

## Dimensions of Adjustable Autonomy

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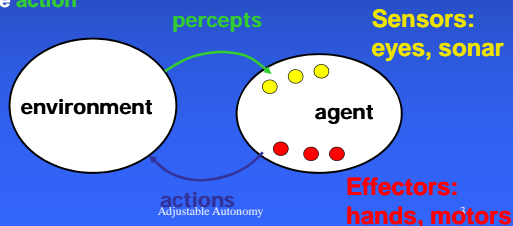
## Outline

- What is an Autonomous Agent?
- What is Adjustable Autonomy?
- Dimensions that can be "adjusted"
  - › Independence
  - › Control
  - › Goals
- Perspectives on AA in participant's systems
- Discussion
- Summary

## What is an Autonomous Agent?

Interacts with its environment

1. can **sense** its environment
2. make **decisions**, and
3. take **action**



## What is Autonomy?

The **breadth** of **goals** that an agent has the authority to accomplish and the **latitude** it has to achieve those goals (Barber et al.)

## What is Adjustable Autonomy?

- Adjustable Autonomy is when the agents (human and/or software/ hardware) in a system **dynamically** change the allocation of authority and latitude for achieving goals among themselves

(Total autonomy in the combined system remains the same)

## Motivation

- "Our goal is to design a framework for human centered autonomous systems that **allows** users of the system to interact with the system at whatever level of control is appropriate whenever they choose to do so, but **minimize the need** for such interaction" - (NASA, 1998)

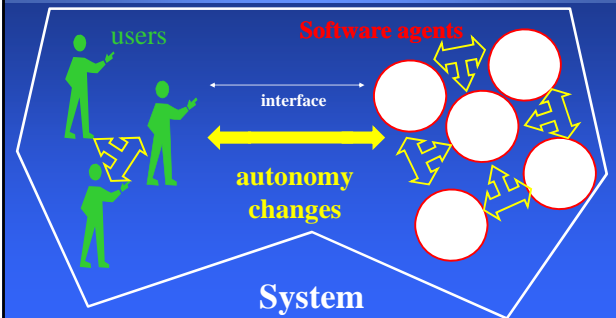
## Ideal Adjustable Autonomy ("the Super Agent")

- Intelligent support e.g. a good secretary (with ESP?)
  - › different levels of autonomy for different tasks
  - › intelligent acceptance of commands: notify if not capable, interpret correctly, clarify ambiguities
  - › if it knows what you want, it does it within its capabilities (quietly), takes care of "details"
  - › if it is unsure - it will ask (if the "cost" of a bad decision is risky or costly)
  - › learns from experience, doesn't repeat errors

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7

## A System with Adjustable Autonomy



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8

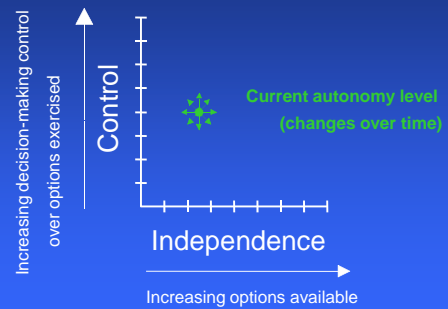
## Dimensions of Adjustable Autonomy

- Goals - control over selecting goals to pursue
- Control - decision-making control over which options are exercised in solving goals
- Independence - range of possible ways available to accomplish a goal

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9

## Autonomy for Each Goal



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10

## Adjusting Independence

- Independence is the number of different ways that an agent is allowed to try to achieve its goals
- Example systems: 3T (Bonasso et al., NASA). RAPs (Firby)

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11

## NASA systems

- NASA Johnson space center, Houston, Texas <http://www.traclabs.com/~korten>, David Kortenkamp's page
- NASA Ames, Moffet Field, California Gregory Dorais

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12

## Independence Control in RAPS

- Developer can specify different methods for achieving the same task
- The system can ask a human to perform a task
- Planner re-plans if a task is failing
- Low-level primitive skills can be combined to accomplish tasks in many ways

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13

## RAPS, cont.

- User can restrict the search space for planning
- Users can “disable” sensors and skills
- Users can have mixed-initiative interaction
- Result – guiding without taking complete control

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14

## Adjusting Control

- Autonomy w.r.t. each Goal is how much control the agent has over how to pursue the goal and the lack of interference by other agent(s)
- Example: Adaptive Decision-Making Frameworks (ADMF), Barber, et al.

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15

## Decision-Making Styles

- Command-driven – no decision-making by “self”
- True Consensus – equal partner with others
- Locally Autonomous/Master – decision making completely by “self” (may delegate)



Decision-making styles and autonomy  
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16

## Decision-Making Frameworks

- A coherent set of individual decision-making styles for all participating agents
- Representation: (D, G, C) where
  - › D = decision-makers and their strengths
  - › G = set of goals under consideration
  - › C = authority-over constraint – agents committed to perform the goals decided upon by the DMF (penalty for failure to perform tasks)

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17

## Adaptive Decision-Making Frameworks

- One framework is not best for all situations the agents may encounter
- Changing the framework allows better performance by adapting to current conditions

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18

## U of Texas at Austin

- Prof. K. Suzanne Barber
- Adjustable autonomy for naval radar communication
- See references

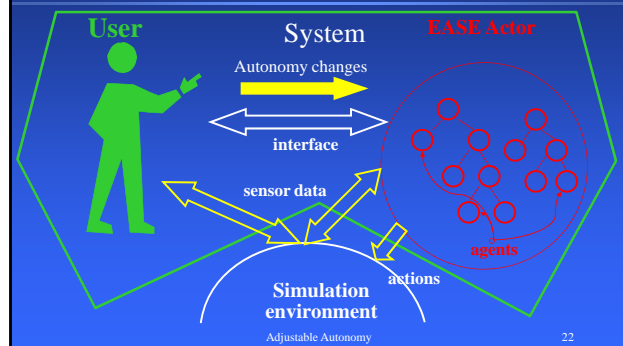
## Goal Adjustment

- Adjustment of Autonomy means changes to goals and objectives of an agent
- Example system: EASE. application: simulation environments (Scerri & Reed)
- User adjusts the autonomy of the MAS by adding, removing, or suspending goals

## Adjustable Autonomy in EASE

- 1 user with 1 software actor (multi-agent system)
- User does all reasoning to decide on changes in autonomy (not agents)
- User makes off-line or on-line changes to modify actor behavior with the available graphical tools

## System of 1 User and 1 Actor



## Discussion

- Three types of adjustable autonomy described
- Others possible
- Much work still to be done in this area

## Who Uses AA?

- NASA
  - » long term space missions, Kortenkamp et al.
- Honeywell
  - » safety critical process control, Musliner et al.
- Interactive theatre
  - » Blumberg, Hayes-Roth, et al.
- Human collaborative support
  - » Tambe, Pynadath, et al.

## Summary

- Different characteristics that are used to adjust autonomy
  - » Goals
  - » Independence
  - » Control

## Questions?

