The critterbot project

The critterbot project

- A series of sensor-rich, animal-like robots
- Dense sensorimotor interaction (>10 Hz)
- A worked example of autonomous, adaptive AI
- Much of the work will be in simulation
- Potentially a focal project for the RLAI group

outline

- Goals and opportunities in subjective robotics
- The current critterbot Mach 1
- Examples of subjective knowledge in the critterbot

Objective robotics

- The robot's knowledge is grounded in public terms like those people use to talk to each other: meters, objects, doorways...
- Robot does not need to understand the knowledge in order for it to work
- But robot and human terms must be kept aligned… mostly manually
- Often brittle to unforeseen situations, and scales poorly - breaking down when the knowledge exceeds what one person can know

Subjective robotics

- Robotics grounded in experience
- Knowledge is in terms of the robot's own sensors and actuators
- Knowledge is predictive or otherwise autonomously verifiable by the robot
- Oriented toward the robot self-maintaining its knowledge
- Ground everything bottom-up in data
- Sounds good, but is it really practical?

For example, in subjective robotics:

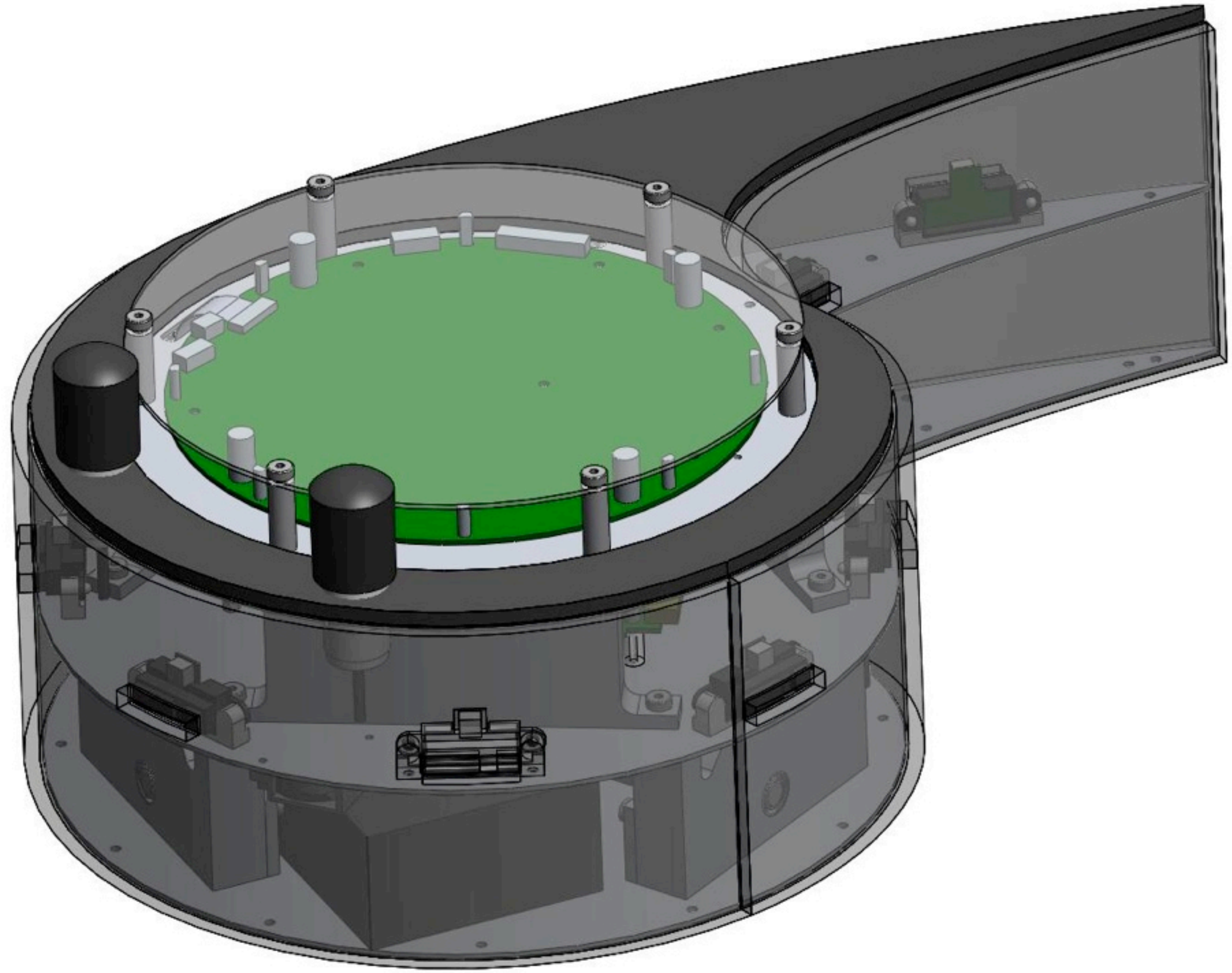
- Instead of calibration, use unsupervised learning
- Instead of filtering and smoothing, use predictive representations
- Instead of training robot to label objects like people, let it learn when its options will succeed

Goals - gain experience in

- Subjective robotics/knowledge
- Sensori-motor models of the world
- Connecting low-level experience to high-level knowledge
- Perception - large sensor spaces
- State
- Teaching, social aspects

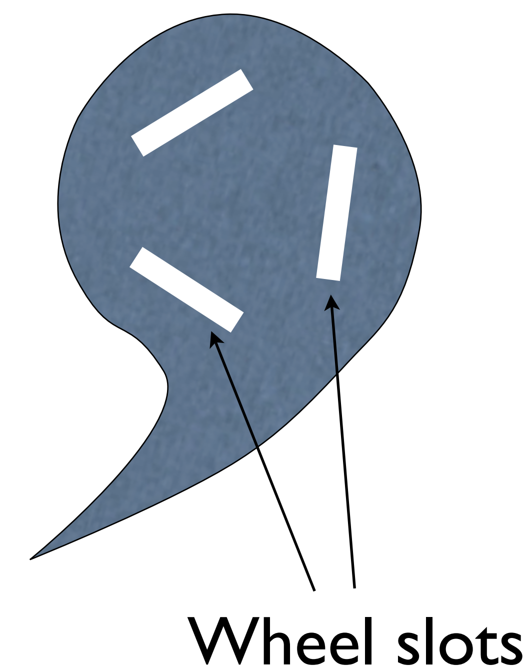
Goals - gain experience in

- Continual, life-long learning, accretion of knowledge
- Living with open-ended knowledge
- Discovery
- Exploration
- Real-time constraints



Mach I critterbot

Actuators



- Wheels (three, holonomic drive)
  - Omni-directional
  - Independent translation and rotation
- Speaker
- Lights (12 polychromatic LEDs)
- Tail/scoop

Sensors I

- Touch/bump/contact
- Inertial
- Proximity (infra-red)
- Light (non-imaging)
- Wheel motions
- Motor resistances

Sensors 2

- Sound (two microphones)
- Radio (sees wireless base stations)
- Magnetic (compass)
- Temperature
- Camera (future)

My Hamming problem

- *How we can know lots of stuff* about how the world works and what we can do, and apply it efficiently to maximize reward
- We know so much! So much sensori-motor stuff
- How can we relate higher-level knowledge to the low-level sensorimotor stuff?
- How can it all be organized and maintained? What are the principles?

Critterbot knowledge

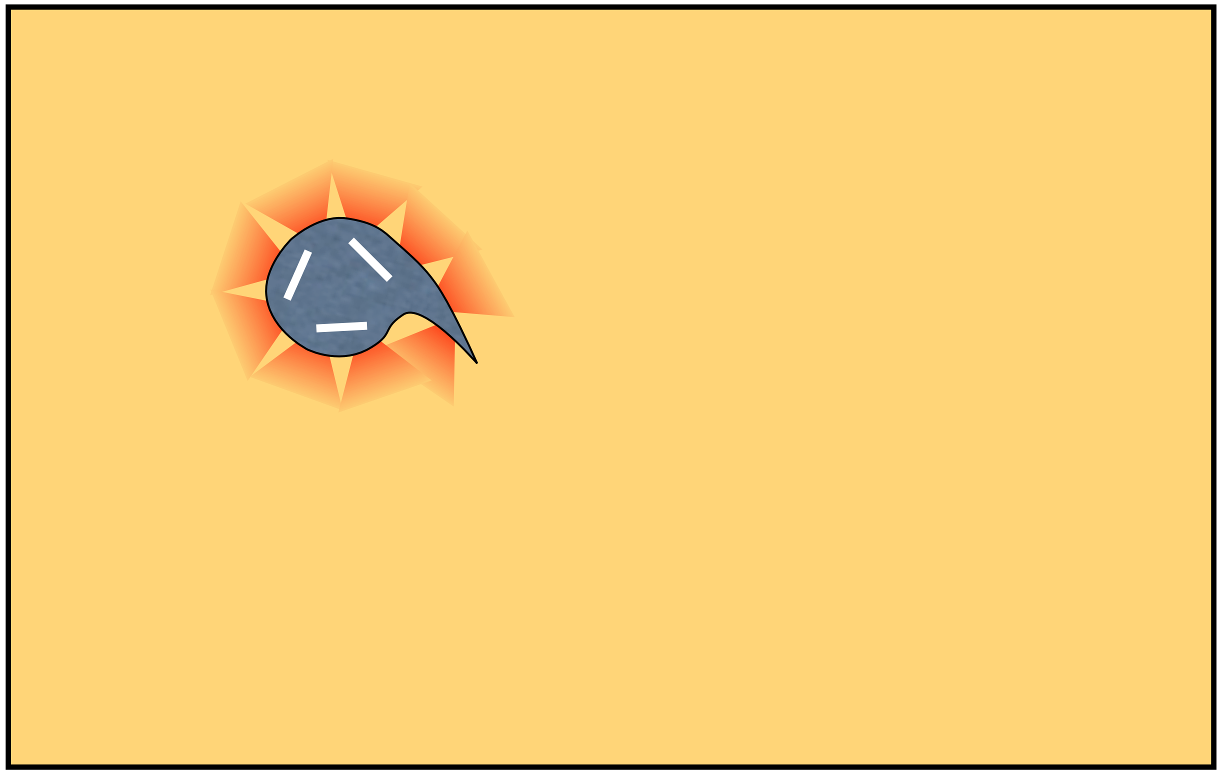
- Base rates (means and variances) for all the sensors
- Some configurations of sensor readings happen, some don't
  - Extend this into time
  - Within and across sensations
- Unsupervised learning in sensor-time space

Critterbot knowledge

- How do motor torques affect wheel rotation?
- How do motor torques affect motor strain?
- How do wheel torques affect compass and inertial sensors?
- How do bumps affect inertial sensors?
- What about velocity?

Critterbot knowledge

- Inter-relationship of touch, proximity, and wheel rotation
- Proximity predicts touch
- Wheel rotation predicts proximity, then touch



- But all in very particular ways - certain motions correlate with certain sensations

Critterbot knowledge

- There is no action for forward or rotate
- But certain wheel motions will cause certain “motions” and associated sensations
- Rotating the body when close to a wall will cause patterns of proximity and contact
- Complex relationships, but lots of regularities.
- Use geometry? No! Use memory and gain robustness and generality, accuracy

Knowledge of state

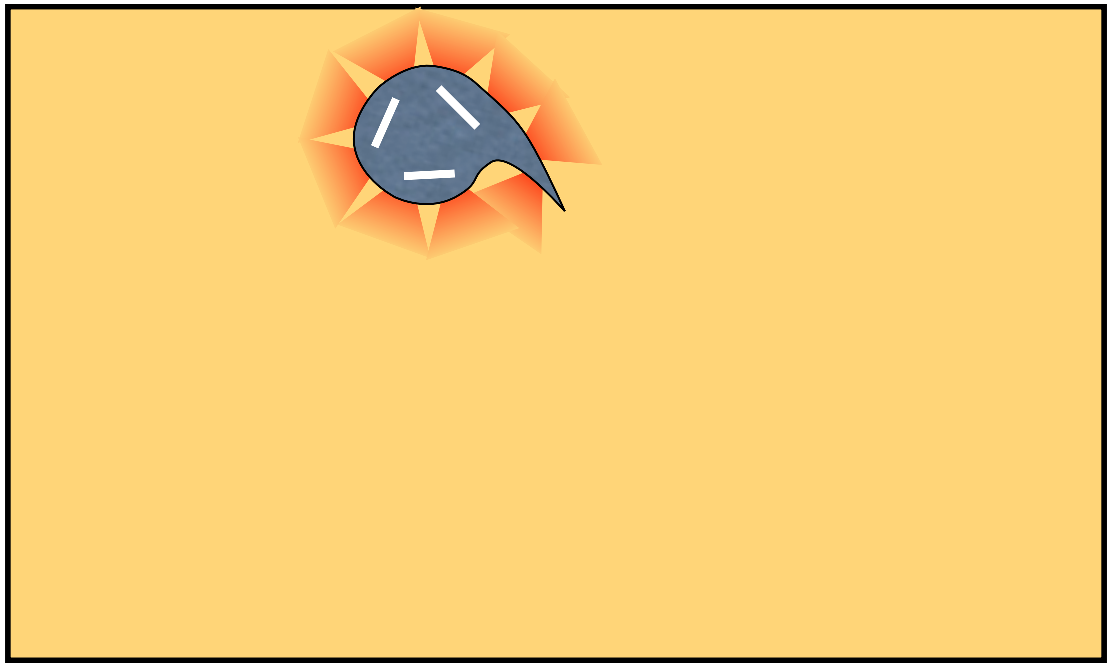
- Wall to the left/right/front/back of me?
  - Naturally represented as predictions of proximity and/or touch readings
- Is there a lot of open space ahead of me?
  - Will running forward cause bump?
- Instead of filtering/smoothing, use predictions
  - Past readings inform future readings

Some options we might build in

- Null options over various time-scales (for predictions that are not action conditional)
- Constant actions over various time-scales
- Move randomly (without motor strain)
- Maximize/minimize each sensor
- Run wheels without changing compass
- Run wheels without changing proximity

Higher-level knowledge

- Places in the room
  - Along a wall?
  - In a corner?
  - Facing open space?
  - Long wall vs short wall, right vs left?
  - Battery charger nearby?



Higher-level knowledge

- The rattle
  - A distinctive sound
  - Some actions may "cause" the sound
  - There are times when it can be caused, and times when it cannot (presence/absence)
  - It has a location
  - The location can change (state)
  - I can move it

Higher-level knowledge

- people
  - Distinctive sounds
    - Voices, door opening
  - Opportunities for reward (clicker, petting)
  - Temporal coherence (presence/absence)
  - Correlated with rattle, learning opportunities…
  - Help. E.g., back to the charger

Teaching

- Can a subjective robot be quickly taught to do new things?
- Think of it as a cooperative dog
- Can we direct it by physically pushing on it?
- Can we reward and/or direct it with tone of voice?
- What about when we don’t want to manually reward it every time?

Agent design principles

- Nested, horizontal agent design
  - Independent layers - reflex, RL, planning, discovery
- Continual learning - long-lived agent
- Incremental, online computation
  - The same algorithms run all the time

stages of progress

- representation - can we represent the solution if we don't worry about learning it
- learning - can we tune the parameters of the solution if we don't worry about discovering its structure
- discovery - can we find the structure of the solution as well?

Conclusion

- An opportunity to really come to grips with subjective, experience-based knowledge
- We may be uniquely positioned to do this well
  - Right robot: lots of sensors, simple dynamics, local hardware expertise, long-running design
  - Right attitude: far-sighted funder, patience, and modest expectations, multiple tries
  - (some) Right ideas: RL, Dyna, PSRs and TD nets, options and option models, learning feels good...