by rapidly re-planning
- Reducing the time required for a team to form a shared mental model of the situation
- Reducing both individual and team errors
- Increasing the cohesion among team members
- Increasing overall team performance

However, collaboration between humans and AI is not always the right approach. In the run-up, it must be considered whether the use of an AI makes sense in the respective project. If the use of AI is considered beneficial, it is necessary for a functioning human-AI collaboration that all team members are aware of the strengths and weaknesses of their teammates (including the AI) and (inter)act accordingly. [Lenox et al. 1999]. What matters most to human team members is that the AI has a high/sufficient skill level. In addition, shared understanding between humans and AI, communication skills, and human-like behavior and performance are considered important characteristics. Whether individuals are willing to collaborate with an AI depends on their previous collaboration experience with humans as well as pre-existing attitudes toward AI. [Zhang et al. 2021]

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Interaction Approaches

Shareable Interfaces

Shareable interfaces allow multiple people to interact simultaneously on a single interface. Interaction can take place either jointly on a single screen (single display groupwork) or on multiple screens (distributed systems), allowing for more flexible collaboration. E.g. the use of shareable interfaces to support learning through exploration and creation is one promising use case. [Rick et al. 2009] However, usability is always an important issue when operating with shareable interfaces.

Distributed systems have the advantage that they can be used by small and large groups. One component may only support one user, but the integration of components make the interface shareable. Single display group work systems are rather suitable for small groups. [Rick et al. 2009]

Embodied Interaction

"Embodied Interaction is interaction with computer systems that occupy our world, a world of physical and social reality, and that exploit this fact in how they interact with us." [Dourish 2004] Thus, embodied interaction is the shift of human-computer interaction from the screen to objects in the real world. The aim is to create an intuitive interface for interacting with computers.

Embodied interaction is based on the embodied cognition theory. Embodied cognition emphasizes the *importance of the relationship between the mind and the body*, and its interactions with the surrounding environment, in the acquisition, development and understanding of knowledge. [Wilson 2002]

In recent years, the opportunities to support embodied interaction have expanded significantly. A range of body-motion sensing technologies have been developed, and ubiquitous computing infrastructures that can capture or display contextual data have evolved [Marshall et al. 2013]. Examples are wearables, handhelds and tabletops, high precision motion tracking systems and virtual reality. [Lee-Cultura 2020]

Multi Experience User Interfaces

When developing novel software systems, it becomes increasingly important to include other types of user interfaces besides the "traditional" graphical user interfaces. For example, Conversational User Interfaces (CUI) such as chat and voice are gaining popularity. For an integrated user experience, all user interfaces in a system should be aware of each other and collaborate. Although they have many advantages, it is challenging to create multiple user interfaces and provide a good user experience. [Planas et al. 2021]

Brain-to-computer Interaction

This type of interaction is controlled by the human's thoughts. It is possible by measuring human brain activity and translating it into computer understandable commands. One example is the BrainNet by Jiang et al.. Using brain to brain communication, they try to solve a Tetris game using the intelligence of multiple players. The brain signals are decoded with real-time electroencephalography data analysis. In addition, transcranial magnetic stimulation is used to transmit information non-invasively to the brain. [Jiang et al. 2019]

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Problem space research

Problem Space

Bouldering is a form of rock climbing on small rocks or artificial walls, which does not require belaying due to a low height (usually 3-4 meters). For safety and to be able to jump off at any time, there are soft mats under the walls. The goal is to reach the top. On the way to the top one has to solve more or less complex so called bouldering problems.
Bouldering as a sport has recently gained popularity, so there are many bouldering beginners. In addition to physical strength, endurance and focus, bouldering also requires different techniques. To acquire those, it is possible to attend courses with a climbing instructor, but since it is not a necessity to take up the sport, beginners often refrain from doing so. However, good technique allows climbing with more ease and efficiency, consuming less energy and reducing the risk of injury. In addition, good technique allows climbing at higher difficulty levels, which is the goal of most hobby boulderers.

Therefore we want to develop an AI-powered system, which analyzes the technique of a climber and helps to improve it. For the analysis, the climber performs some standardized bouldering routes while being filmed. The AI analyzes the footage in near real-time using skeletonization, and performs a motion analysis. If technique flaws are detected, such as for example poor footwork or grip technique, improper use of momentum or incorrect body positioning, this is communicated to the climber in a subsequent video analysis. To help the climber improve, the AI defines a set of routes for the climber that are specifically designed to train the climber's weaknesses.

Related Work

ClimbTrack with betaCube

ClimbTrack is a proposed assistance technology for climbing.[2] It was developed with a similar idea to ours: to facilitate explaining moves to others and to improve your bouldering. Its features include detecting climbing walls, projecting saved climbing routes or moves directly onto the wall, and providing detailed video analysis. The components of the system include a *mobile camera-projector unit, the betaCube, a smartphone app and a wearable*.[3] The betaCube is a self-calibrating camera-projection unit that features 3D tracking and distortion-free projection. The system works with augmented reality. [Wiehr et al. 2004] In the ClimbTrack app one can plan and save new climbing routes. When the system is connected to the athlete's personal wearable, sensor data can also be used to generate assistance.[4]

Differentiation to our technology

[2] http://climbtrack.com/landing.html#tf-team, accessed February 2023
[3] https://www.dfki.de/web/news/climbtrack-gewinnt-den-cebit-innovation-award-2016, accessed February 2023
[4] https://www.dfki.de/web/news/climbtrack-gewinnt-den-cebit-innovation-award-2016, accessed February 2023

We both start from the same idea to improve the climbing or bouldering technique, but we have a different implementation concept. Our system is based on a training concept in cooperation with an AI as a trainer. ClimbTrack does not use AI. Here, other climbers are supposed to give the input to improve the climbing technique. Then their input, e.g. correct movements and body positions is shown to the others by projecting them. Both ClimbTrack and our technology use video analysis. But, ClimbTrack doesn't have a sophisticated training process following this analysis process.
The setup and technologies used are also different from ours. A projector is used by ClimbTrack to display the routes that the climber could climb. We use illuminated climbing holds. We think that these allow a more pleasant climbing atmosphere, as projectors are usually very noisy. One disadvantage is that our system can only be used for climbing walls with these special holds. ClimbTrack's system is more versatile here.
For planning routes we only provide a display nearby the climbing wall. In the ClimbTrack solution the climbers can plan their routes with the app. Unlike ClimbTrack, we do not use wearables that measure sensor data. Our system works solely through video analysis. We think that this is sufficient. It also simplifies the use of such a system in a climbing gym.

Positive aspects which we might adopt
So far, no app has been integrated into our system. However, saving the learning progress in an app would also be a logical and possibly useful extension for our proposed solution.

BouldAR

BouldAR is a mobile augmented reality application to support collaborative boulder training. The system is designed to achieve three main requirements: defining problems and goals, managing a training diary and collaboration and sharing of problems. You use it by pointing your smartphone's camera at the wall. Then you can touch the holds you want to include in your route on the display. They will be marked in augmented reality on your smartphone's display. This way, they don't need any additional interface elements. [Daiber et al. 2013]

Differentiation to our technology
The main difference is that the concept of BouldAR doesn't include a video analysis of your technique. Moreover, the collaboration in BouldAR only includes the climber and its friends, no additional AI collaborator. In addition, the setup is kept much simpler, which makes it more flexible, but probably less attractive.

Positive aspects which we might adopt
In their work BouldAR offers a lot of ideas for collaboration between friends, e.g. sharing of routes. Some of their ideas might be a good extension for our solution. As a first idea, we could offer the possibility to share boulders which we really liked with others.

Multi-Axis Climbing Load Cells (MACLoC)

MACLoC aims to collect data on climbing to provide athletes with detailed feedback on their training progress and the technique used. Their solution provides real-time information on hold contact forces and body center through complex technology attached to the climbing holds. Their patented system offers several uses, such as a learning curve comparison of different climbers. Their idea is that knowing how experienced climbers progress through the route and applying force to holds can help coaches and trainers develop specific training programs.[5]

Differentiation to our technology
We have decided against attaching sensors to climbing holds. On the one hand, this is associated with high costs and, on the other hand, we assume that video analysis can provide sufficient or more information about climbing technique.

InterPoser

The goal of InterPoser is to facilitate the communication between a trainee and a trainer. Because according to them the problem here is that climbers cannot mimic the trainer's movement in parallel. InterPoser is a video feedback system which creates an intermediate motion from the movement combination of a beginner climber and a more experienced climber. Afterwards, the combined motion is transferred into realistic images of the climber. The system is expected to support beginners to acquire more detailed observation and understanding of the motion in climbing. [Shiro et al. 2019]

Differentiation to our technology
Conceptually, this approach is quite different from ours. Our goal is not to show the exact movement to the climber, but to help the climber learn more efficient movements. In addition, the illuminated climbing holds and sound give us the opportunity to communicate with the climber directly during the bouldering.

Positive aspects which we might adopt
InterPoser also uses skeletonization for motion analysis. Here we can take an example from this technology.

ClimbAX

ClimbAX addresses the same problem space as we do. They also have the goal of reaching automated coaching. The system consists of two wearables (for the left and right arm) and an app. With the wearables they detect climbing sessions and moves, which form the basis for the performance assessment via app. The assessment parameters include: power, control, stability, speed. [Ladha et al. 2013]

Differentiation to our technology
Although their aim is to reach automated coaching, they don't provide a full automated coaching system like we do. Also they only focus on the parameters power, control, stability and speed and not on climbing technique in general.

Learnings
This technology was brought to the market by the swiss brand "Mammut" in 2021. Unfortunately, it couldn't break through and was therefore taken off the market.[6] Although they did evaluations

[5] https://www.hbm.com/de/7900/macloc-die-intelligente-kletterwand/, accessed February 2023
[6] https://www.mammut.com/at/de/support/climbax, accessed February 2023

of the product with about 50 climbers [Ladha et al. 2013], users somehow didn't want this product. We can only make assumptions about why this was the case. We assume that the high additional costs for a new technology (the two wearables) are not in balance with the benefits of this technology for the user. At the end of the day, the technology offers similar features as a pedometer for runners, but cannot provide concrete training tips. We assume that users do not want to put money into a technology that can only serve a very specific purpose. Therefore, we have designed a technology that does not require any material from the user. Only the climbing gym has to invest in different technologies. However, this should be profitable for them due to the possibly increasing number of visitors.

ClimbSense

The goal of ClimbSense is to provide tracking technology for climbing. For that they introduce a system that automatically recognizes climbed routes using wrist-worn inertia measurement units (IMUs). [Daiber et al. 2015] Since their objective is very different from ours, the approach will not be analyzed further here.

AugKlimb

AugKlimb is a project where parallel to different user tests an app for intermediate climbers was developed to improve their training. It was explored which form of data-capture and output-features could improve a climber's training. Furthermore, it was analyzed how climbers reacted to viewing their data throughout a climbing session. [Storry 2020]

Positive aspects which we might adopt

This project gives us ideas which technologies climbers want to integrate in their training. Additionally, it is a source of inspiration for different user-centered approaches we can adopt in the future to our project.

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Conceptual Model

Assumptions & Claims

Assumptions	Claims
As a climber you want to improve.	Our AI-based solution will help climbers to improve.
It's hard to assess for yourself what your climbing strengths and weaknesses are.	The AI can automatically and reliably detect strengths and weaknesses in climbing.
If you know your weaknesses in climbing, you want to explicitly train them.	The AI can generate boulders that target a weakness to train.
Climbers want to train specific moves or routes.	The AI can generate boulders to train certain moves or routes.
Not everyone can or wants to afford a personal trainer or training lessons.	The AI as a cheaper alternative can replace a personal trainer for hobby climbers, for advanced climbers the AI can support the trainer.
Climbing coaches want support in conducting their training.	The AI can provide useful support for climbing coaches.
The concept will be profitable for the climbing hall.	Climbers will enjoy training with the AI on a regular basis.

Metaphors & Analogies

The AI as a climbing coach. Users of our system can imagine the AI as a human climbing coach. The coach watches them climb, analyzes what they do, and explains (in natural language) to them where their weaknesses lie. The climber and the coach decide together which weakness should be trained next.

Illuminated holds. The concept of illuminating holds on the wall to define a route is something climbers already know from other systems such as the Moonboard[7].

Define/Generate a route. Climbers are already familiar with the concept of defining routes from training on the system wall, where they define routes for themselves or for others in order to practice a particular movement or technique.

[7] https://www.moonboard.com/

Concept

The situation. Hobby climbers often have technical weaknesses (which they themselves are not aware of), leading to a higher risk of injury and higher energy consumption, and preventing them from getting better.

Current user experience. Weaknesses can be uncovered and addressed in training with a climbing coach, but these training sessions are expensive and require commitment.

Why is a change needed? Many hobby climbers do not attend training sessions, thus exposing themselves to an increased risk of injury. Moreover, some of them lose interest in climbing because they do not get better.

How will this change improve the situation? The AI-based solution is not only cheaper than a climbing coach, but also requires much less commitment, as you don't have to make an appointment, but can simply train when you want and as long as you want. Training with the AI should make climbing safer and more fun, especially for beginners and hobby climbers, as they will progress more quickly.

AI-Climber Interaction

Interactions

- The AI analyzes the weaknesses of the climber while they climb
    - Recording of a video with a camera in front of the climbing wall
    - Analyzing the recordings by means of the motion analysis
- The AI informs the climber about their weaknesses
    - The detected weaknesses are displayed on a screen and assessed according to severity
- Climber decides which of the weaknesses they want to train
    - For each weakness, details can be displayed (on the screen) that describe the respective problem and its possible correction in more detail
    - The climber chooses (on the touch screen) from a list of their individual weaknesses which of them they would like to train
- The AI generates routes targeted to the climber
    - The AI generates routes tailored to the climber's choice and displays them to the climber by illuminating the respective holds on the climbing wall
- The climber can define (parts of) routes themselves
    - Holds can be selected or deselected by double tapping them on the climbing wall or on the touch screen
    - An on-screen option allows the climber to indicate that the AI should generate a completion for a partially selected route

Set-up

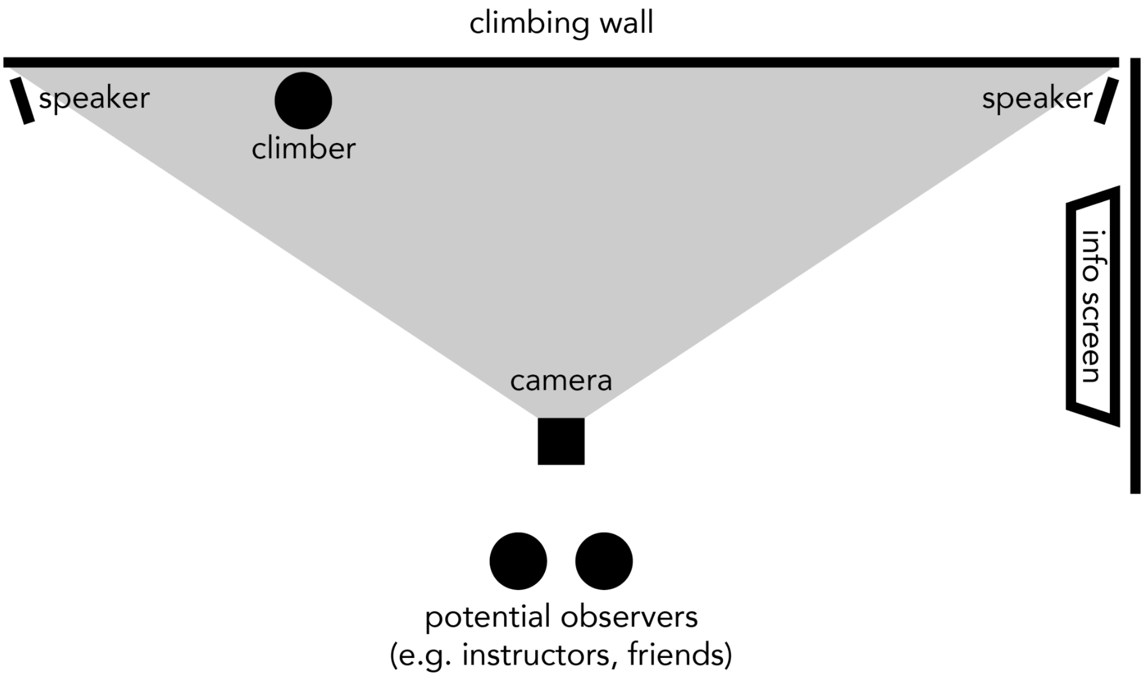
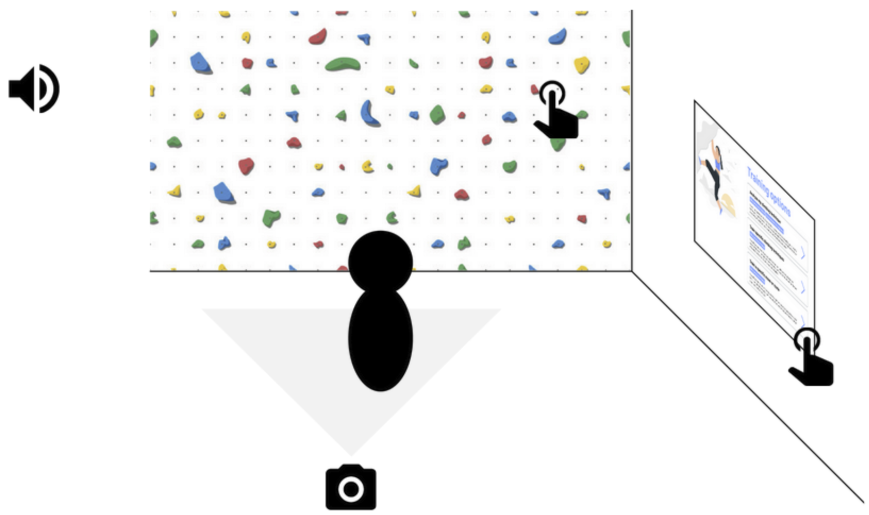


Image source: https://www.climbfit.com.au/wp-content/uploads/2020/11/kilter-board-kirrawee.jpg

Interactive Components

- Climbing wall
- Touch-Screen
- Camera
- Audio Speaker



Articulation of interaction types

Instructing

- Climber can choose from different training options
- After the analysis the climber can decide what they want to train
- The climber can define (parts of) a route themselves

Conversing

- AI guides climbers through the analysis and training process through on-screen instructions, audio feedback and illumination holds on the climbing wall
- The climber can define parts of a route and let the AI complete the route
    - Individual holds can be selected and deselected and parts of the route can be regenerated until the climber is happy with it

Manipulating

- The climber can select or deselect individual holds by touching them on the climbing wall or on the touch screen

Exploring

- The climber can explore the climbing wall, i.e. look at and try out individual holds
- The climber can explore the listing of their weaknesses and view details about them

Responding

- The AI suggests a route, the climber decides whether to climb the route or not
- The AI suggests weaknesses that can be trained, the climber decides if they want to do so

Collaboration Approches AI-Climber

Option 1: The climber does not know their weaknesses

Briefing phase

- Climber indicates their climbing level

Climbing phase

- AI generates routes, targeting different techniques

- Climber completes these routes, while AI analyzes the technique in real time
- AI adapts routes if weaknesses are detected (to analyze them more accurately)

Analysis phase

- AI lists the detected weaknesses
    - AI “presents” findings (video/foto analysis)
    - Climber selects out of provided options

Climbing phase

- AI suggests routes to train a specific weakness(es)
- AI continuous to analyze the technique during training

Each climbing phase can be followed by another analysis phase, which in turn can be followed by a climbing phase.

Option 2: The climber knows which weakness(es) they want to train

Briefing phase

- Climber articulates which weakness(es) they want to train

Climbing phase

- AI generates routes to analyze the indicated weakness(es)
- Climber completes these routes, while AI analyzes the technique in real time
- AI adapts routes if weaknesses are detected (to analyze them more accurately)

Analysis phase

- AI shows the climber where the indicated weakness(es) were noticed
    - AI “presents” findings (video/foto analysis)
    - Climber can decide if they want to continue training

Each analysis phase may be followed by another climbing phase, which in turn may be followed by an analysis phase.

Option 3: Climber wants to train a specific move or route

Briefing phase

- Climber indicates their climbing level
- Climber can define (parts of) a route themselves
    - AI proposes completions for this route

Climbing phase

- Climber climbs the (jointly) defined route, while AI analyzes the technique in real time

Analysis phase

- AI shows the climber where the indicated weakness(es) were noticed
    - AI “presents” findings (video/foto analysis)
    - Climber can decide if they want to continue training

Each analysis phase may be followed by another climbing phase, which in turn may be followed by an analysis phase.

Reflecting on the Solution

In this section we are investigating the appropriateness of the use of technology in our solution with the three questions of Baumer and Silberman[8].

Could the technology be replaced by an equally viable low- tech or non-technological approach to the situation?

Since our goal was to replace the non-technical version (a coach) with an automated coaching system, our solution requires some technology. However, it can be debated whether the analysis by AI is necessary or whether a solution that simply suggests routes to train certain techniques would be sufficient.

Does a technological intervention result in more trouble or harm than the situation it's meant to address?

There is a danger that bouldering beginners are overwhelmed by our training concept. Instead of focusing on bouldering and getting better, they might be too distracted by the technology options and technique tips. This could result in the opposite of our intention and dampen their learning progress. Because in the beginning, you improve the most by bouldering as much as possible.

Furthermore, it could be problematic if the routes suggested by the AI are too easy or too difficult for the climber. If the routes are too easy, the climber can hardly improve, and if the routes are too difficult, the climber could get frustrated or even injure himself trying to climb the route.

Does a technology solve a computationally tractable transformation of a problem rather than the problem itself?

That remains a point of discussion. It could be that the real problem is that people focus too much on themselves and do not work together i.e. experienced climbers refuse to pass on (technical) climbing tips to less experienced climbers. On the other hand, if a group of friends goes bouldering and everyone is at the same level, it is difficult to give each other advanced technique tips. Also, our solution gives a detailed overview of all the weaknesses of your climbing technique in general. For such a detailed analysis, a trainer would need a lot of time. The AI system is much faster here than the human. Therefore, our system provides hobby climbers with an analysis and training that is otherwise reserved for professional athletes. Of course, it still needs to be tested how helpful this analysis and training really is for hobby climbers and whether they need and accept it. However, if the concept would work out it could certainly provide added value for hobby climbers.

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[8] Eric P.S. Baumer and M. Six Silberman. 2011. When the implication is not to design (technology). In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11). Association for Computing Machinery, New York, NY, USA, 2271–2274. https://doi.org/10.1145/1978942.1979275

Grounding of design

Internet of Things

Internet of things describes the integration of things with the world of the Internet. By adding intelligent hardware and/or software capable of communicating with each other, new forms of communication between people and things, and between things themselves, emerge. [Mouha 2021] We would locate our solution in this paradigm. AI and climbers communicate in our system via the climbing wall, the touch screen and via audio. Also, the AI's analysis system consists of several components communicating with each other, e.g. the camera (hardware) and the software to analyze the movement.

Vision

How to enable people to access and interact with information in their everyday lives?

Our solution allows climbers to access and interact with the information collected about their climbing skills. On the one hand, they are informed about their weaknesses and on the other hand, they receive training tips based on them.

How to design user experiences where there is no obvious user control?

We provide various feedback mechanisms for this purpose. For example, when the climber reaches the top, he gets feedback from the AI through a sound that he has now completed the route. Moreover, the AI automatically detects when the climber has failed on a route and suggests to generate an easier one. The illuminated climbing holds serve as affordances to touch them or to climb the route. These features replace traditional controls.

How and in what form to provide contextually-relevant information to people?

In our solution, the climbing wall is at the center of the interaction i.e. screen, camera and sound are aligned accordingly. Furthermore, AI and climber also communicate directly via the climbing wall, which in this context is a very natural interaction.

How to ensure that information passed around interconnected devices and objects is secure

Since our data is not so sensitive, this point is not of great importance for our solution. Moreover, so far the data transport only takes place within our system in the local network of the climbing hall.

Turn to Embodiment

Our solution is based on theories and models developed under the paradigm "turn to embodiment". Interaction in this paradigm is explored through hands-on experimentation in the context of the social and physical environment. It considers approaches like "thinking through doing". [Rogers 2012] One organizing principle in this paradigm is the "Embodied interaction". Researchers and designers can adopt these principles to uncover problems in the design and use of technologies. Everyday practices can be examined, analyzed and critiqued in relation to principles, claims and arguments about embodiment. [Rogers 2012]

We took these ideas from the paradigm to develop our solution with a mainly embodied interaction. Instead of talking to the AI, the climber communicates his skills and weaknesses through bouldering. In addition, climbing routes can be defined together with the AI by directly tapping on holds on the climbing wall, which is a very natural interaction in this context.

Turn to the Wild

In the wild approaches are about prototyping new technologies to augment people, places, and environments, install interventions, and encourage different behaviors. Observing how people react, change, and integrate new technologies into their daily lives is a key concern. [Rogers 2012]

In our case, an interesting question could be how climbers react to an AI trainer and whether its use can make climbing safer (especially for hobby climbers) because they learn the technique better through it. On the other hand, one could also investigate whether the AI coach motivates hobby climbers to practice the sport longer and more regularly (because they are constantly improving and therefore have more fun doing it).

AI for Analysis in Sports

In general, there is the vision that AI can support or replace coaches in sport by providing performance analysis. [Araújo et al. 2021] There are already several approaches and example studies on the use of AI for performance analysis. One example is the study by Novatchkov and Baca, which deals with the implementation of pattern recognition methods for the evaluation of strength training. [Novatchkov & Baca 2013]

Use of Video Analysis in Sport

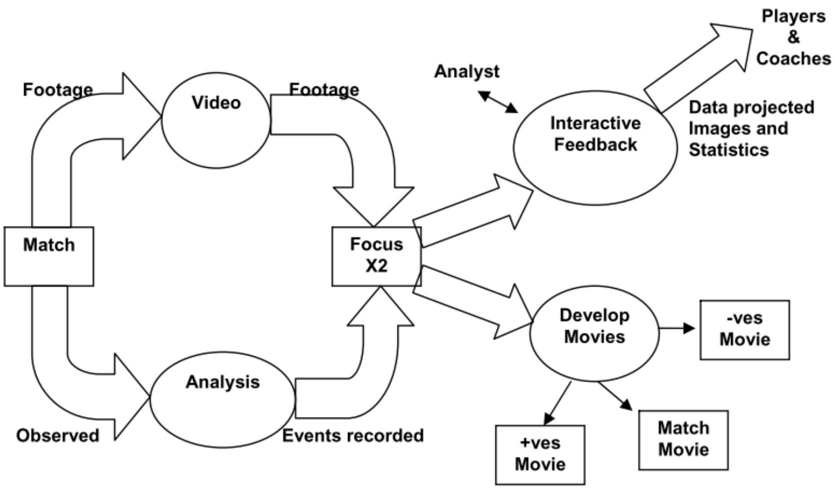
O'Donoghue provides a framework for the use of videos for match analysis within the coaching process.

Process

- Rekord match
- Main events of interest in recorded video are identified (either simultaneously with video recording or afterwards)

- Selection of events is highlighted to give the possibility to provide feedback
- System provides statistical information summary about match so the coach can identify particular problems of the match
- Before showing videos to the team coach previews videos

[O'Donoghue 2006]



Functional model of the process by [O'Donoghue 2006]

References

Araújo, D., Couceiro, M., Seifert, L., Sarmento, H., & Davids, K. (2021). Artificial Intelligence in Sport Performance Analysis (1st ed.). Routledge. https://doi.org/10.4324/9781003163589
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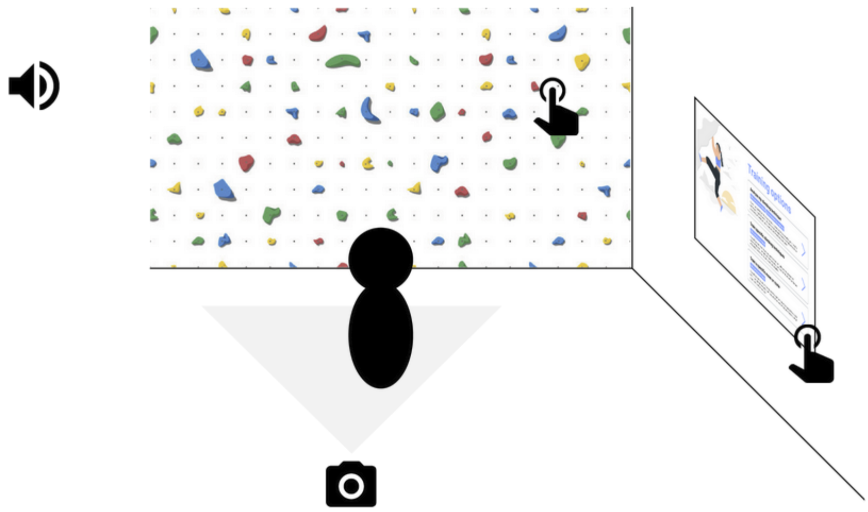
Mouha, R. A. Internet of things (iot). Journal of Data Analysis and Information Processing 09 (01 2021), 77–101

Novatchkov H, Baca A. Artificial intelligence in sports on the example of weight training. J Sports Sci Med. 2013 Mar 1;12(1):27-37. PMID: 24149722; PMCID: PMC3761781.

Rogers, Yvonne (2012). "HCI Theory: Classical, Modern, and Contemporary". In: Synthesis Lectures on Human-Centered Informatics 5, pp. 1–129.

Prototype

As already described in the chapter "Conceptual Model - AI-Climber Interaction" the interaction setup would look as follows:



The interaction on the touch screen has been prototyped with figma. View the prototype here: https://www.figma.com/proto/OOEAmo898TiRXcXvJs8kKR/AI'm-bouldering?page-id=0%3A1&node-id=4%3A5&viewport=86%2C349%2C0.18&scaling=scale-down&starting-point-node-id=4%3A5

If the climber selects "Highlight foot and hand holds" on the touch screen, the climbing wall adjusts accordingly:

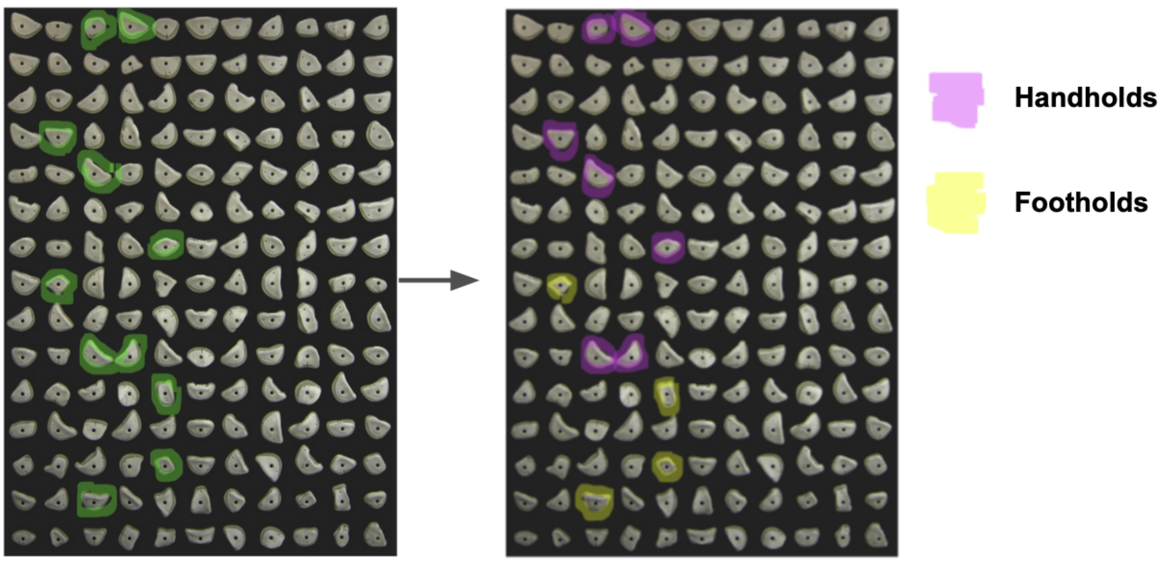


Image source: [*https://climbing-culture.com/media/61/5b/d5/1634055152/7956_KLTRBRDHM710.jpeg*](https://climbing-culture.com/media/61/5b/d5/1634055152/7956_KLTRBRDHM710.jpeg)

If the climber instructs the AI to complete a route after selecting some holds to be included, the climbing wall will look like this:

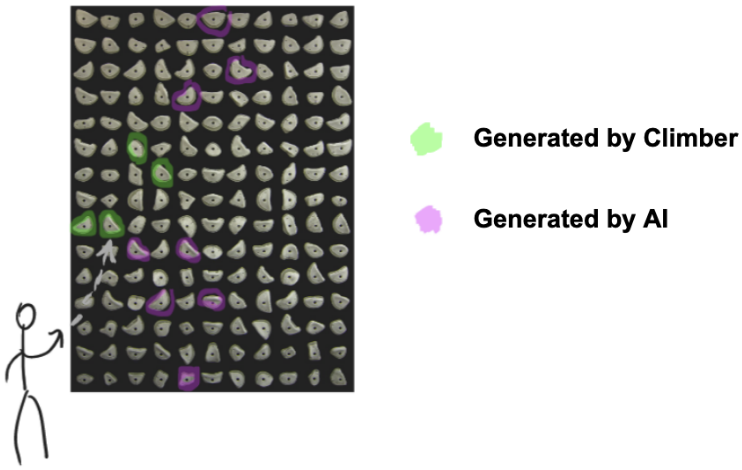


Image source: [*https://climbing-culture.com/media/61/5b/d5/1634055152/7956_KLTRBRDHM710.jpeg*](https://climbing-culture.com/media/61/5b/d5/1634055152/7956_KLTRBRDHM710.jpeg)

The climber can select or deselect holds by double-tapping on the climbing wall (or on the touch screen):

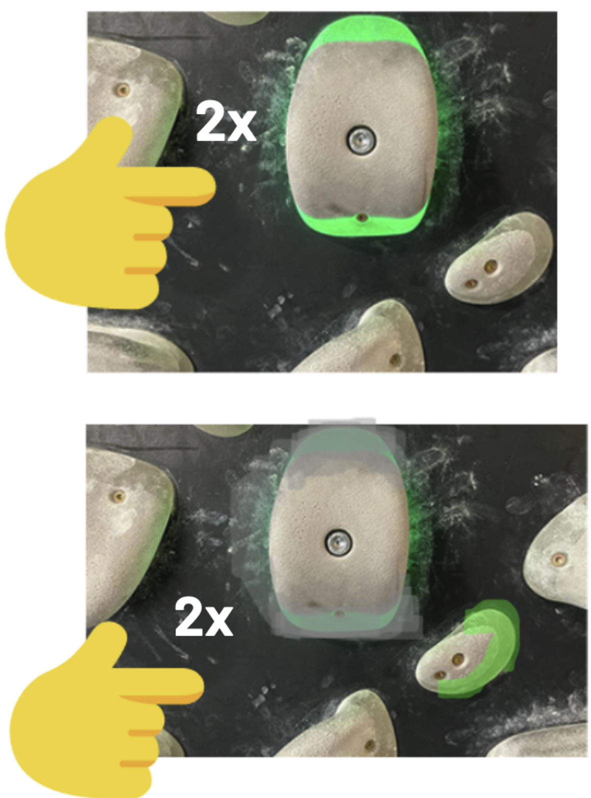


Image Source: [*https://die-kletterei.de/kilterboard/*](https://die-kletterei.de/kilterboard/)

Future Work

The concept described above focuses on the elementary interaction steps only, on the one hand to be able to communicate the idea clearly and on the other hand not to exceed the scope of this project work.

However there are many extension possibilities that could build on this concept, here are some examples:

- The system could perform a strengths/weaknesses analysis and, based on that, pair up climbers to teach each other.
- The system could be more focused on collaboration between multiple climbers. For example, if some want to train the same thing, they could take turns and learn from each other (and from AI).
- The system could have a fourth training option where it suggests routes that are similar to a given route (to train similar things).
- The system could support route setters in defining new technical routes.
- The system could be more focused on assisting climbing coaches in the training of climbers.
- One could investigate different motivational mechanisms, e.g. what do you do when a climber fails a route - will the next route then be more difficult or easier?