NRI:INT: Ad-hoc collaborative human-robot swarms

Award #1830471

Verifiable Robotics Research Group, Human-Robot Collaboration & Companionship Lab, and the Collective Embodied Intelligence Lab

Cornell University

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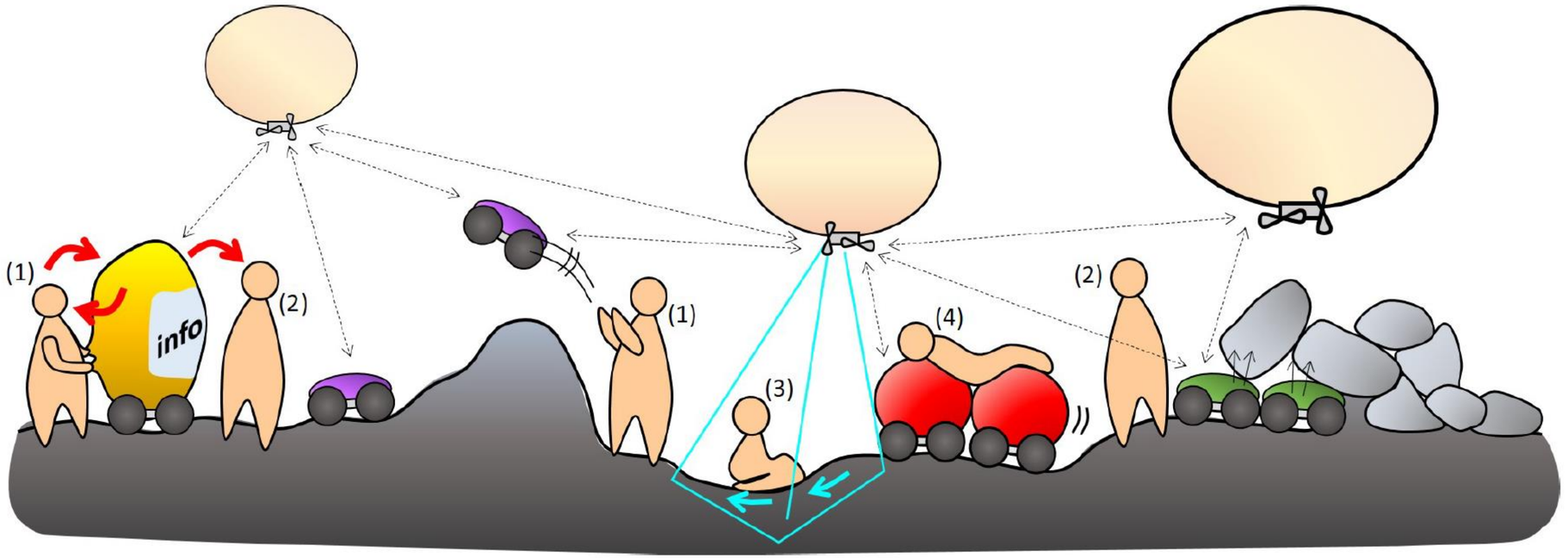
Goal: Design the autonomy, interaction, and hardware that will enable an ad-hoc collaborative swarm of robots and non-expert humans to accomplish a high-level task without central coordination.



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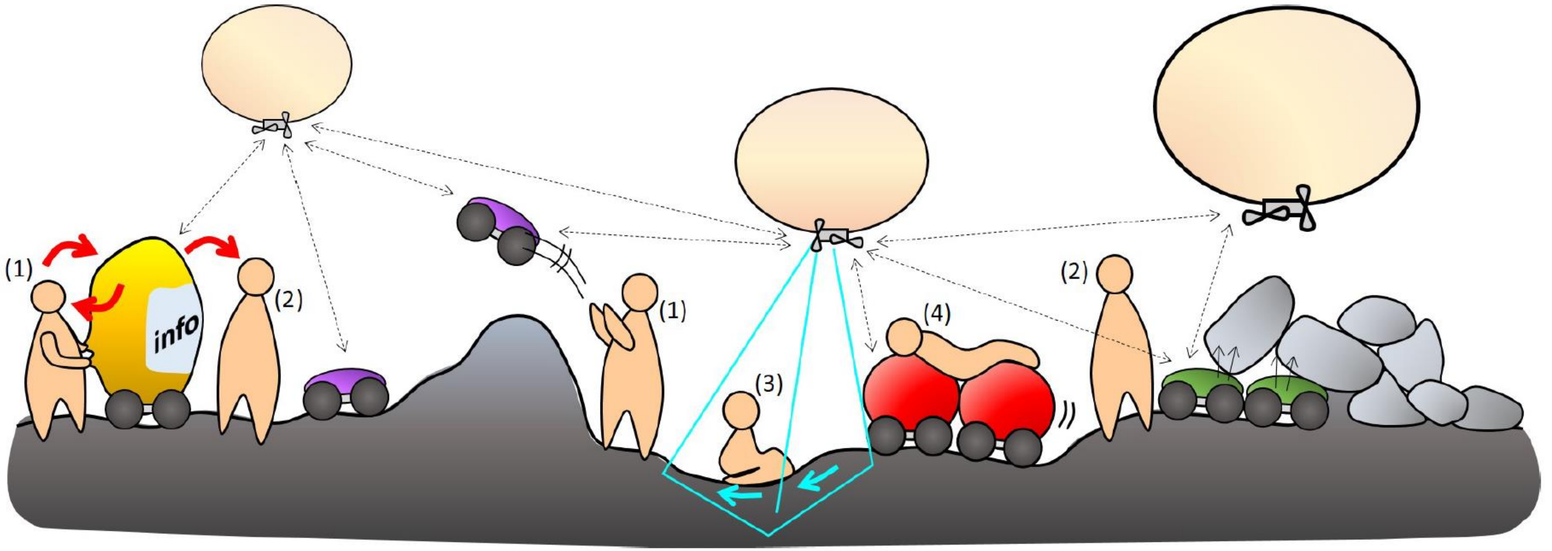

- Hardware that is designed for interaction
- Interaction with people in different roles
- Autonomy that enables the interaction

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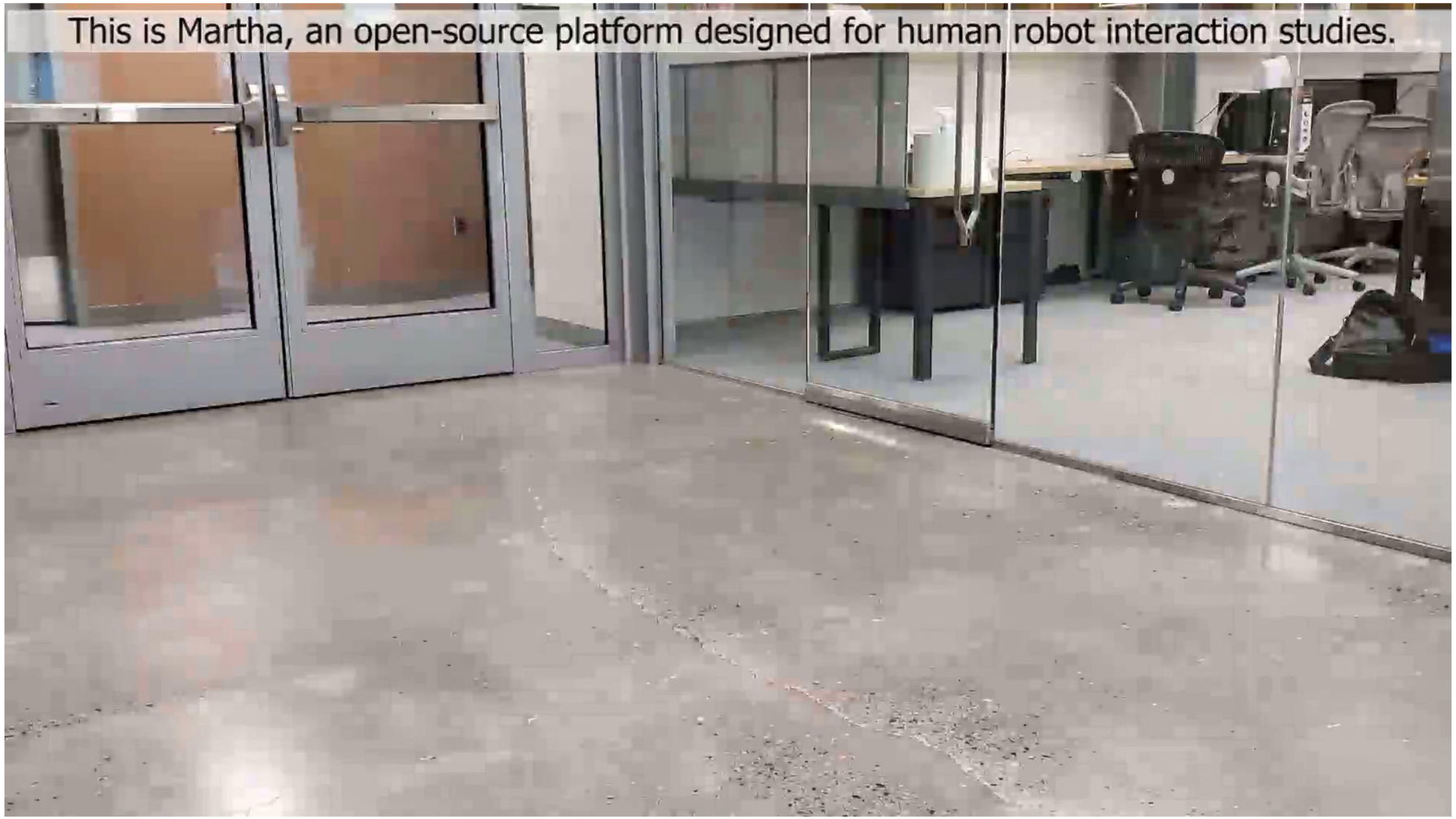

[Jaramillo et. al. URAI ’21, Hu et. al. IMWUT ‘20]

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Event-based Signal Temporal Logic

Syntax:

$$\varphi ::= \mu \mid \neg\mu \mid \varphi_1 \wedge \varphi_2 \mid \varphi_1 \vee \varphi_2$$ predicates

$$\alpha ::= \pi \mid \neg\alpha \mid \alpha_1 \wedge \alpha_2$$ Propositions (uncontrolled)

$$\Psi ::= G_{[a,b]}\ \varphi \mid F_{[a,b]}\ \varphi \mid \varphi_1\ U_{[a,b]}\ \varphi_2 \mid$$
$$G(\alpha \Rightarrow\ \Psi) \mid \Psi_1 \wedge \Psi_2 \mid \Psi_1 \vee \Psi_2$$

[Gundana and Kress-Gazit, RA-L ’21, under review]

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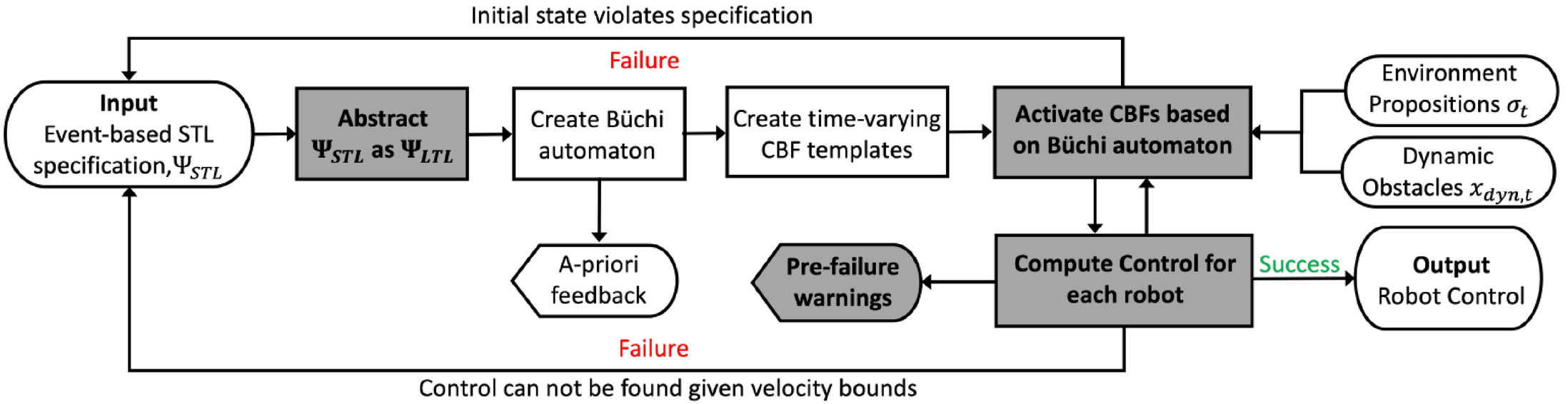
Event-based Signal Temporal Logic



[Gundana and Kress-Gazit, RA-L '21, under review]

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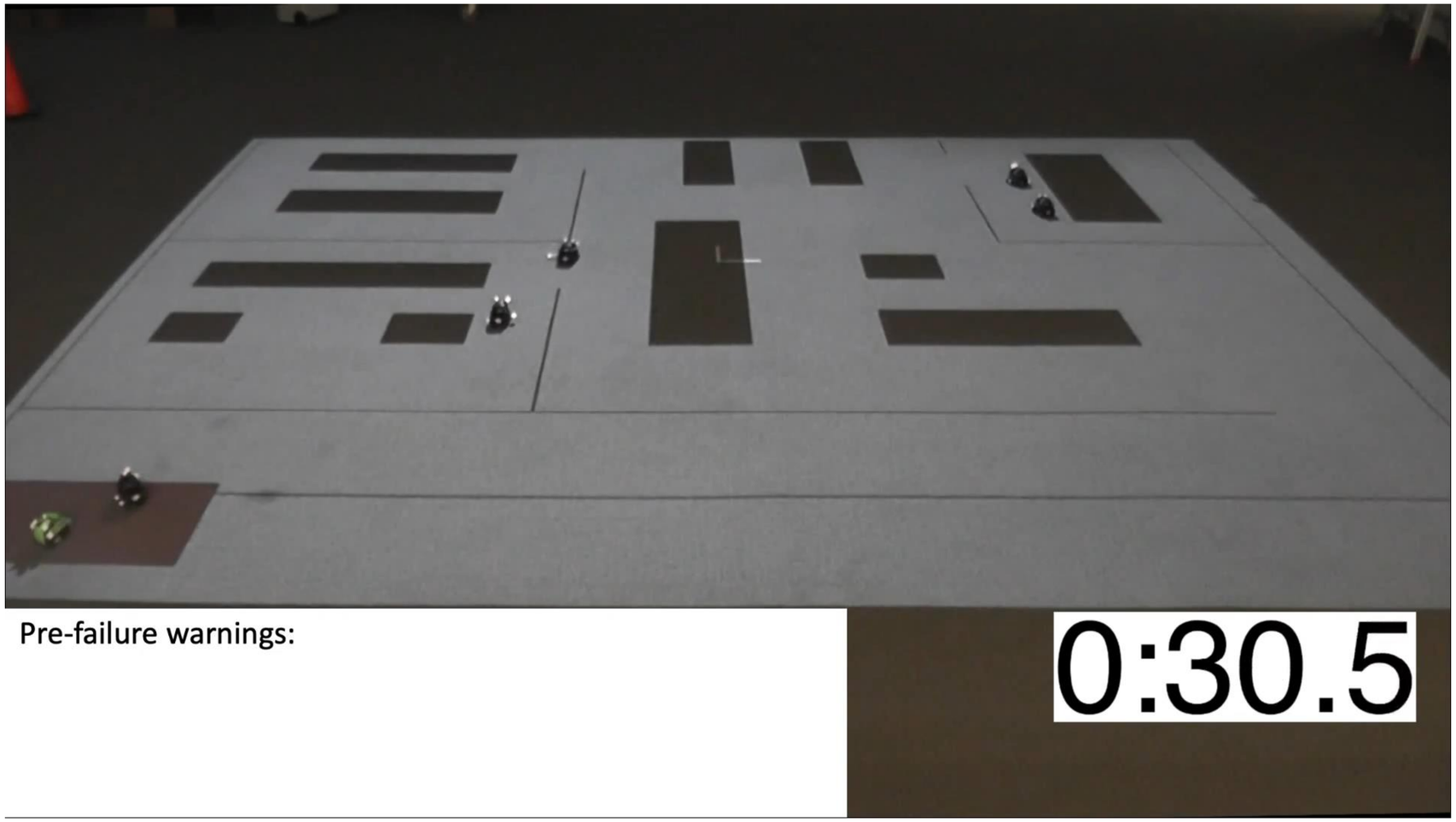

[Gundana and Kress-Gazit, RA-L ’21, under review]

User study – Simulation

Which robot behavior is most effective to evacuate people who are not completely compliant?

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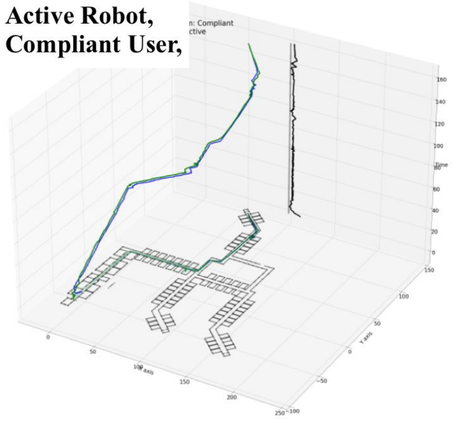
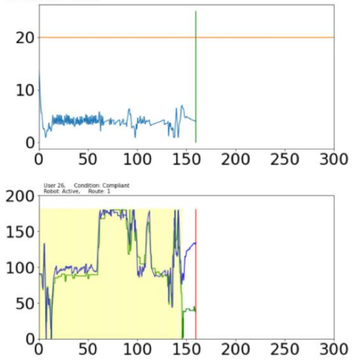
User study – Take 1

Active Robot, Compliant User,

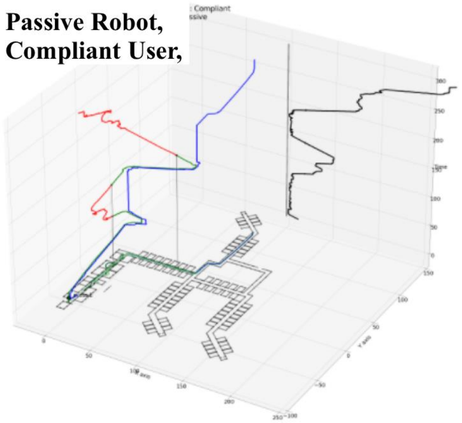


Distance



Orientation

Passive Robot, Compliant User,



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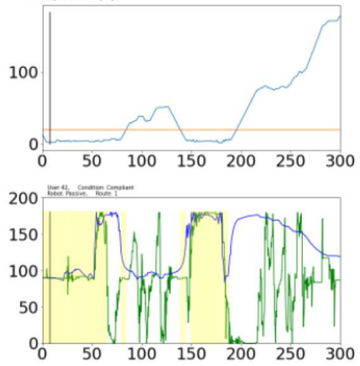
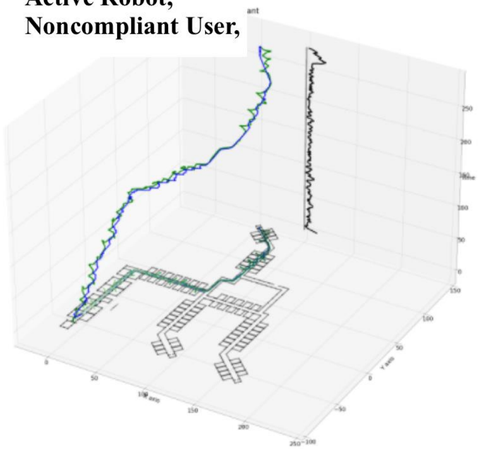


Orientation

Active Robot, Noncompliant User,



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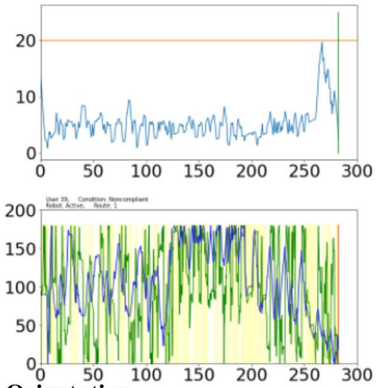
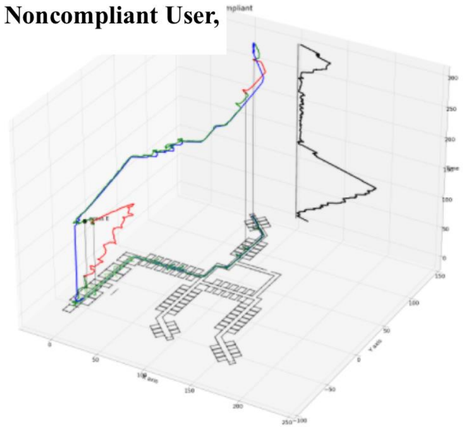


Orientation

Passive Robot, Noncompliant User,



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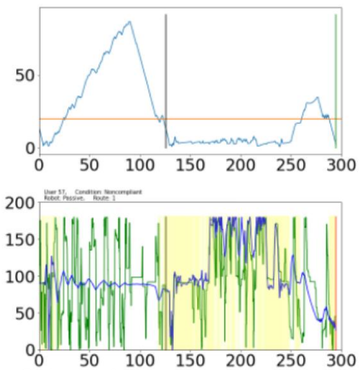

Orientation

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User study – Take 2

Passive

$F_{[0,20]}findHuman$

$G_{[0,300]}avoidHumans$

$G_{[0,300]}avoidWalls$

$G(\neg close \Rightarrow F_{[0,30]}findHuman)$

$G(goToExit \Rightarrow F_{[0,600]}goToExit)$

Active

$F_{[0,20]}findHuman$

$G_{[0,300]}avoidHumans$

$G_{[0,300]}avoidWalls$

$G(\neg lineOfSight \Rightarrow F_{[0,60]}findHuman)$

$F_{[0,300]}goToExit$

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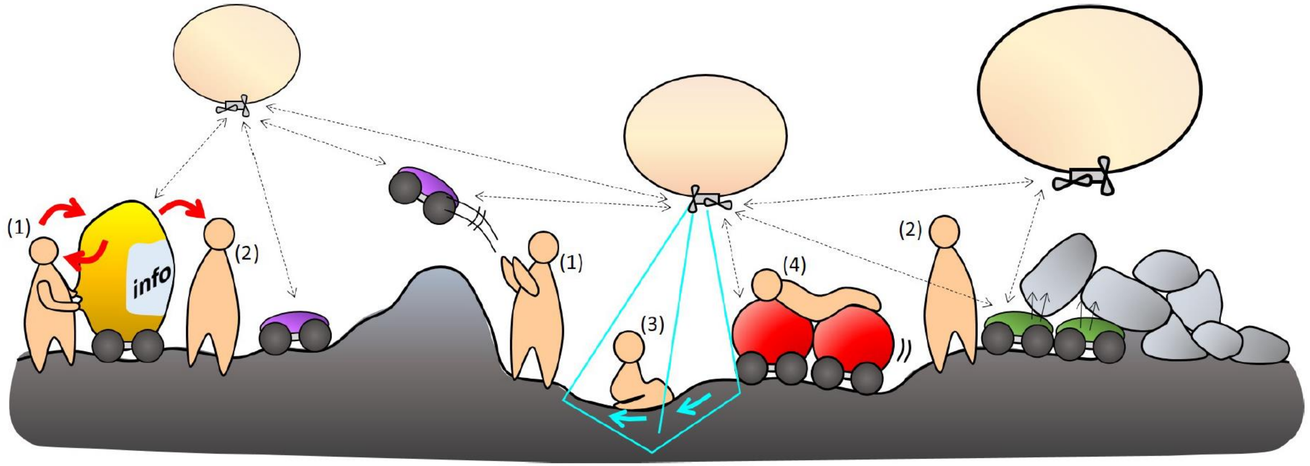
Next steps

- Complete and analyze simulation user study
- Design physical user study (fully autonomous robot)
- Blimp – hardware and interaction
- On-the-fly specification change



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