ARROCH: Augmented Reality for Robots Collaborating with a Human

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Robot Applications

- Robots are increasingly ubiquitous
- Used enormously in warehouses, manufacturing, etc.
- Increase productivity and decrease costs

Amazon Robotics

ABB

Human-robot Collaboration

Amazon Robotics

- Many robots work in human presence
- Most of these robots do not collaborate with humans in their tasks

Human robot collaboration (HRC),

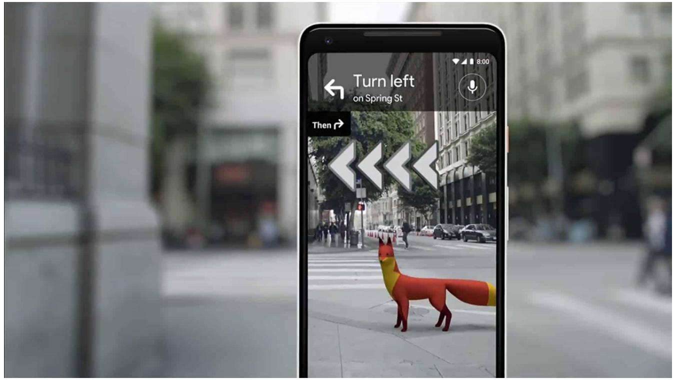
as a kind of multi-agent system, is still rare in practice

Motivation

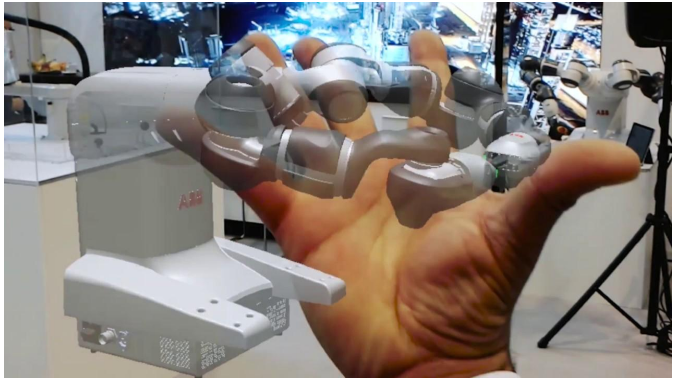
- HRC needs extensive communication of intentions
- Modalities like language can lead to ambiguity
- Agents' actions can produce conflicts and synergies

Augmented Reality (AR)

- Aims at overlaying information on the real world
- Enables interactive experience

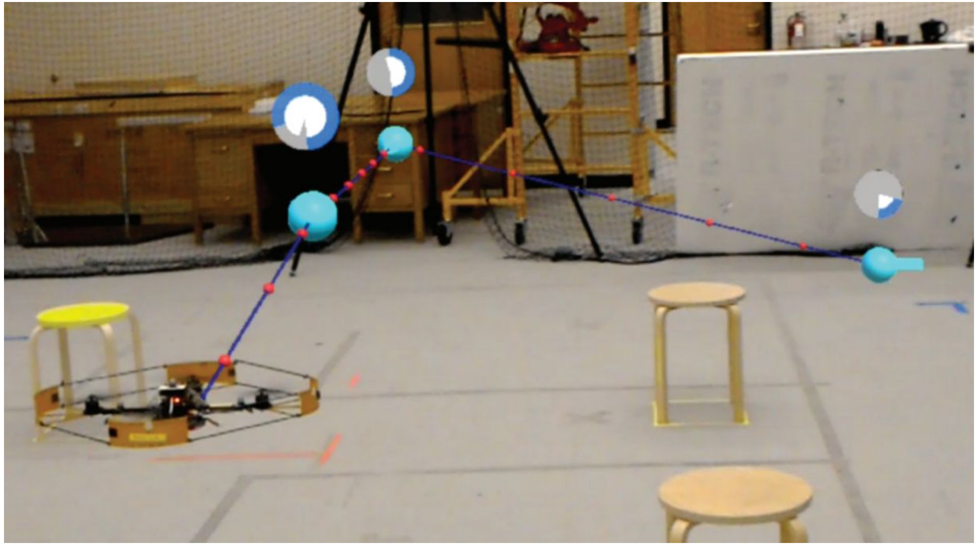


Google



ABB

Related Work



AR for visualizing UAVs planned motion intentions

[Walker et al. 2018]

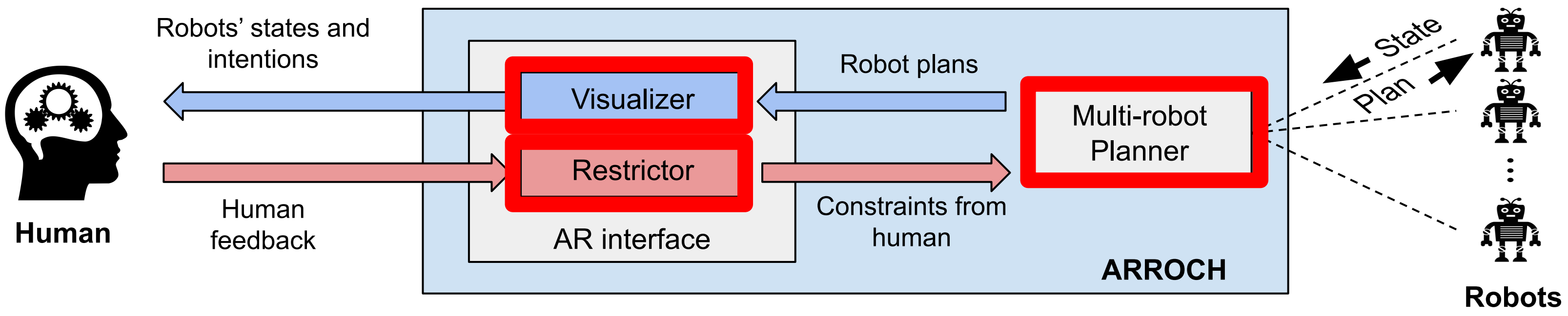
AR for visualizing robot's sensory information

[Muhammad et al. 2019]

ARROCH - Augmented Reality for Robots Collaborating with a Human Framework

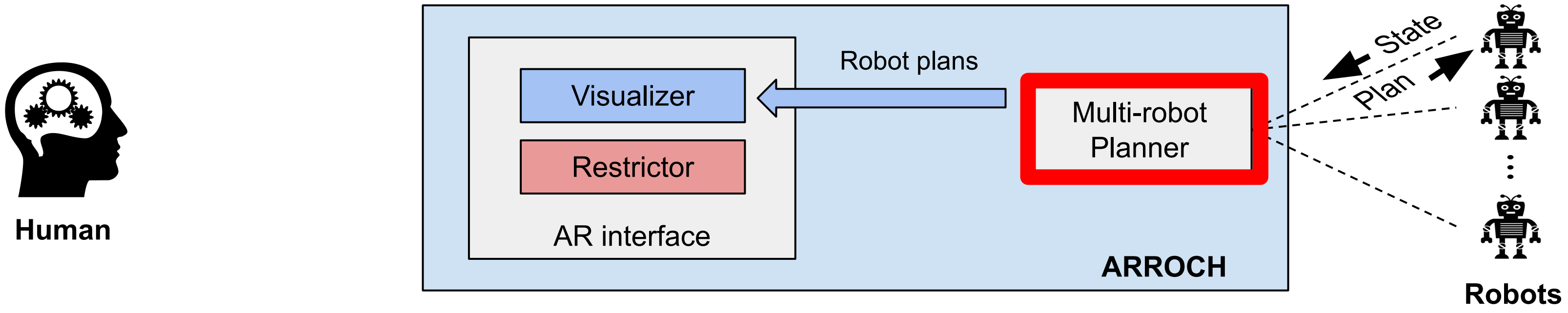
- Existing research on AR for Human-Robot Interaction:
  - Is Unidirectional
  - Lacks task (re)planning capability
- Features of ARROCH
  - High Bandwidth
  - Bidirectional
  - Human multi-robot system

Components of ARROCH Framework



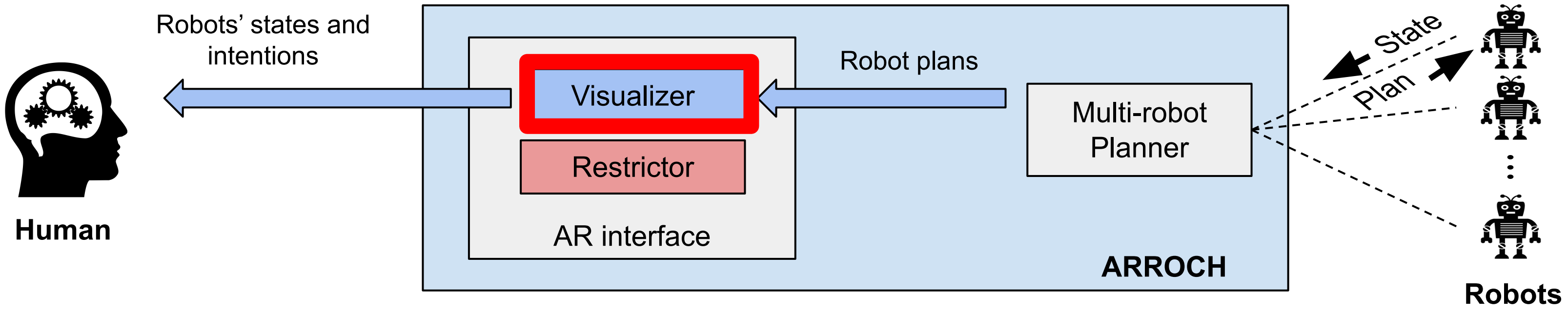
- **Multi-robot Planner**: Generates plans for the robots
- **Visualizer**: Converts the robots' plans to visualizable 3D objects in AR
- **Restrictor**: Converts the human feedback to planner readable constraints

Planner (1/3)



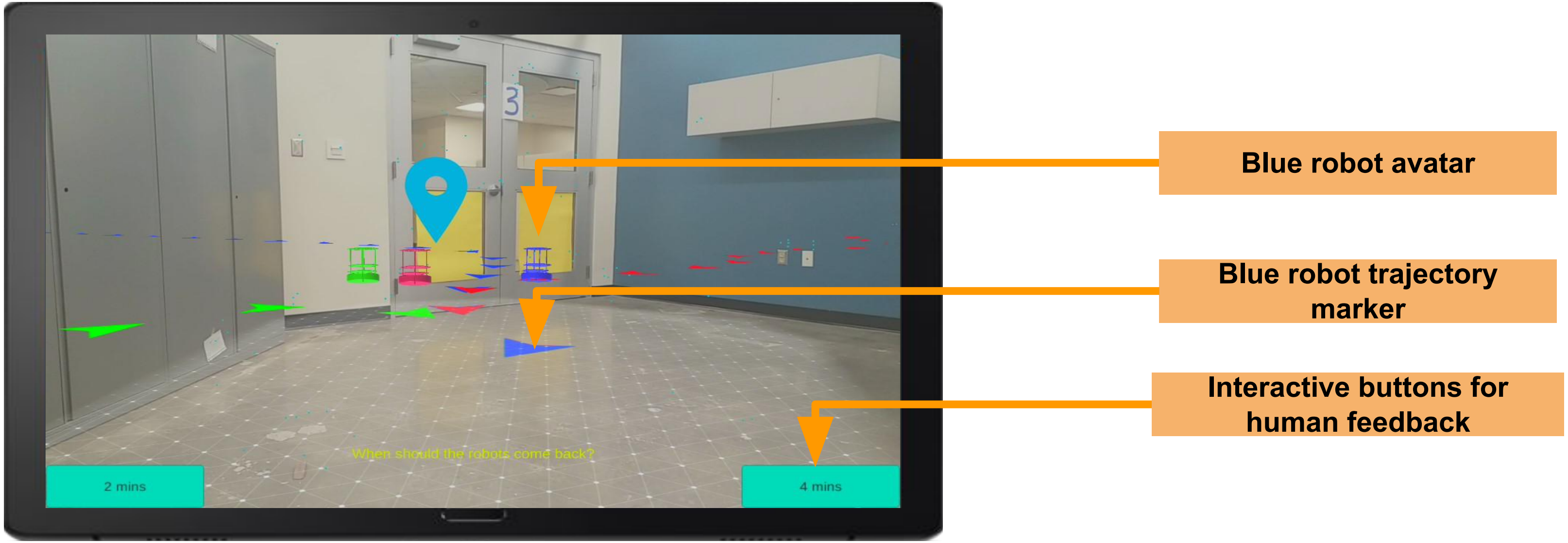
- Planner generates a symbolic plan for each robot
- The set of generated motion trajectories (for N robots) is sent to Visualizer

Visualizer (2/3)



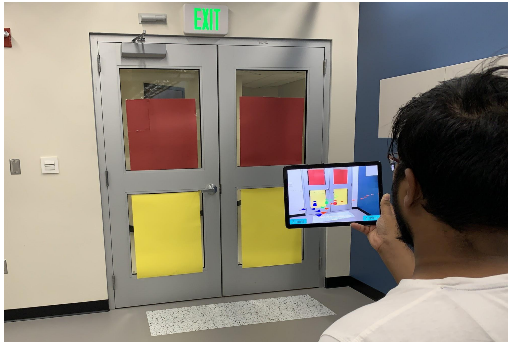
- Visualizer converts the robots' plans into visualizable trajectories and shows robot live location as avatars
- Trajectories are overlaid on the real world using the AR interface

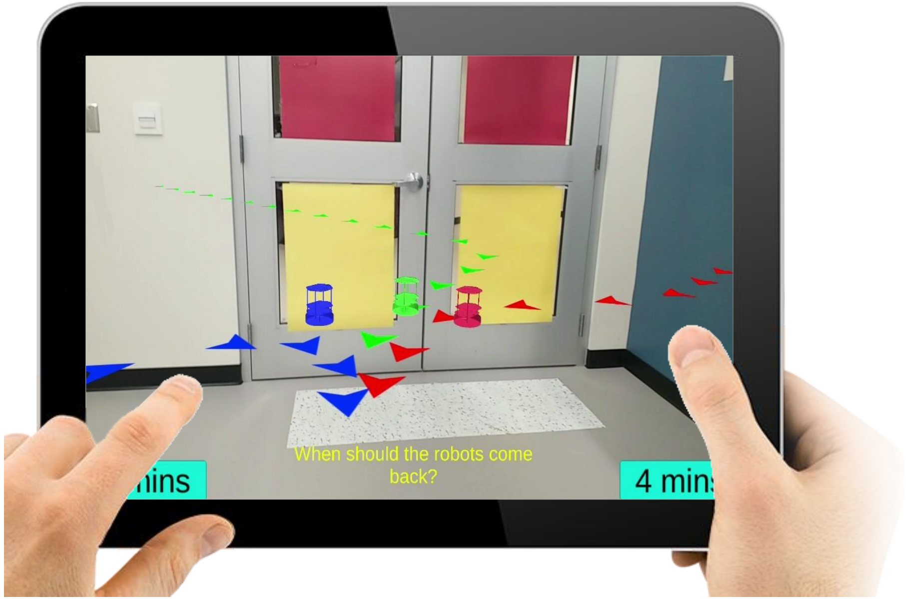
Our AR Interface



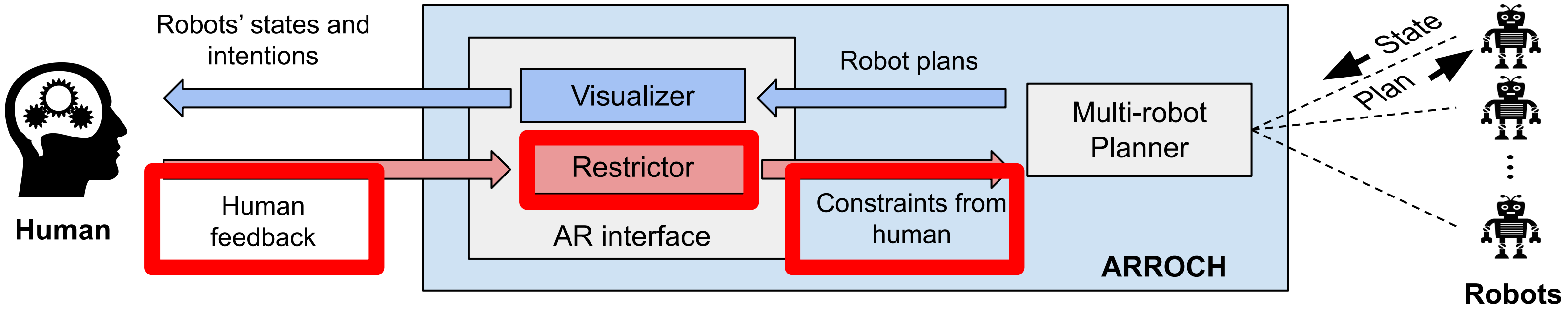
- Robot avatars show the live location of robots
- The trajectory markers are used to show the robot's planned motion trajectories
- The interactive buttons allow the human to give feedback to robots' plans

Our AR Interface





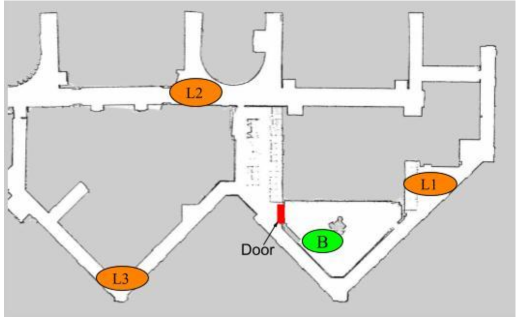
Restrictor (3/3)

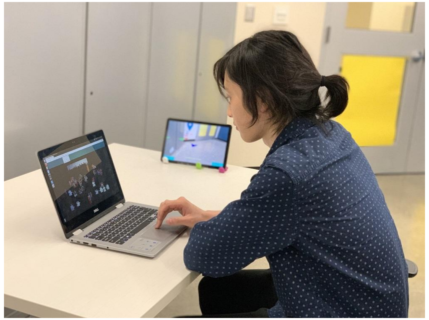


- Human can give feedback on the robots' plans which is passed on to the Restrictor
- Restrictor processes human feedback and passes it as constraints to Planner
- The constraints are then used for computing plans for the robots, closing the control loop

Experimental Setup

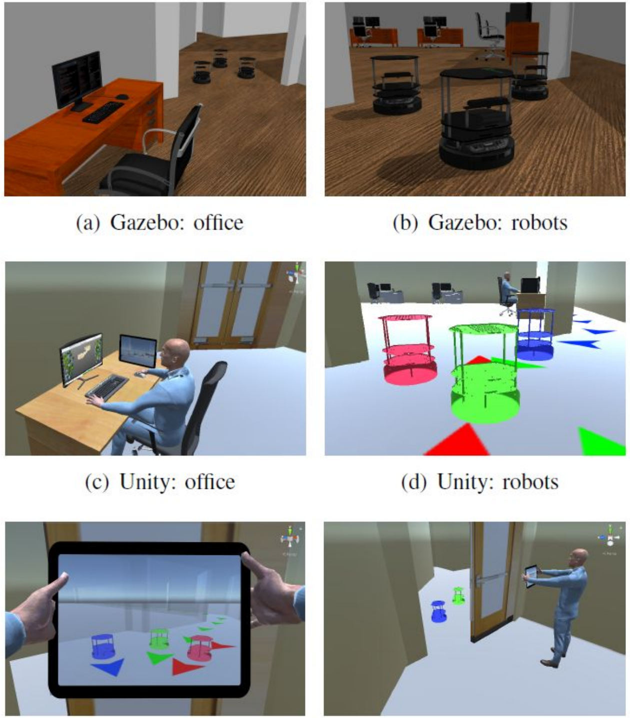
- Human-robot collaborative delivery task
- Three turtlebots - delivery tasks
- Human participant - solving the Jigsaw puzzle





Experiment Video

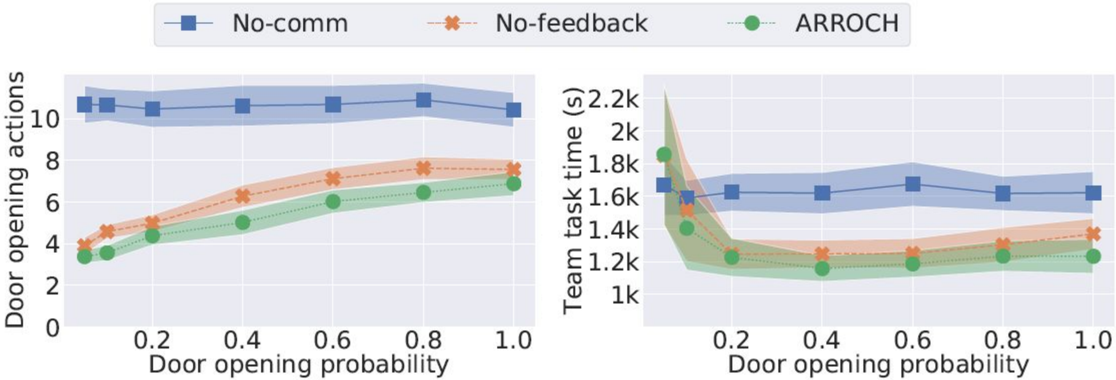
Results: Simulation



(a) Gazebo: office (b) Gazebo: robots

(c) Unity: office (d) Unity: robots

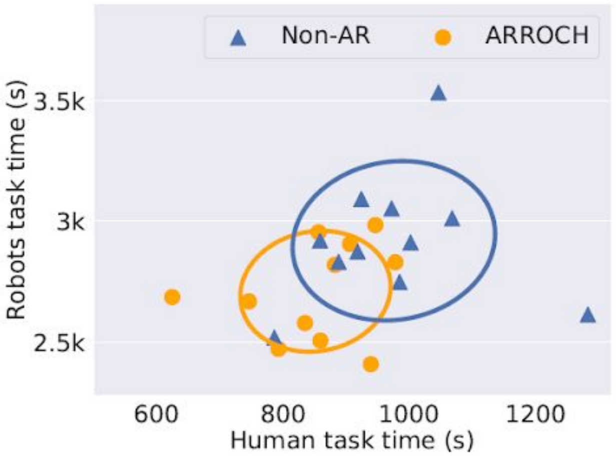
(e) Unity: AR (1st person POV) (f) Unity: AR (3rd person POV)

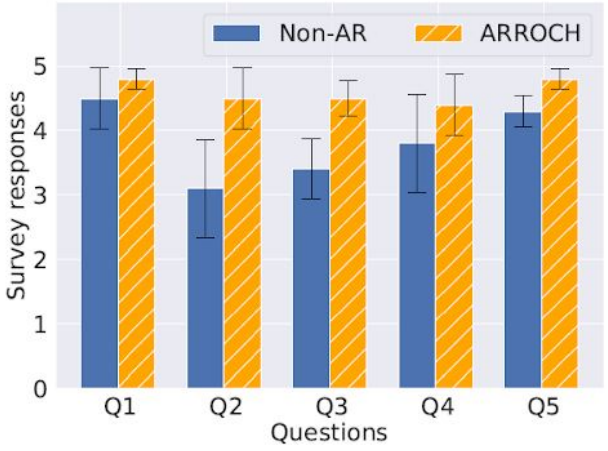


ARROCH performed better than baselines:

- Less door opening actions, and
- Shorter task completion time

Results: Real-world





ARROCH enables ***bidirectional*** communication within a human-multi-robot team about ***current and future*** behaviors toward effective collaboration

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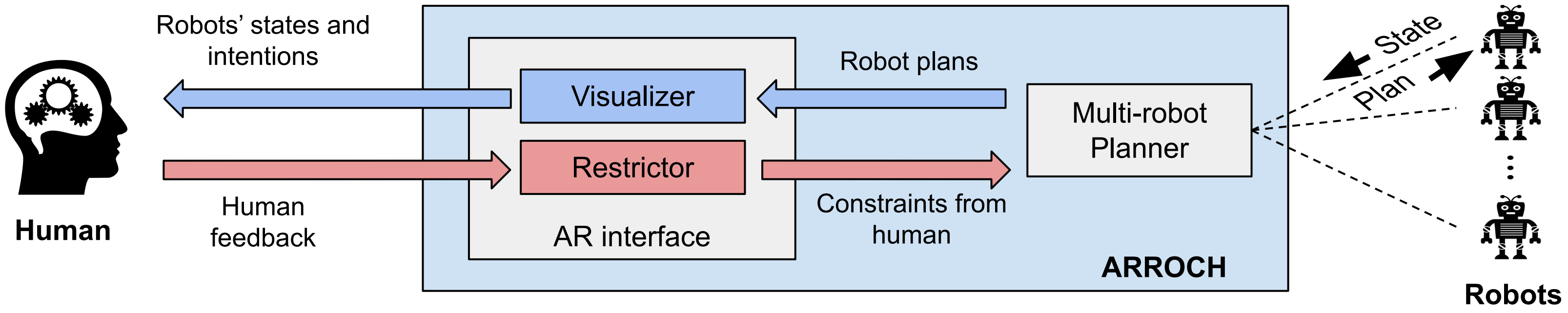
Thank You!



Robots' states and intentions
Human
Human feedback
Visualizer
Restrictor
AR interface
Robot plans
Constraints from human
Multi-robot Planner
ARROCH
State
Plan
Robots