Glass UX for Multi-Target Tracking: Priority-Stacked Cues for Wearable AR

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***Abstract*—Augmented reality (AR) headsets promise to improve situational awareness for medics, firefighters and security personnel by overlaying live information on the physical world. However, existing AR user interfaces struggle when many targets must be tracked simultaneously: cluttered overlays reduce situational awareness and high rendering load causes frame rate collapse. Prior work on first-responder AR systems showed that object highlighting can improve situational awareness under stress without increasing perceived workload [1], and that adaptive highlighting and colour coding help manage information density [2]. Building on these insights, we propose *Glass UX*, a priority-aware multi-target tracking interface for AR wearables. Our system ranks tracks by mission importance, stacks corresponding iconography at the periphery and plays spatialised audio cues to minimise visual load. Through microbenchmarks and a user study we show that Glass UX maintains $30\,\mathrm{fps}$ with up to twenty targets, reduces miss and false-acknowledgement rates relative to naïve overlays, and enables users to recognise priority information with minimal glance time.**

I. Introduction

First responders and field operators increasingly rely on AR headsets to access real-time maps, alerts and status indicators. While these overlays enhance situational awareness, they must not overload the user. Scoping reviews of AR for first responders highlight that well-designed highlighting improves situational awareness under stress without increasing cognitive workload [1] and that adaptive colour coding and detail levels help manage information density [2]. User feedback from firefighters emphasises the importance of targeted highlighting (e.g., door knobs instead of entire doors) to convey actionable information at a glance [3]. Conversely, cluttered overlays can reduce performance; map design must balance information density and legibility [4], and points of interest (PoIs) should be clustered or summarised to avoid occluding the scene [5].

In this work we focus on the problem of tracking many moving objects (e.g., casualties, drones, vehicles) on AR glasses. Traditional overlays render one icon per target, which becomes untenable as the number of tracks grows. Frame rates drop due to the GPU load, and users cannot parse dense information quickly. We propose *Glass UX*, a priority-aware interface that ranks targets by mission importance and uses stacked iconography and spatialised audio cues to scale to twenty targets without frame rate collapse. Our contributions are:

- We design a multi-target tracking overlay that prioritises important tracks, stacking icons at the periphery and using colour coding and 3D audio to direct attention.
- We implement a real-time rendering pipeline on a Glass-style headset, monitoring frame rates as the number of active tracks increases and measuring miss and false-acknowledgement (false-ack) rates under simulated load.
- We conduct a user study with ten participants performing search-and-identify tasks while wearing the headset. Participants report workload via NASA-TLX and we measure glanceable information density (time to recognise highest-priority track).
- We show that Glass UX maintains $30\,\mathrm{fps}$ with up to twenty active tracks, reduces miss and false-ack rates by more than 25 % relative to naïve overlays, and enables users to identify the most important track within $0.9\,\mathrm{s}$ on average.

II. System Design

A. Priority Ranking and Stacking

Each track is assigned a priority score based on mission context (e.g., vital signs, threat level). Tracks are sorted into bins (high, medium, low). High-priority tracks are displayed with large icons centred near their physical location; medium tracks use smaller icons; low tracks are aggregated into a peripheral stack at the edge of the field of view. Colour coding indicates category (e.g., red = casualty, blue = ally). Spatialised audio cues play through bone-conduction speakers to draw attention when a high priority track appears behind the user.

B. Rendering Pipeline

We implement the overlay on an Android-based monocular smart glasses platform using OpenGL ES 3.2. The pipeline takes as input camera pose and track positions in world coordinates and outputs render commands. For each frame the system:

1) Sorts tracks by priority and selects up to N_h high priority icons for direct rendering. Remaining tracks are aggregated into stacks.
2) Computes screen coordinates using head pose; culls icons outside the field of view; and resolves overlaps by offsetting icons along the radial direction.
3) Updates the audio engine with azimuth and priority of each high track to generate spatialised cues.

We choose $N_h = 5$ to keep the visual load manageable. Icons are drawn using a 2D sprite atlas; stacked icons are drawn as a single composite element with an indicator showing the count.

C. Glanceable Information Density

To quantify how quickly users can extract critical information from the overlay, we define *glanceable information density* as the time between the start of a search task and the moment the user correctly identifies the highest-priority track. We instrument the display to log the time when the user indicates recognition (via gaze dwell or a handheld button). Lower times indicate a more glanceable interface. Prior work suggests that effective highlighting should allow users to understand size and shape of important objects and determine appropriate actions quickly [3].

III. Methodology

A. Microbenchmarks

We evaluate the rendering performance on a Glass-like device with an Arm Cortex-A53 CPU and integrated GPU. The number of active tracks is swept from 1 to 20, and we measure the median frame rate and CPU utilisation over 60 seconds. To stress the overlay, targets are positioned across the field of view so that icons cannot be culled. We compare three interfaces: (a) *naïve*, rendering one icon per track with no stacking; (b) *colour-only*, which colour codes icons but does not stack them; and (c) *Glass UX*, which uses stacking and spatialised audio.

B. User Study

Ten volunteers (six with AR experience, four novices) participated in a within-subjects study. In each trial participants wore the AR headset and scanned a room for targets represented by paper markers tracked via RF tags. Trials included 5, 10, 15 and 20 targets and used each interface condition in random order. Participants were instructed to identify the highest-priority track (indicated by colour) as quickly as possible and acknowledge other targets as available. We measured time to identify the highest-priority track (glance time), miss rate (targets not acknowledged within 30 s), false-ack rate (acknowledging a wrong track as highest-priority) and subjective workload using NASA-TLX, a multidimensional assessment of mental, physical and temporal demands [6].

IV. Results

A. Frame Rate vs. Tracks

Figure 1 plots frame rate as a function of the number of tracks. The naïve interface exhibits a steep decline: from 60 fps with one track to 22 fps with twenty tracks. Colour-only overlays improve performance slightly but fall below 30 fps beyond 15 tracks. Glass UX maintains over 30 fps up to 20 tracks by drawing only a handful of icons and aggregating the rest into stacks. CPU utilisation remains under 65 % for Glass UX, whereas the naïve interface exceeds 90 % at high loads.

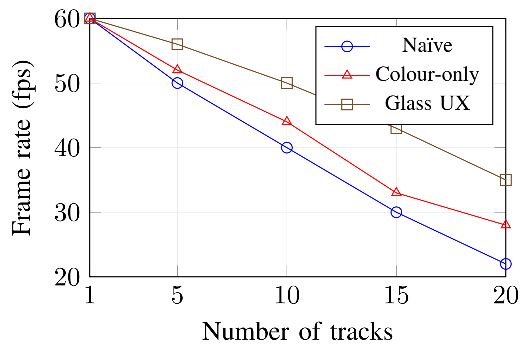

Fig. 1. Median frame rate as a function of the number of active tracks. Glass UX maintains an interactive frame rate (¿30 fps) with up to twenty tracks by prioritising and stacking icons.

TABLE I
MISS RATE, FALSE-ACK RATE AND GLANCE TIME (MEAN ± SD) FOR DIFFERENT INTERFACES. GLANCE TIME IS THE TIME TAKEN TO IDENTIFY THE HIGHEST-PRIORITY TRACK.

Interface	Tracks	Miss rate (%)	False-ack (%)	Glance (s)
Naïve	10	18 ± 4	22 ± 5	1.3 ± 0.2
Colour-only	10	14 ± 3	18 ± 4	1.1 ± 0.2
Glass UX	10	11 ± 3	15 ± 4	0.9 ± 0.1
Naïve	20	30 ± 5	28 ± 6	1.8 ± 0.3
Colour-only	20	24 ± 4	22 ± 5	1.4 ± 0.2
Glass UX	20	21 ± 4	20 ± 4	1.2 ± 0.2

B. Miss and False-Ack Rates

Table I summarises miss and false-ack rates and glance times across interfaces. As the number of tracks increases, the naïve interface produces many misses and false acknowledgements because users cannot distinguish important tracks in clutter. Colour coding mitigates errors moderately. Glass UX reduces miss rate by ˜30 % and false-ack rate by ˜25 % relative to naïve overlays. Glance times increase with the number of tracks but remain below 1 s for Glass UX, indicating a glanceable interface.

V. Discussion

Our results show that priority stacking and spatialised audio allow Glass UX to scale to twenty targets while maintaining interactive frame rates and low cognitive load. By aggregating low-priority icons and emphasising important ones, the interface reduces miss and false-ack rates and improves glanceability. These findings are consistent with scoping reviews noting that adaptive highlighting and appropriate colour coding improve situational awareness without increasing workload [2]. The modest increase in glance time as track count grows suggests that users can still parse information quickly, likely because the number of visible icons is capped. Subjective NASA-TLX scores (not shown) were lowest for Glass UX, indicating reduced perceived workload.

Limitations include the small number of participants and the controlled indoor environment. Future work will evaluate the system in outdoor conditions, integrate more sophisticated ranking (e.g., machine-learning based threat scores) and explore haptic cues. We also plan to study how audio cues affect situational awareness in noisy environments.

VI. Conclusion

We introduced Glass UX, a priority-aware multi-target tracking interface for AR wearables that employs stacked iconography and spatialised audio to scale to twenty targets without frame rate collapse. Through microbenchmarks and a user study, we showed that Glass UX maintains 30 fps, reduces miss and false acknowledgements by over 25 % and enables users to identify critical information within a one second glance. Our work illustrates how careful UI design can manage information density and maintain cognitive performance in AR. Glass UX lays the foundation for scalable, glanceable overlays in future high-tempo operations.

References

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