Increasing the Resilience of Autonomous Robots by Keeping Humans in the Loop

Bill Smart

Washington University in St. Louis
and
Willow Garage, Inc.

Work supported by NSF under
award OCI 0753340,
and by Willow Garage, Inc.

What We're Interested In

Increasing the robustness, resilience, and reliability of human-robot systems

- “co-robots”
- (mostly) constant interaction
  - no long periods of inactivity
- in the real world
- doing real tasks that help people
- today

What do We Mean by “Robot”?

Controlling Robots: Two Options

Teleoperation

- human controls all functions of the robot
- no real autonomy on robot

Autonomy

- robot is controlled by clever software
- human gives very high-level directions

Teleoperation

Easy for a simple mobile robot

- plug in a joystick, and away you go
- problems with situational awareness
- problems with eyes-on coordinate transforms

Hard for more complex robots

- many degrees of freedom
- it takes a month to train a Packbot operator

Teleoperation

Impossible for more than one robot

- just too many things to directly control

Teleoperation is (almost) never better than you

- it's easier and faster to just do it yourself
- unless there's a reason not to

Autonomy

Software maps from sensor data to motor actions

- sense-think-act

Perception is hard

- especially on a moving, shaking platform
- especially in the real world

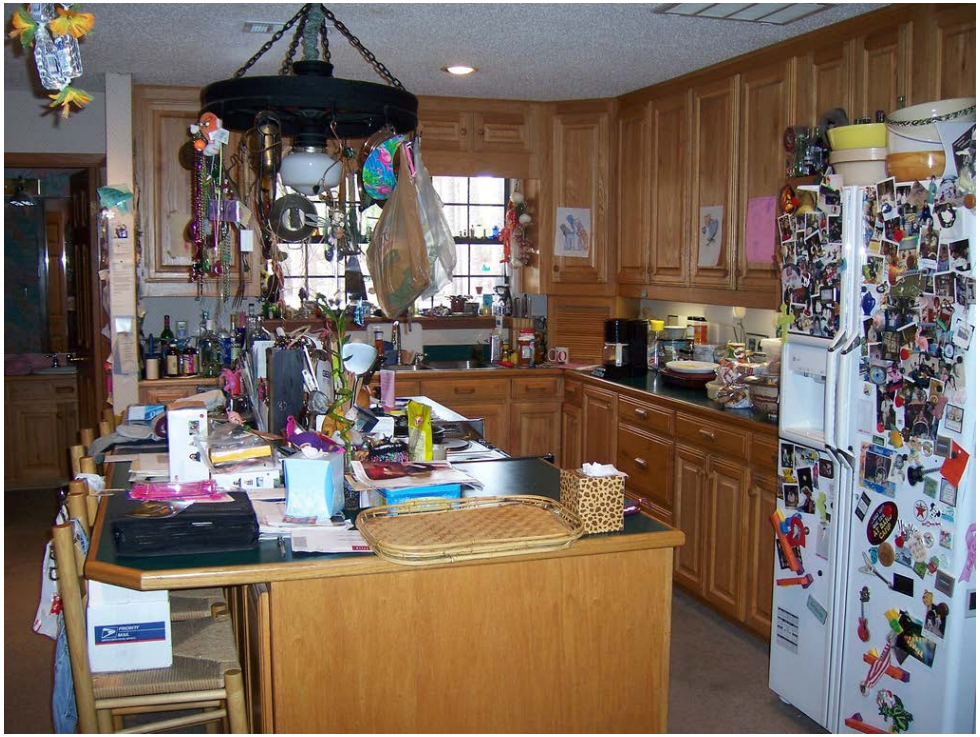
Reasoning is hard, too

- once you perceive the world, how to make sense of it?

Autonomy

We'd like autonomous robots

- operating in the real world
- doing tasks we care about
- “better” than us
- soon



“Robot, fetch my coffee cup.”

So...

Neither approach is resilient in the real world today

- teleoperation: too hard to control well
- autonomous: too hard to do perception

For this talk, I'll ignore other, lower-level resilience issues

The Key Insight

Humans are good at some things.

Robots are good at some things.

They can complement each other.

This can make the overall system more resilient in the face of the real world

Humans

We're typically good at

- high-level decision-making
- semantic labeling
- perception

Robots

They're typically good at

- low-level planning
- closed-loop feedback control
- repetitive tasks
- some autonomous tasks

Shared Autonomy Control

Robots are mostly-autonomous

- use the human to fill in the gaps
- performing sub-tasks that robots find hard

As autonomy gets better, human role is reduced

- eventually we get to full autonomy

Why Shared Autonomy?

It gets us to useful robots more quickly

- don't have to wait for autonomy to be “solved”
- can tackle real-world problems today

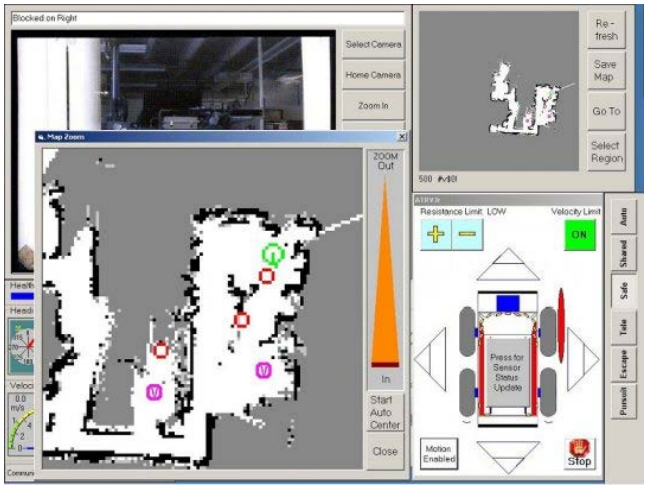
It puts a human in the loop

- increases the overall resilience of the system
- also important for legal and ethical reasons
- also useful for acceptance issues
- all of these help get robots out into the world

Previous Work

Mostly in assisted teleoperation

- wheelchair control [Nuttin et al. 2001, Miller & Slack 1995, Mazo et al 1995, Bühler et al 1995, ...]
- search robots [Bruemmer at al 2005, Keyes et al 2006, Few et al 2006, ...]
- game-like interfaces [Jones & Snyder, 2001]

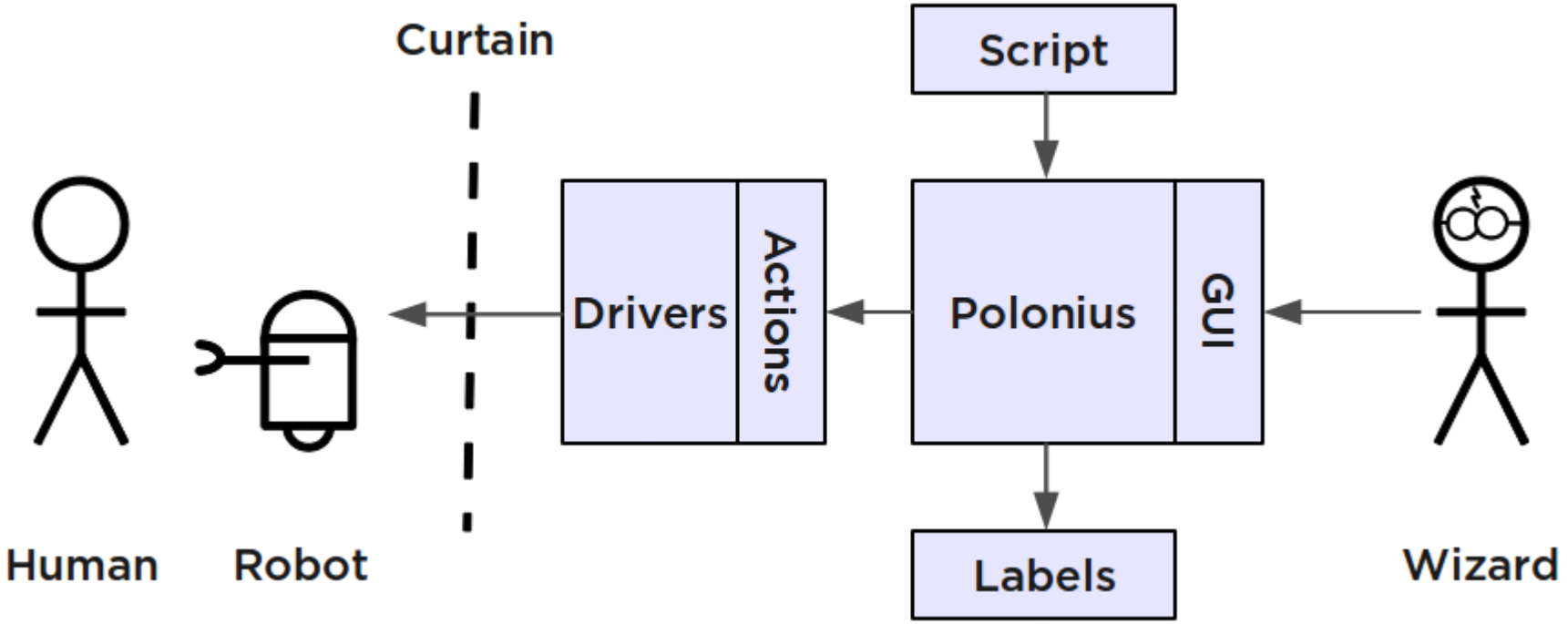


[adaptiverobotics.inl.gov]

A Very Simple Example

Simple interface for robots in the theatre

- behaviors are autonomous
- timing and interaction cues are triggered by human



Polonius

Took “script” as input

- essentially a FSM
  - with error recovery and “abort”
- human-triggered transitions
  - timing
  - interaction with human actors

human solves the perception problems

RIDE

The Robot Interactive Display Environment

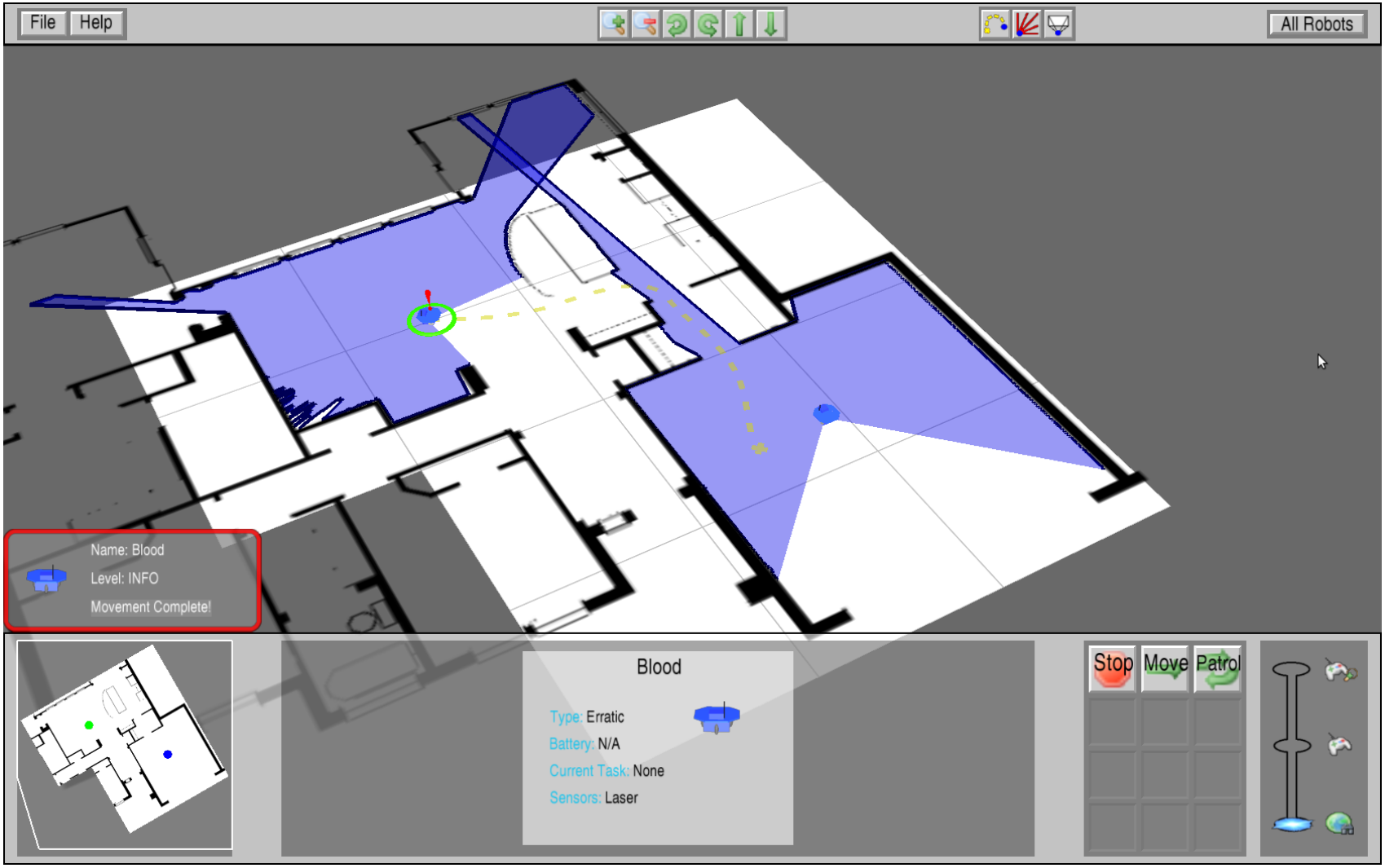
- supervisory control of a number of mobile robots

We'd like to control a (large) number of robots

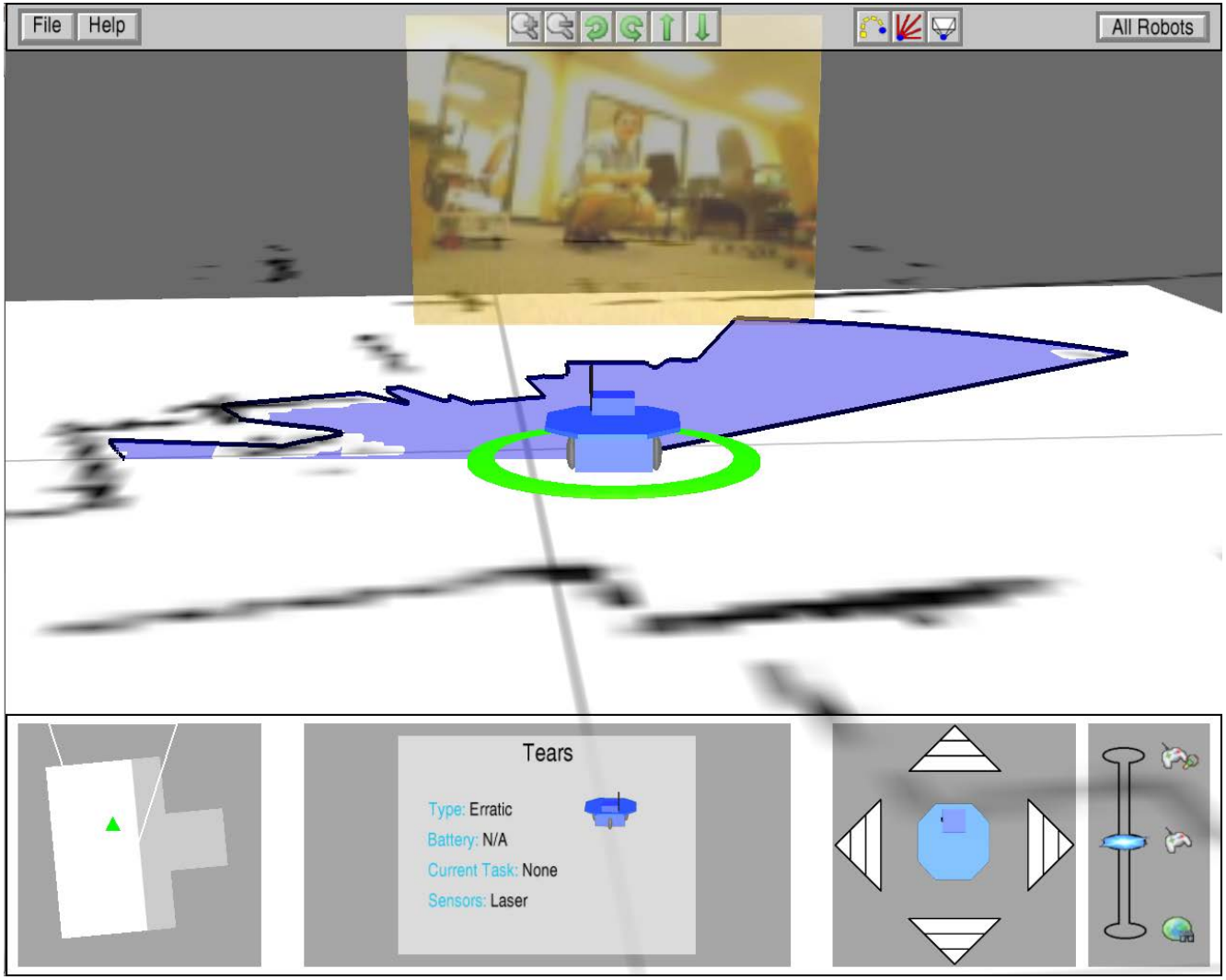
- mostly autonomous
- heterogeneous
- without knowing much about robots

RIDE

human supplies high-level planning and makes up for failures in autonomy



RIDE


File
Help
All Robots
Tears
Type: Erratic
Battery: N/A
Current Task: None
Sensors: Laser

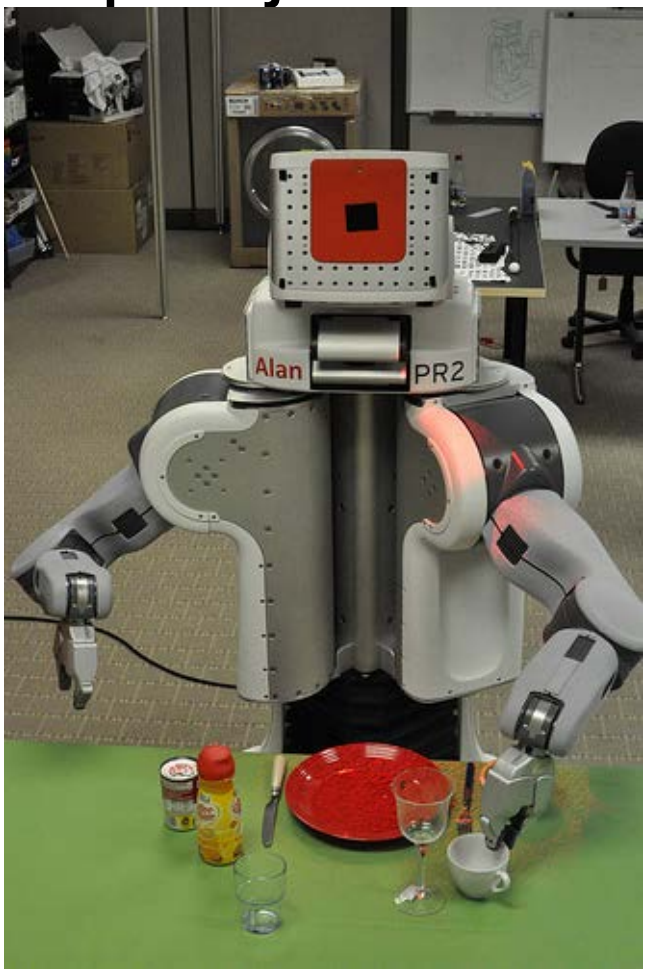
RIDE

[video]

Interactive Manipulation

Autonomous manipulation of tabletop objects

- cups, bottles, bowls, plates, etc
- pick up, put down
- surface can often be cluttered



Autonomous Grasping

Pipeline of operations

- sense world
- build model of tabletop and objects
- segment and identify interesting objects
- select one
- determine good grasp points
- plan trajectory to get into grasping position
- execute trajectory
- grasp object
- plan trajectory to get back to start position (with object)

human supplies perception and high-level planning

Interactive Manipulation

[video]

Helping People Today with More Resilient Systems

Robot assistant for a mute quadriplegic

- good low-level manipulation abilities
- limited reasoning and perception

Mute quadriplegic for a robot assistant

- very limited physical abilities
- full mental abilities

combine these two and get a much more resilient system

Helping People Today with More Resilient Systems

Who Else?

Polonius (WU)

- David Lu

RIDE (WU)

- Tim Blakely
- Erik Karulf
- Marshall Strother
- Parker Dunton

Interactive Manipulation (WG)

- Matei Ciocarlie
- Kaijen Hsiao
- David Gossow
- Adam Leeper

Robots for Humanity (GT)

- Charles Kemp
- Philip Grice
- Hai Nguyen

Who Else?

Robots for Humanity (WG)

- Steve Cousins
- Leila Takayama
- Caroline Pantofaru
- Bianca Soto
- Jonathan Cousins

Robots for Humanity (GT)

- Kelsey Hawkins
- Aaron King

Robots for Humanity

- Henry Evans
- Jane Evans

Questions?

Washington University in St. Louis
School of Engineering & Applied Science

wds@cse.wustl.edu

Willow Garage

wds@willowgarage.com