Visuo-tactile AR for Enhanced Safety Awareness in Human-Robot Interaction

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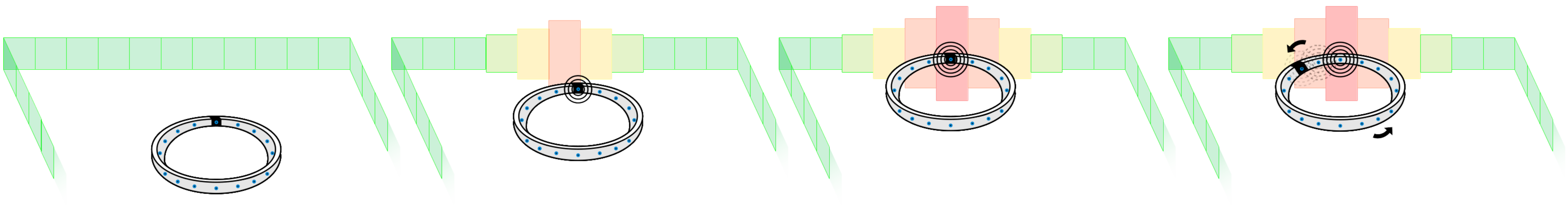


Inside the safe zone | Approaching the unsafe border | Contact to the unsafe border | Feedback updates during rotation

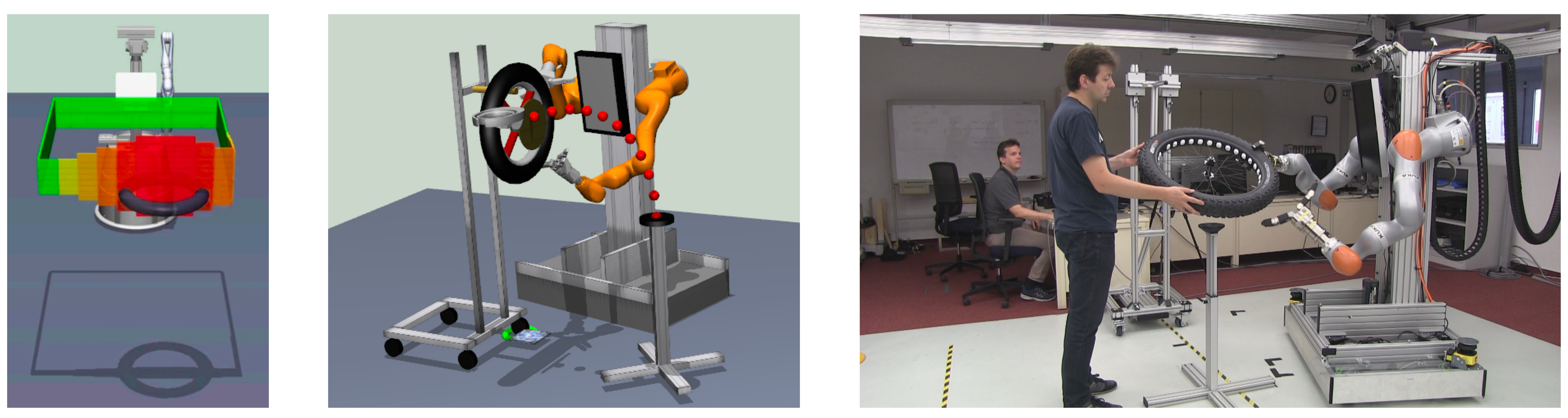
Human-Robot Interaction

Motivated by a competition for attentional resources between the need for safety-maintenance and achievement of a primary task, we employ multimodal cues that inform a user about unsafe proximities to dangerous areas. We call this system AwareWear.

AwareWear = Visual AR Zone + Vibrotactile Feedback

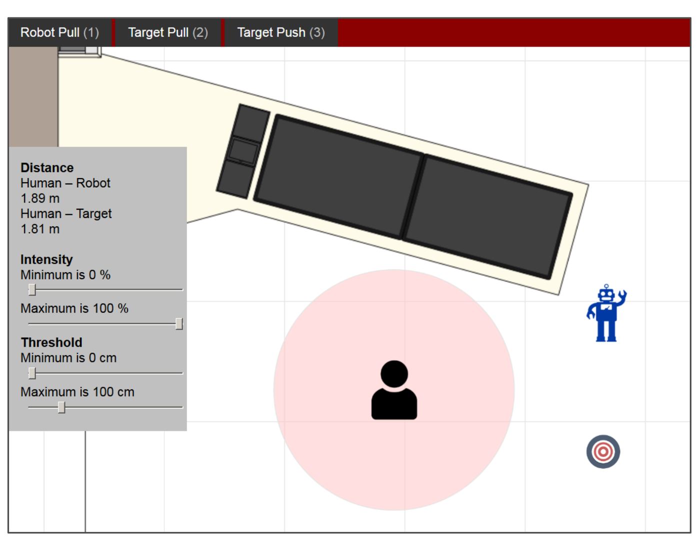
AwareWear allows the user to focus the attention on a primary task while keeping him or her safety-aware. We use this system in a collaborative task of moving an object with a robot, e.g., a motorcycle wheel.

Interaction Scenarios



UX Prototyping

We build a Wizard of Oz (WOZ) system to explore how informed and naive users respond to different tactile stimuli that encode location information. We chose to provide stimuli through a tactile belt from feelSpace GmbH.



To control the belt we created a GUI. It allows a user to change the 2D positions of multiple entities (e.g., human and robot). The tactile stimulus is generated by a set of adjustable stimulus parameters and the relative arrangement of the entities.

User's favored a repelling signal generated at the location opposite to the targeted movement direction and a decreasing stimulus when the user moves away from the stimulus direction.

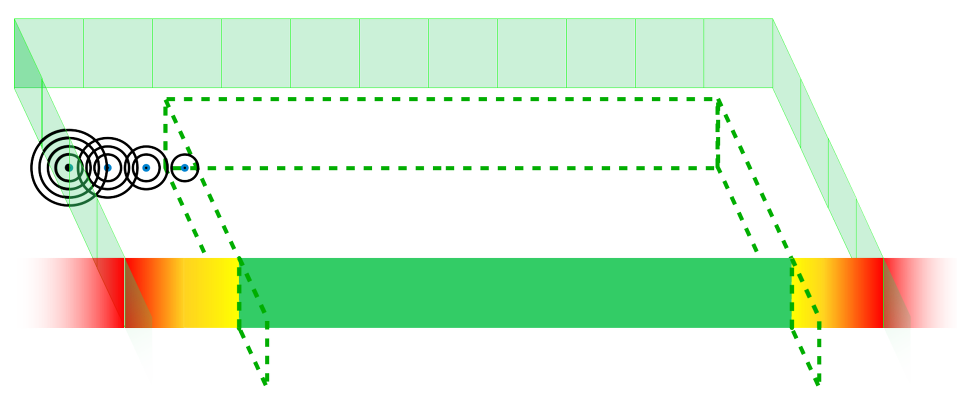
Visuo-Tactile Augmentation

The safety system combines visual and tactile feedback.

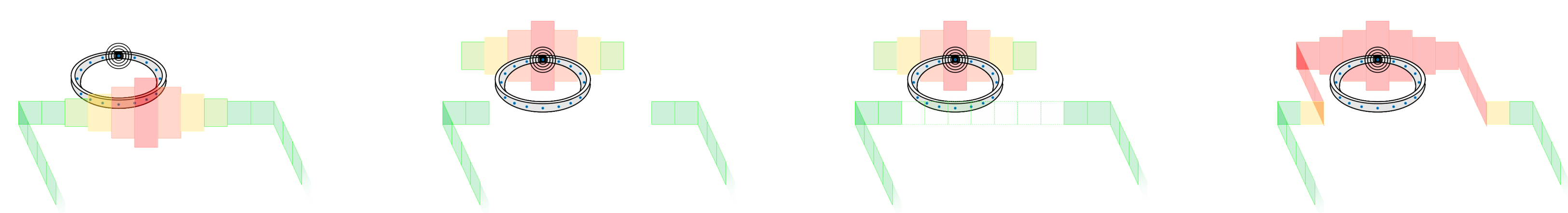
Visual Feedback: The safety border is shown to the user using augmented reality glasses (Microsoft HoloLens). The border consists of multiple segments, which can individually change color and size depending on the proximity to the user.

Tactile Feedback: The vibrotactile belt contains 16 equally spaced vibromotors for omnidirectional 2D feedback. To improve the spatial resolution we express angles as a combination of two neighboring tactors. The tactile feedback always points towards the unsafe direction, i.e., repels the user from the unsafe region.

The tactile intensity and visual colors scale with the distance towards the safety zone border.

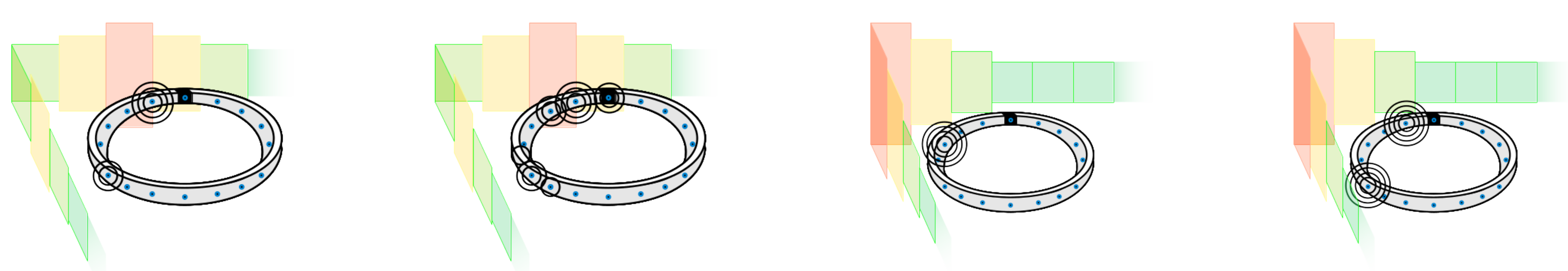


Representations Outside the Safety Zone



There are many possible visual and tactile representations to signalize that the user is outside of the safety zone. The most left visualization might be interpreted as locking out the user. Hence, we chose to move the visual border in the direction of the unsafe region.

Encodings for Multiple Location Errors



There are multiple possible encoding techniques to signal that the user is close to multiple borders. The optimal choice depends on the application scenario and zone geometry. In our scenario, we indicate each border as a separate visual and tactile stimulus (left picture).

This work is a step towards enhancing safety awareness in Human-Robot Interaction using a with a visuo-tactile AR system.

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