Beyond the Reach: A Proposal for AR Assistance for Novice Climbers

Philipp S. Fabritius
philipp.fabritius@phil.tu-chemnitz.de
Chemnitz University of Technology
Chemnitz, Germny

Lena M. Nischwitz
lena-marcella.nischwitz@phil.tu-chemnitz.de
Chemnitz University of Technology
Chemnitz, Germany

Ketjona Lepuri
lepuriketjona@gmail.com
Chemnitz University of Technology
Chemnitz, Germany

Dominik Krumm
dominik.krumm@mb.tu-chemnitz.de
Chemnitz University of Technology
Chemnitz, Germany

Lewis L. Chuang
lewis.chuang@phil.tu-chemnitz.de
Chemnitz University of Technology
Chemnitz, Germany

Giuseppe Sanseverino
giuseppe.sanseverino@phil.tu-chemnitz.de
Chemnitz University of Technology
Chemnitz, Germany

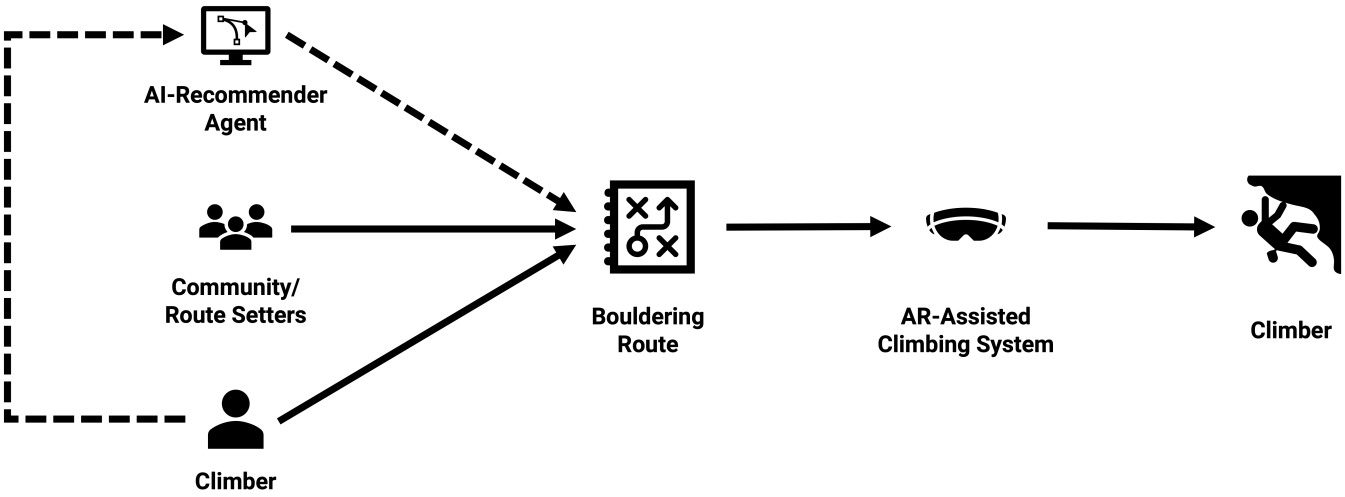

Figure 1: Schematic display of the proposed system using user input and/or an AI-based recommender system for route generation (left), visualized through augmented reality to assist the climber (right)

Abstract

Indoor bouldering is a highly dynamic, on-the-move activity: climbers move continuously, viewpoints change rapidly, and attention must stay on balance and safety. We propose a constraint-based route-generation approach that uses user-specified anthropometric parameters (e.g., height and reach) to generate personalized, body-aware bouldering problems. We envision augmented reality (AR) glasses that overlay selected holds and movement sequences directly in the climber's field of view on existing climbing walls, supporting glanceable guidance while the user is in motion. This scenario highlights key AR on-the-move challenges and opportunities, including robust hold detection under occlusion and changing viewpoints, managing latency and visual stability during locomotion, and designing cues that improve feasibility without distracting from safety in shared social spaces.

CCS Concepts

• **Human-centered computing** → **Mixed / augmented reality**.

Keywords

Augmented Reality, Climbing, Assistive Technologies, Sports Technologies

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1 Introduction

Indoor bouldering has become a widely adopted sport and training activity [3]. It takes place at low heights without ropes, using thick mats on the ground for protection. The lack of specialized equipment, aside from climbing shoes and chalk, draws in many novice climbers. There, they face certain challenges before they can fully engage with the sport. A significant aspect of bouldering is climbing routes, often called problems, created by the gym's experienced staff. Although these problems are graded to indicate difficulty, they do not systematically consider differences in body size, reach, or skill level. While this variation adds to the challenge for seasoned climbers [1], it can make problems hard to interpret, limit the effectiveness of training, discourage new climbers, and, in some cases, increase the risk of inappropriate movement patterns or injury. A possible solution is to use AI recommender systems to generate individual routes based on users' morphology. In early preliminary work, we found it to be feasible to use these route recommendations, especially for beginners [10]. Bouldering is also an archetypal AR on-the-move setting: climbers are in continuous locomotion, viewpoints change rapidly, and attention is tightly coupled to balance and safety. This makes in-situ guidance valuable but also raises interaction risks related to distraction, glanceability, and visual stability during movement. Existing digital tools in climbing largely focus on route grading, classification, performance analysis, and training, using computer vision or wearable sensors [7] [11] [2] [14]. These systems rarely integrate climber-specific physical constraints into the way routes are presented on the wall, for example, by highlighting reachable holds, previewing feasible movement sequences, or adapting visual guidance to the user's morphology and skill level. As a result, they provide limited support for in-the-moment decision-making and do not leverage AR's capacity to deliver personalized, situated feedback directly in the climber's field of view.

To address this gap, this paper proposes an AR-mediated generative system that creates and visualizes personalized indoor bouldering routes. The system uses deterministic logic informed by user-defined physical parameters, such as height, reach, limb proportions, and predefined wall layouts, to construct feasible movement sequences. We envision each route to be rendered as an AR overlay on the wall, complementing a step-by-step instruction set. By blending generative logic with AR visualization, the approach aims to make every move legible for the intended user, lowering barriers for novices while enabling richer, more individualized training experiences.

2 Related Work

Research on digitally assisted climbing explores the use of various technologies and applications. Wearable sensors are mainly used to analyze performance and log training success [9]. Recommender systems have been used in outdoor rock climbing to suggest locations based on specific needs, such as weather conditions, transportation methods, and family suitability [5]. Previous research in climbing-focused AI has largely concentrated on classification tasks, motion analysis, or grading prediction. Systems such as Strange Beta [12], Planfitting [13] have made early attempts to support or automate aspects of route setting. However, these approaches often rely on visual perception or learned models that do not generalize well across user types, and rarely account for climber-specific variables such as height or reach. Wall projections have been studied as a way to visually highlight holds for climbers, helping them learn complex movements that are usually acquired through mimicry and interaction with more experienced climbers or trainers. [14]. Existing work on augmented climbing walls demonstrates that projected graphics can transform ordinary bouldering walls into interactive surfaces for training and play by combining computer vision with real-time projection to highlight holds, show projected routes, visualize movement trajectories, and provide delayed video feedback directly on the wall [6]. Although full-scale wall projections can help learners grasp complex movement sequences [8], their usefulness is restricted by occlusion caused by the climber [6]. Besides projections, AR glasses have been explored, but participants gave mixed feedback, mainly criticizing the image quality, which made it difficult to identify holds. [8]. Although an important consideration, the past years since the paper's publication have seen many improvements in wearable AR glasses, which are expected to continue in future iterations [4]. The approach in this paper extends the current landscape of digitally assisted climbing by proposing the combination of insights from AR-based climbing interfaces and artificial intelligence, shifting the focus from selecting or annotating existing problems to generating body-aware, climber-specific routes and rendering them through AR overlays.

3 Toward Augmented Reality Climbing Assistance

We envision a deterministic, constraint-based route generation coupled with AR overlays that render holds, sequences, and movement hints on the climbing wall visualized through AR glasses. At the core of the approach are user-specified body parameters that become explicit constraints for route generation. Climbers provide basic anthropometric information, such as height, arm span, maximum reach, and leg length relative to torso length, optionally augmented by constraints on specific climbing styles, such as large dynamic moves. These values set limits on distances between holds and on vertical and horizontal offsets, immediately pruning out moves that would be unreachable or unsafe for that individual, since they are not yet able to use the techniques needed to overcome these problems.

We foresee the generated route projected back onto the physical environment through AR overlays. Holds belonging to the problem are highlighted directly on the climber's wall. The sequence is indicated via numbering, arrows, or subtle connecting paths, and optional movement hints, such as suggested hand or foot placement, can be encoded using simple icons or animations. Because climbers are moving, visual cues should be glanceable and low-clutter (e.g., minimal highlights that update at key moments rather than persistent dense overlays). This visualization clarifies the route, unlike traditional systems that use LEDs beneath each hold to indicate the correct one (e.g., Kilter Board; MoonBoard). Those LEDs can be difficult to see due to occlusions from nearby holds. The improved augmented visualization makes the route easier to read, especially for beginners.

A typical use scenario illustrates the interaction: a novice climber enters their height, reach, and preferred difficulty range into the system. The generator produces a problem that avoids extreme spans and high steps, favoring smaller, controlled moves consistent with the given profile. When the climber puts on an AR headset or points a mobile device at the wall, the start hold is highlighted. As they progress, the next hold in the sequence is clearly indicated, making it straightforward to follow the route without prior experience or a more experienced climber acting as a coach. This method enables beginners to gradually develop essential skills and movement patterns, helping them advance to more complex challenges with minimal frustration and making the sport more easily accessible.

4 Challenges and Opportunities

4.1 Challenges

The proposed system currently relies on predefined climbing walls with known layouts, such as standardized training boards, limiting its applicability to arbitrary gym walls. To generalize to real-world bouldering facilities, the key requirement is to robustly recognize and localize holds on uninstrumented walls. Extending hold detection to generic indoor walls presents significant challenges, as holds often feature complex profiles and colors that are difficult to reliably identify from a distance, even for human observers. Additionally, climbing gym environments are filled with magnesium dust, which can impact the performance of AR glasses through lens contamination and sensor interference, demanding robust hardware for sustained use. Using the system on the move introduces extra challenges: head and body movements increase tracking errors, occlusion and shifting perspectives can destabilize overlays, and latency may delay cues, affecting safety. Ensuring safety means managing attentional demands, deciding when to display guidance, how much to show, and how to prevent visual distraction during risky maneuvers.

While the system offers the greatest benefits for novice climbers seeking clear guidance and feasible routes, experienced boulderers may resist full route visualization, as problem-solving and beta discovery are integral to the sport's challenge.

4.2 Opportunities

To address the challenges, the AR interface could offer configurable visualization levels, allowing individuals to tailor assistance to their skills and preferences. An additional key opportunity lies in structured training progression: the system could aid the creation of structured training progression by generating problems with systematically increasing "offset" values based on the user's input. This includes increasing the maximum reach distance, or vertical span between holds, to facilitate deliberate progression and skill development. This enables beginners to build confidence through achievable successes and transition gradually to independent problem-solving. Beyond static configuration, a natural next step is to adapt assistance dynamically to the climber's movement and moment-to-moment risk. This context offers a testbed for AR on-the-move guidance that modulates when and how cues appear (e.g., emphasizing cues at rest positions or before commitment points), raising design questions around timing, visual salience, and safety that we aim to explore in future prototypes and in-the-wild studies.

Acknowledgments

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