MERTZ: Toward a Robust Sociable Humanoid Head Robot

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Outline

- The Robot
- Introduction
  - Research Direction
  - The Case for Robustness
  - Design Criteria
- Robot Design and Construction
  - Mechanical Design
  - System Architecture
- Experiments

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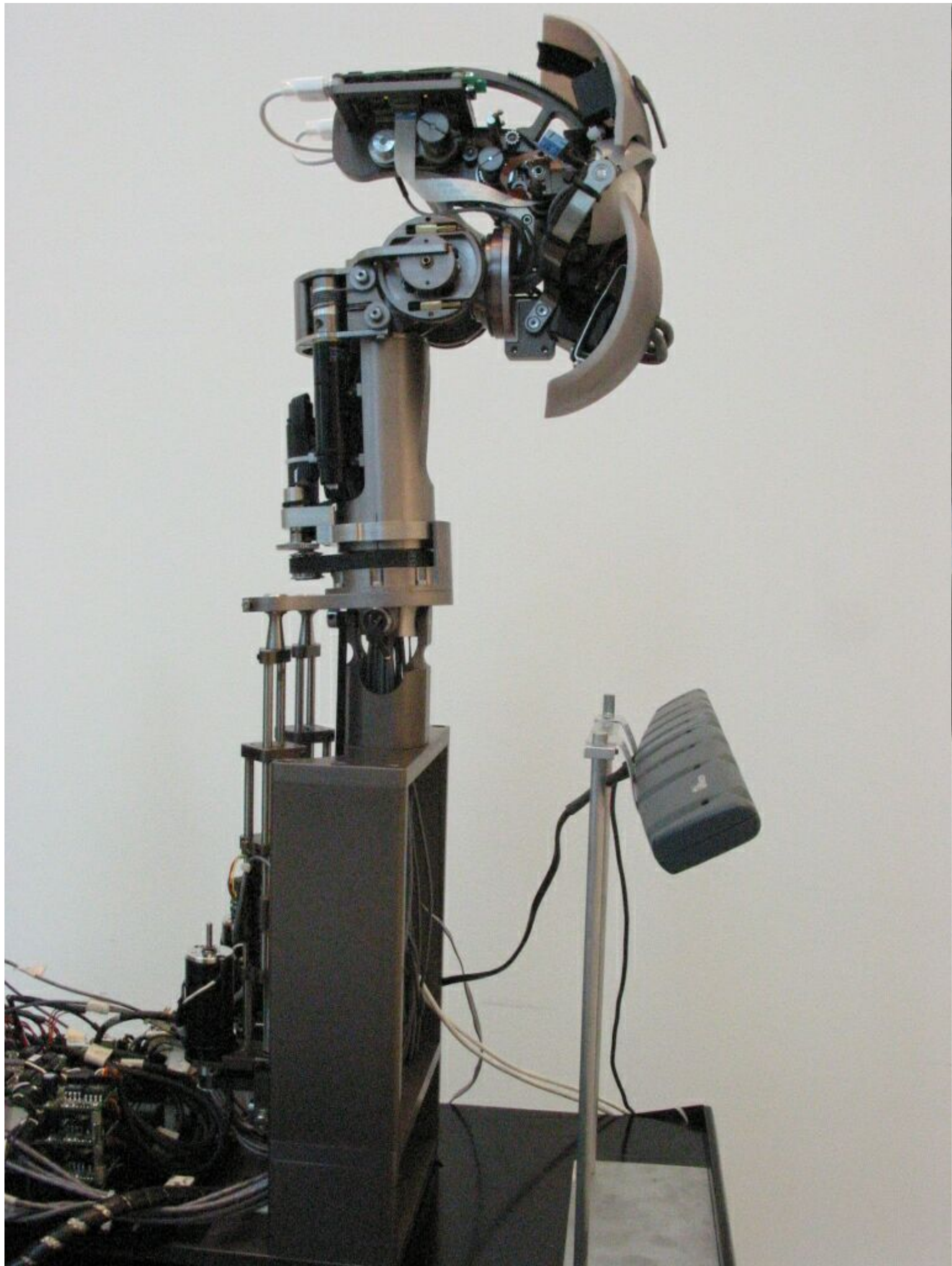
The Robot: Mertz



- Sensors:
  encoder
  potentiometers
  2 digital cameras
  microphone
- Actuators:
  9 DC brushed motors
  4 RC servos
  speech synthesizer

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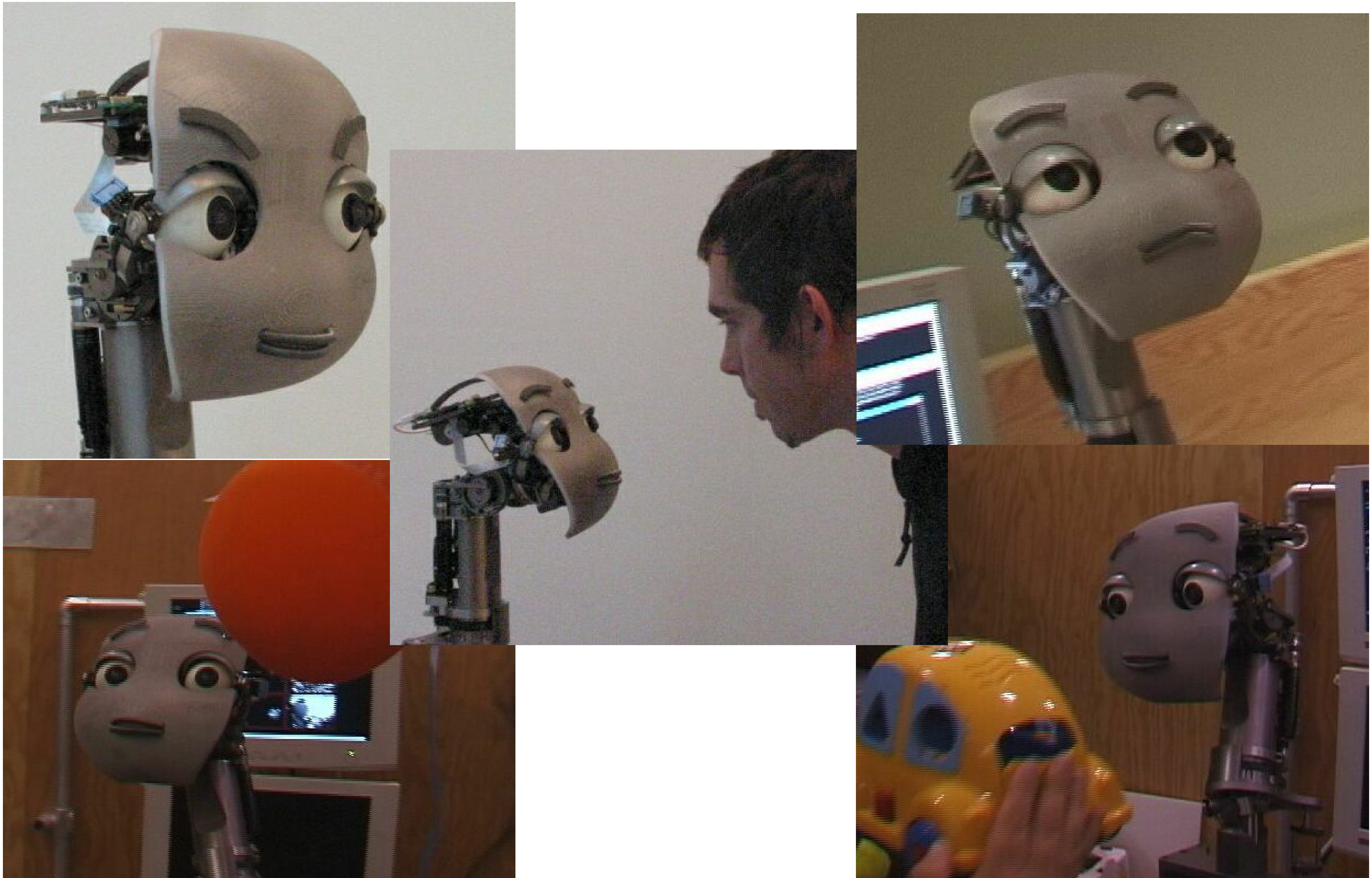
The Robot: Mertz



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Research direction

- Incremental learning from experience in social context
  - Individual recognition
  - Recognize own name and others
- Developmental approach: child machine (Turing, 1954)
- Must be situated in human space and time scale

The case for robustness

- Current limitations
  - Limited running period, short video demo, short-cuts, and specialized environment
- Robust platform
  - Long-term continuous operation
  - Multiple public spaces
  - Unconstrained social interaction with many people
- Motivation
  - Long-term online learning experiments
  - More dynamic social interaction
  - Avoid tuning algorithms to specific settings
  - Encourage scalable solutions

Design criteria

- Continuous long-term operation
- Modular control
- Custom-made hardware
- Easy and fast start-up sequence
  - Automatic calibration
  - Robust to human error
- Reduce risk of failures
- Long-term testing
- Safe interaction
- Complexity vs robustness
- Easily movable platform

Other issues

- Social interface
  - Visual design
  - Behavioral design
- Perceptual capacity
- Learning

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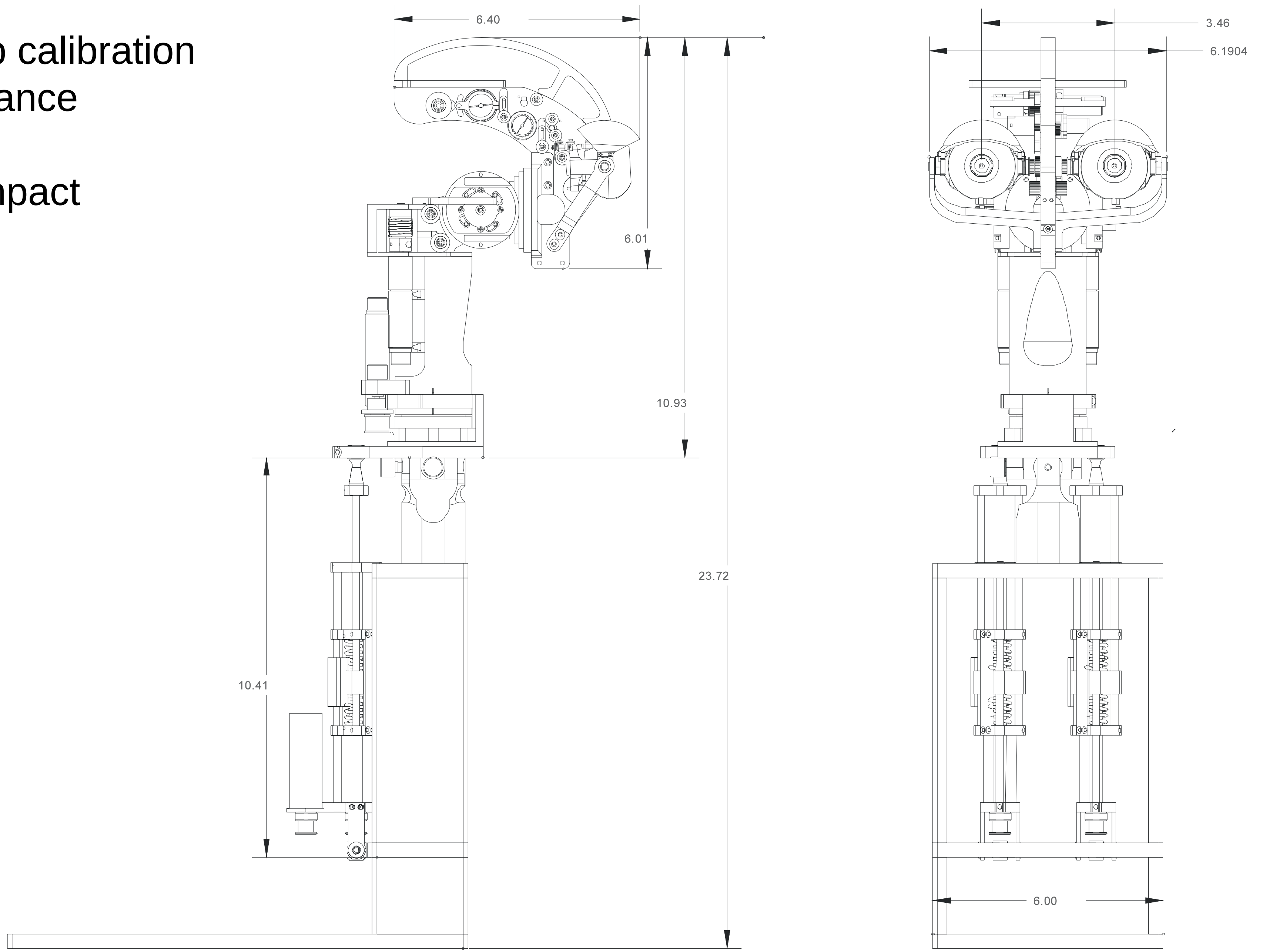
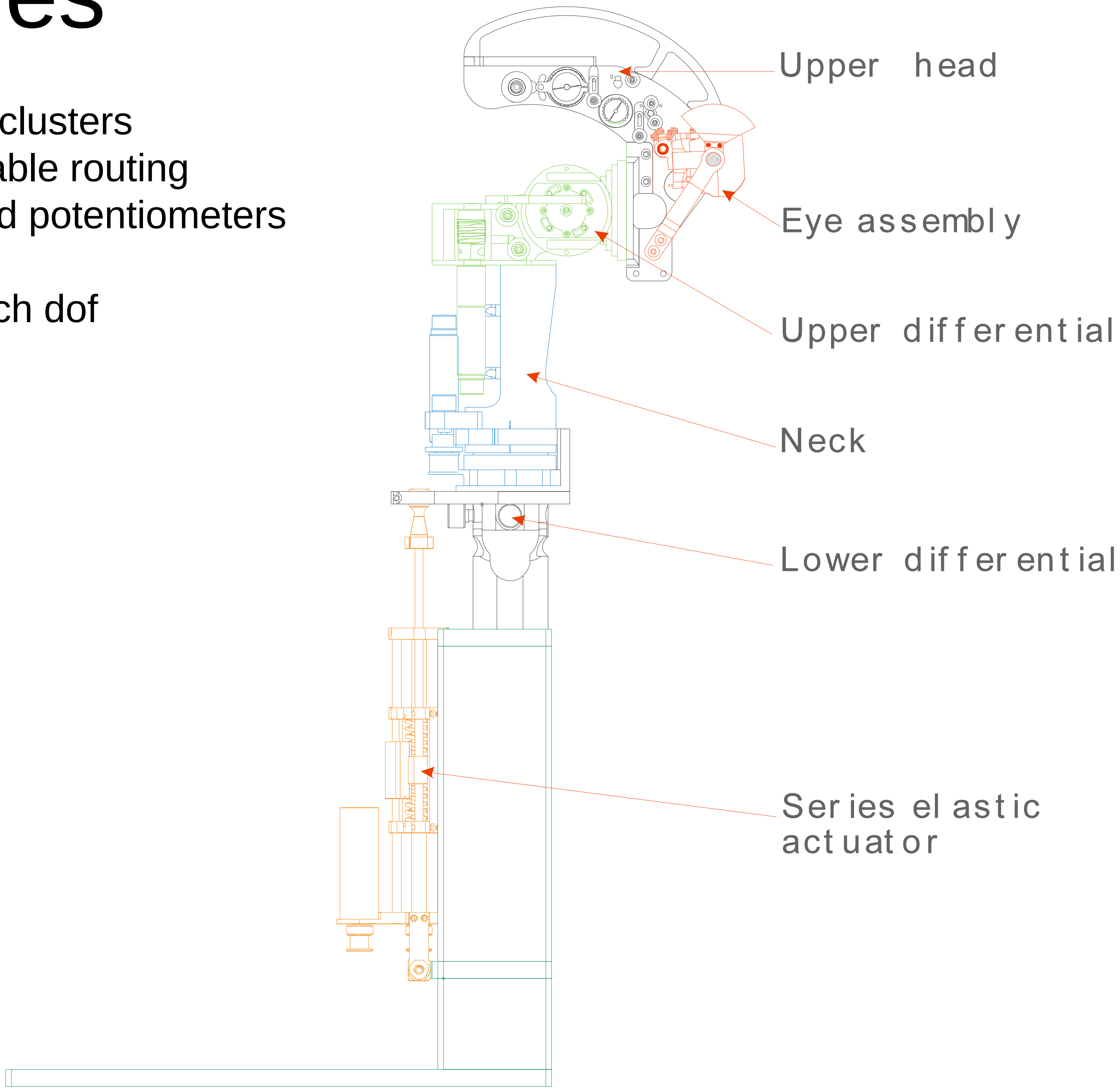
Mechanical design goals

- Robust Platform and indefinite operation
- Safe interaction
- Absolute startup calibration
- Simple maintenance
- Cable routing
- Lightweight compact Construction



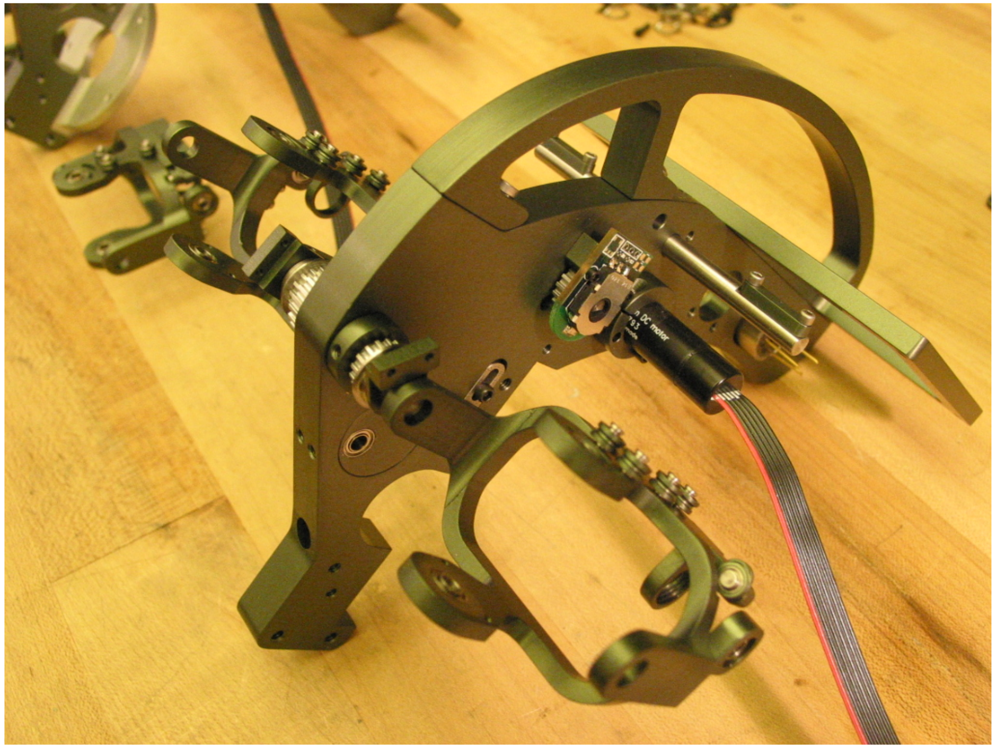
Assemblies

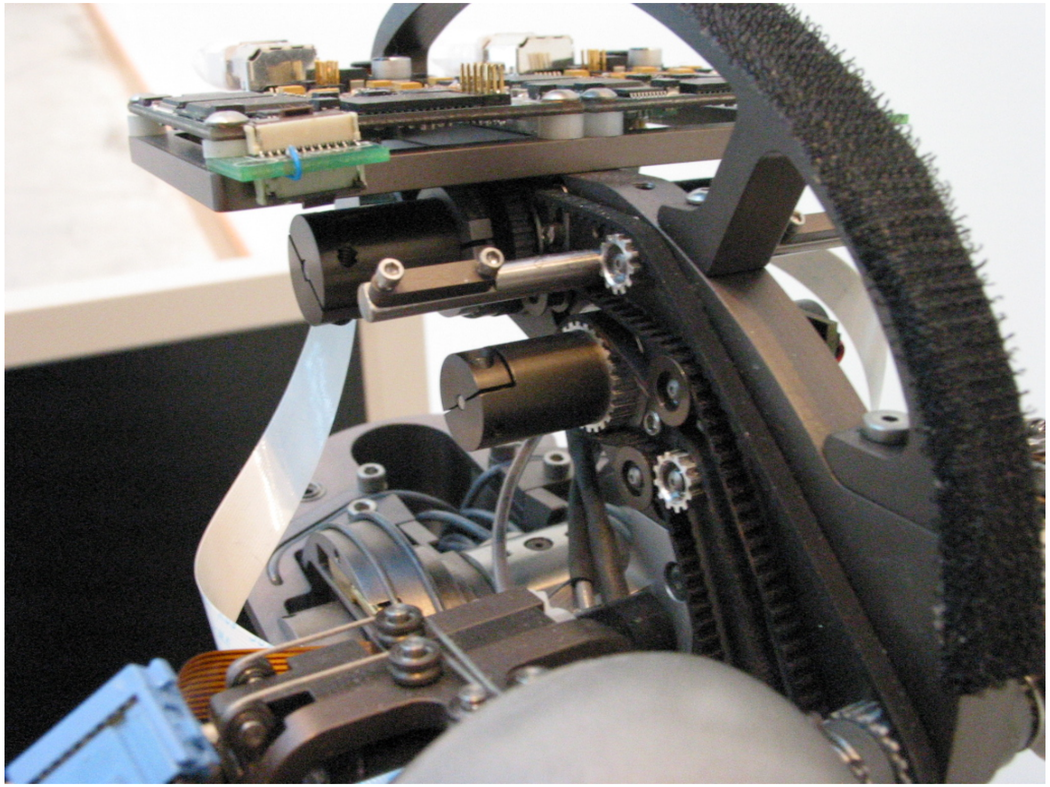
- Modular design
- Easy disassembly of clusters
- Central concealed Cable routing
- Position encoders and potentiometers at each of the 9 dof
- Physical stops for each dof

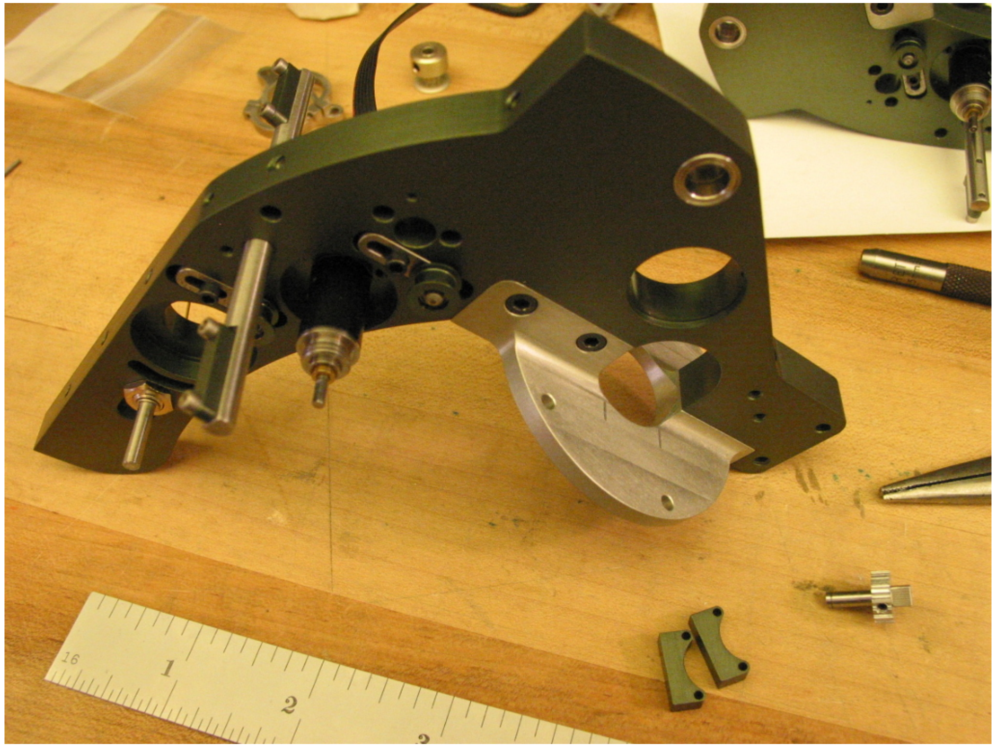


Head frame

•Eye, motor, and face shell support
•Belt drive routing
•Dense mechanics allowing for expansion of expressive elements

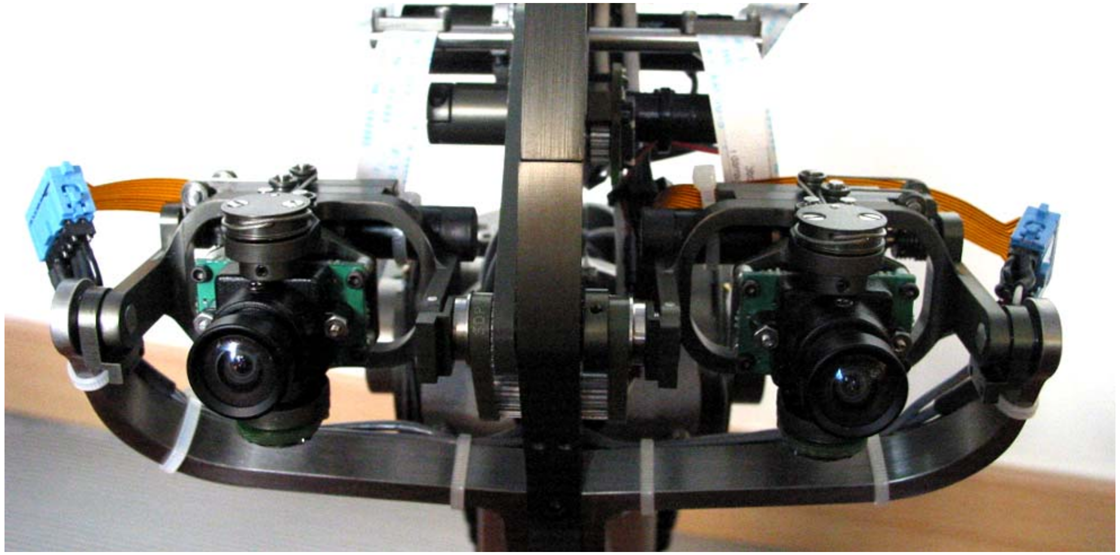


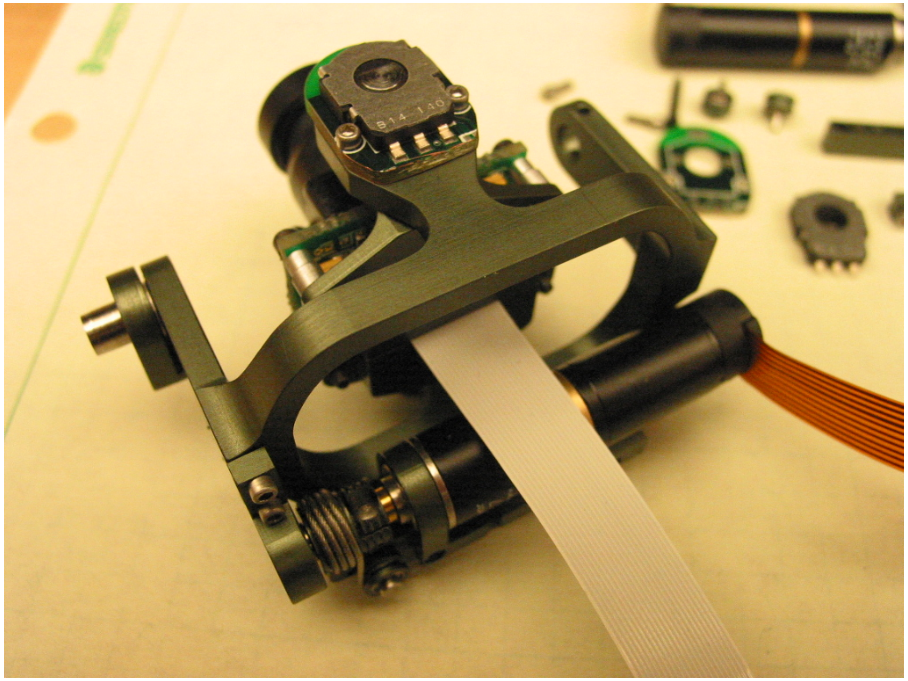


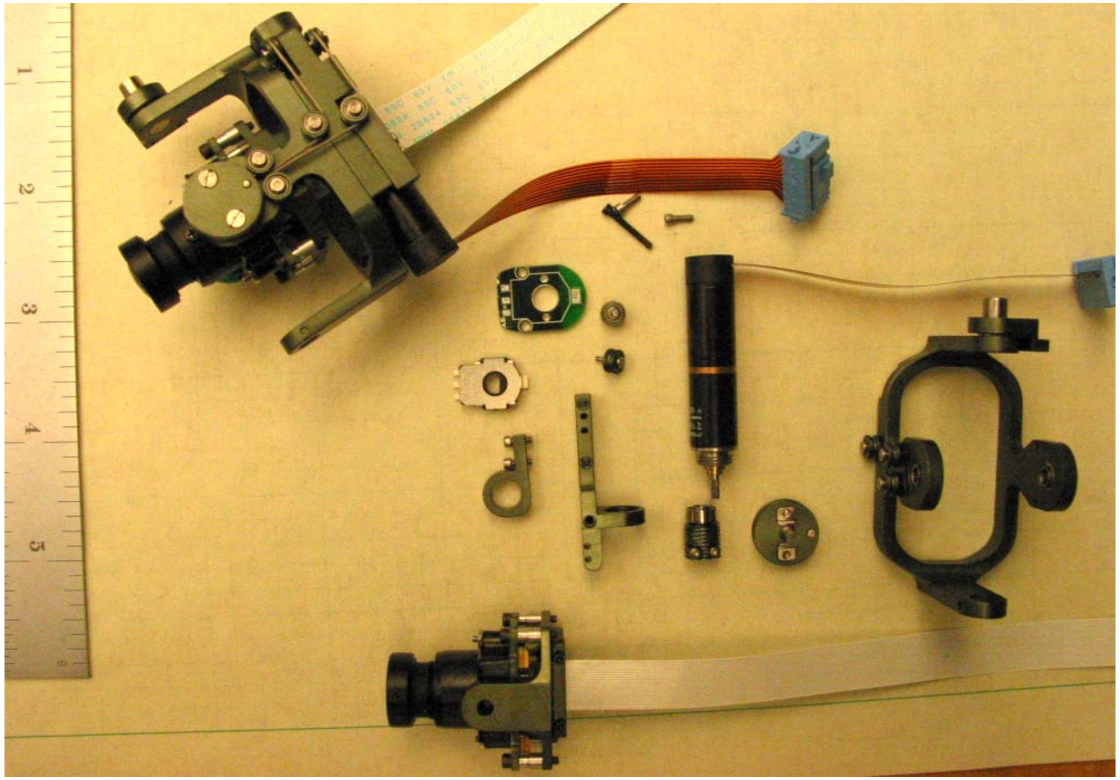


Active vision

- •Individual pan, combined tilt
- •10mm .75w motors with 256 count encoders and 64:1 gear heads for individual pan
- •900dg/s saccades, smooth pursuits
- •Off-board pan drive motor with cable drive

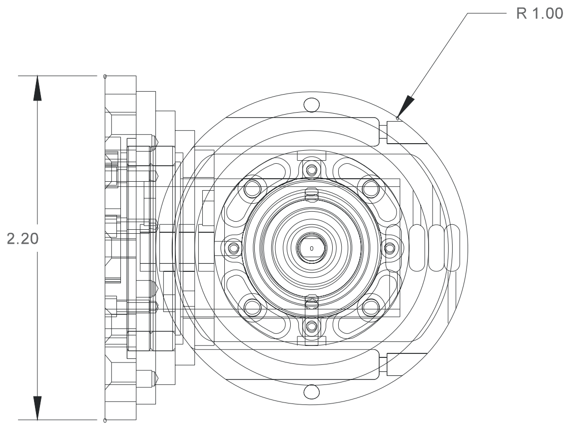


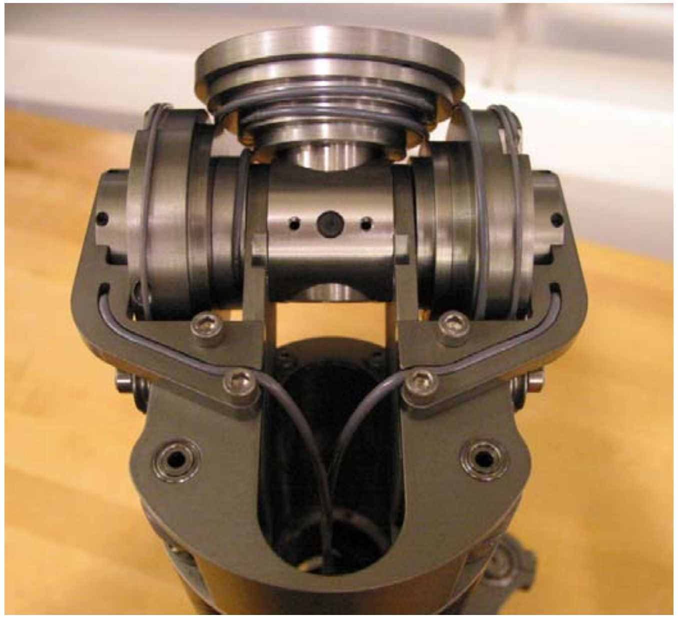


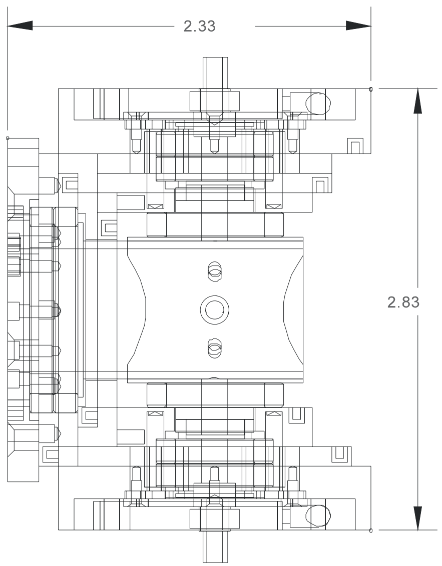


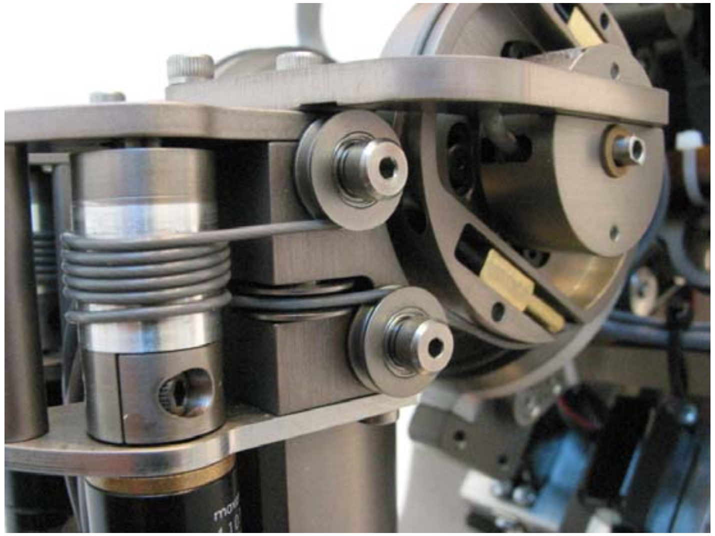
Upper differential

- Pitch and roll to 90deg. in one compact unit
- Dual motors for each movement
- No backlash and high efficiency between degrees of freedom
- Hollow center for cable routing







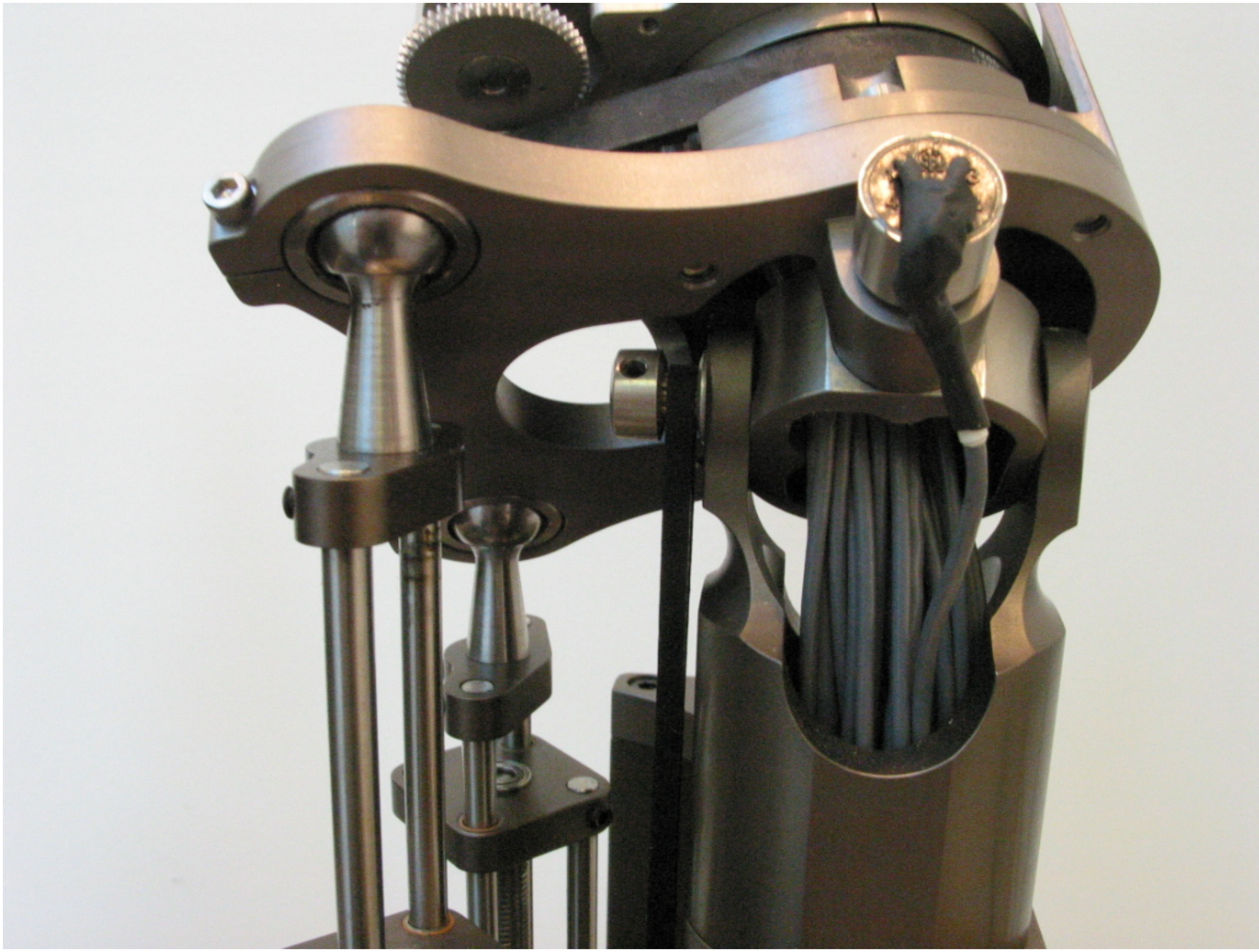


Neck pan

- Pan with internal cable routing
- Simple clamp together assembly
- Pre-loaded bearing cluster eliminating lateral play

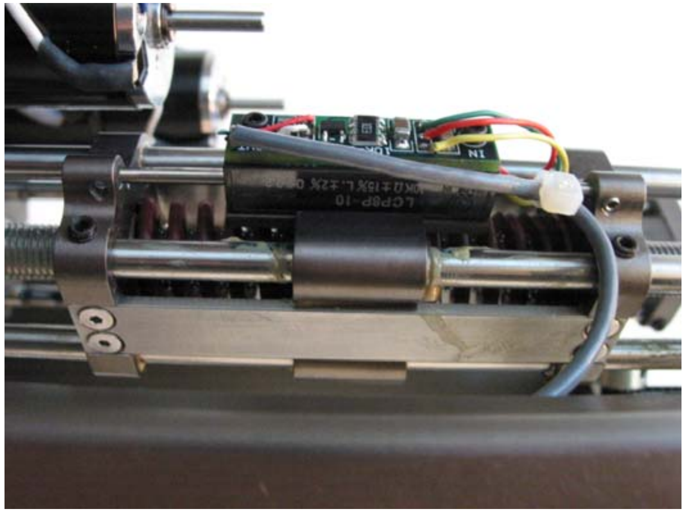
Lower differential

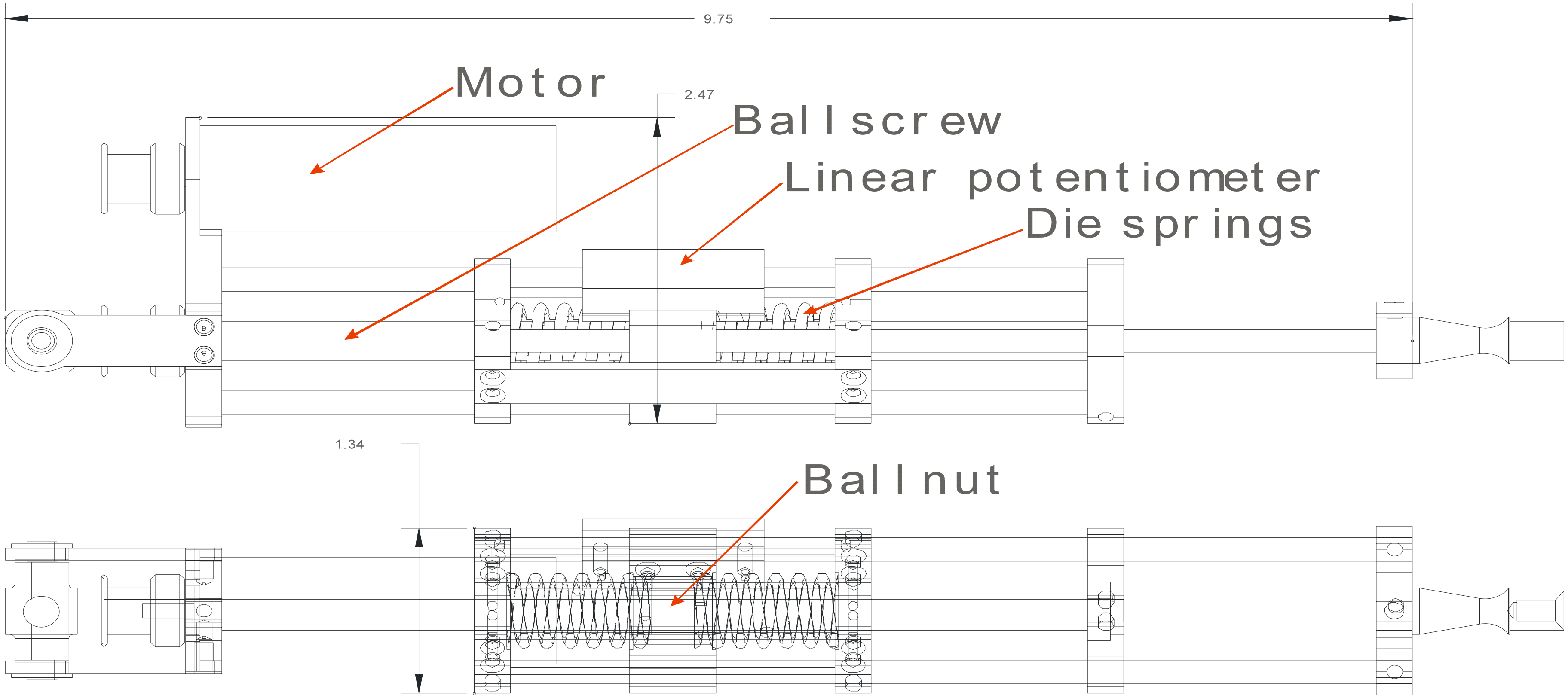
- universal type differential supporting the full head
- Safely driven by compliant actuators
- 90 deg. of pitch and yaw
- Internal cable routing
- Backlash free



Series Elastic Actuators

- Pratt & Williamson
- Compact linear actuators support full head weight
- Actively and passively back-drive-able
- Force sensing and compliant
- 40lbs force output each at less than 1A combined peak
- Hold head in place on shutdown





No
power

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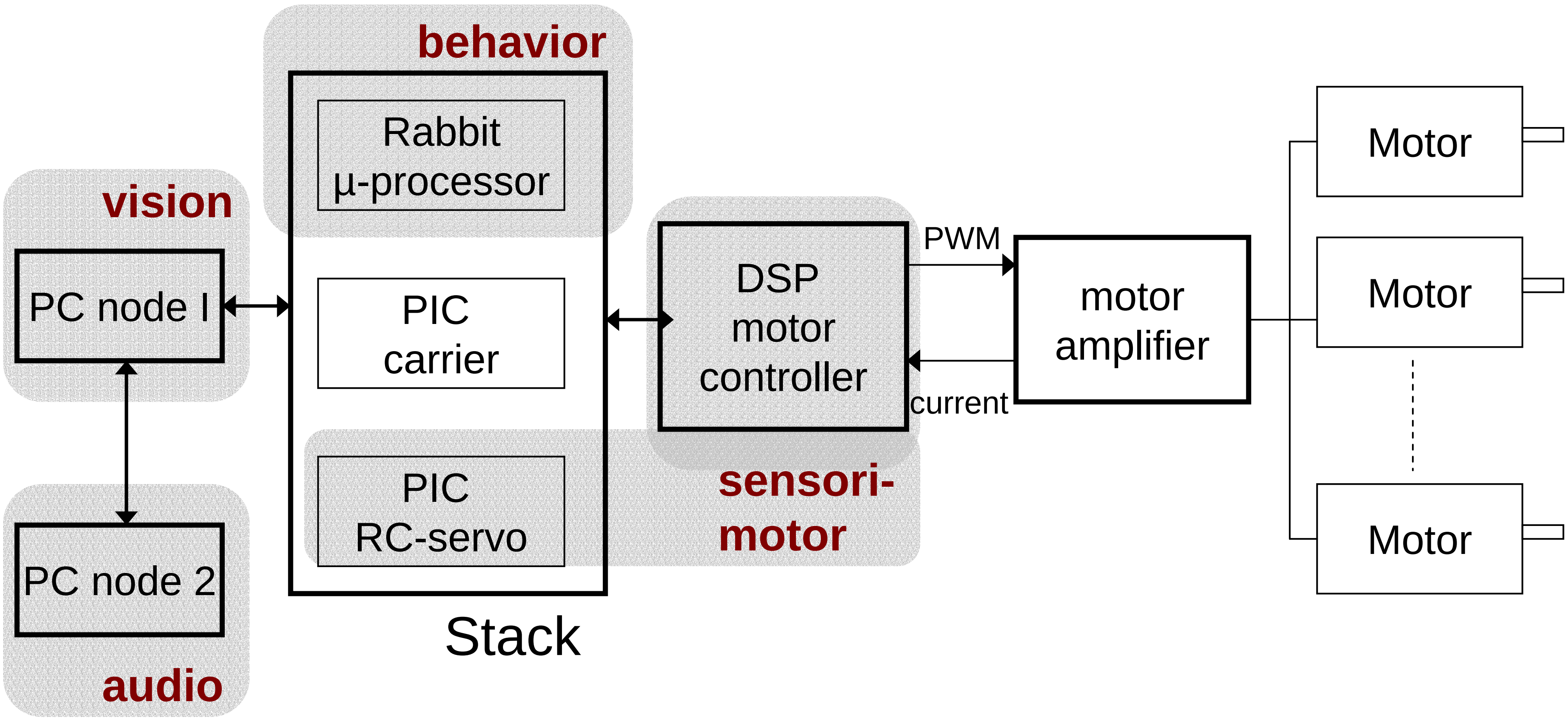
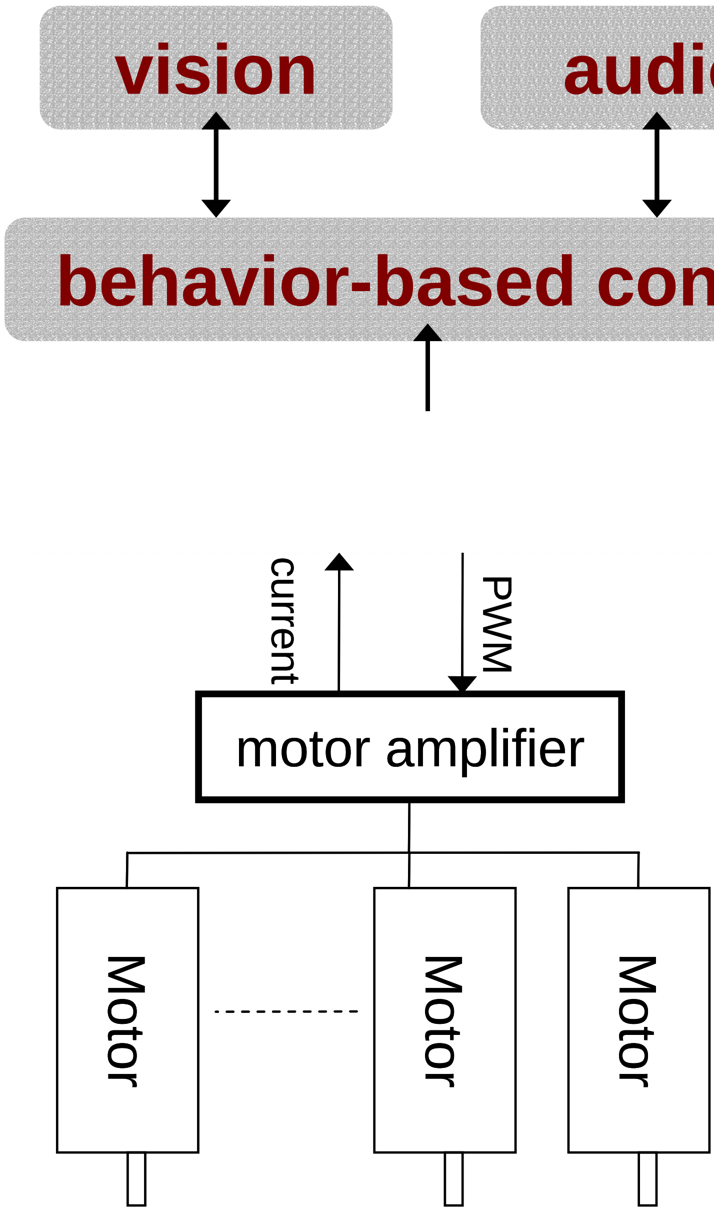
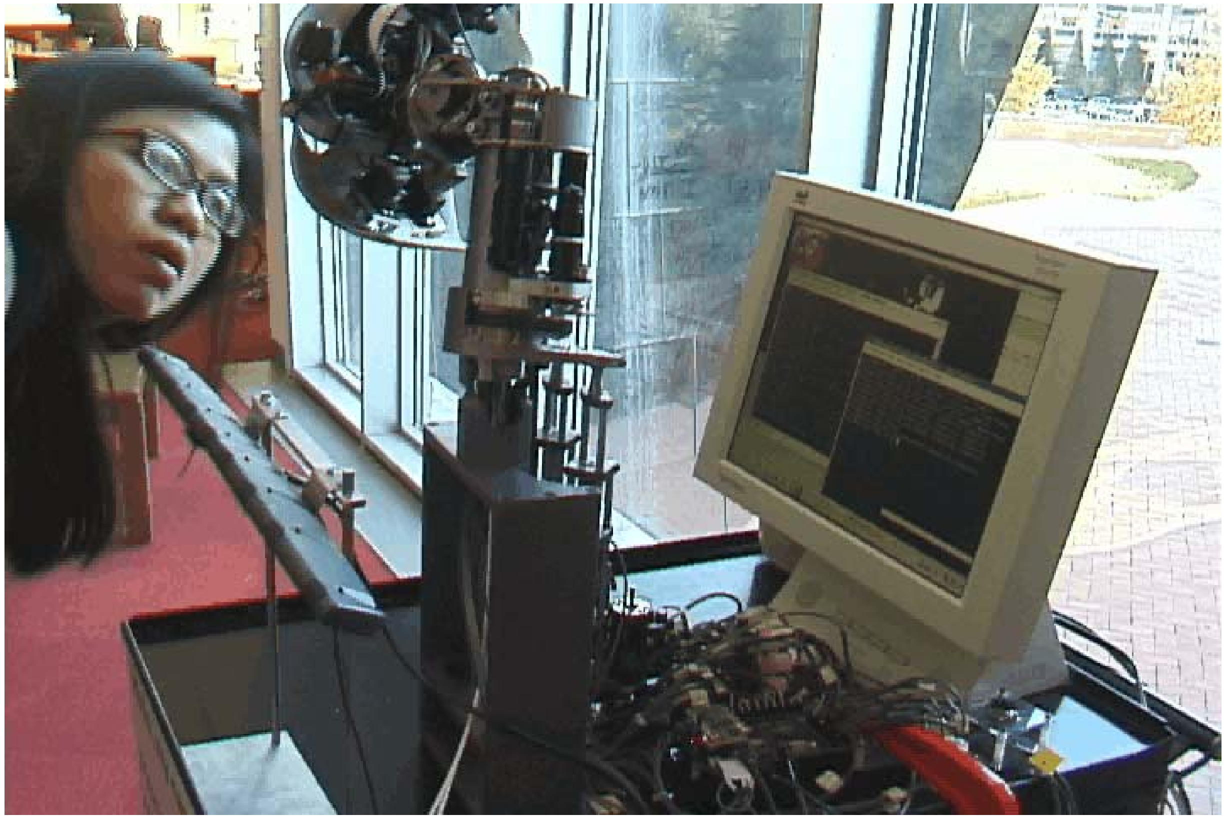
System architecture



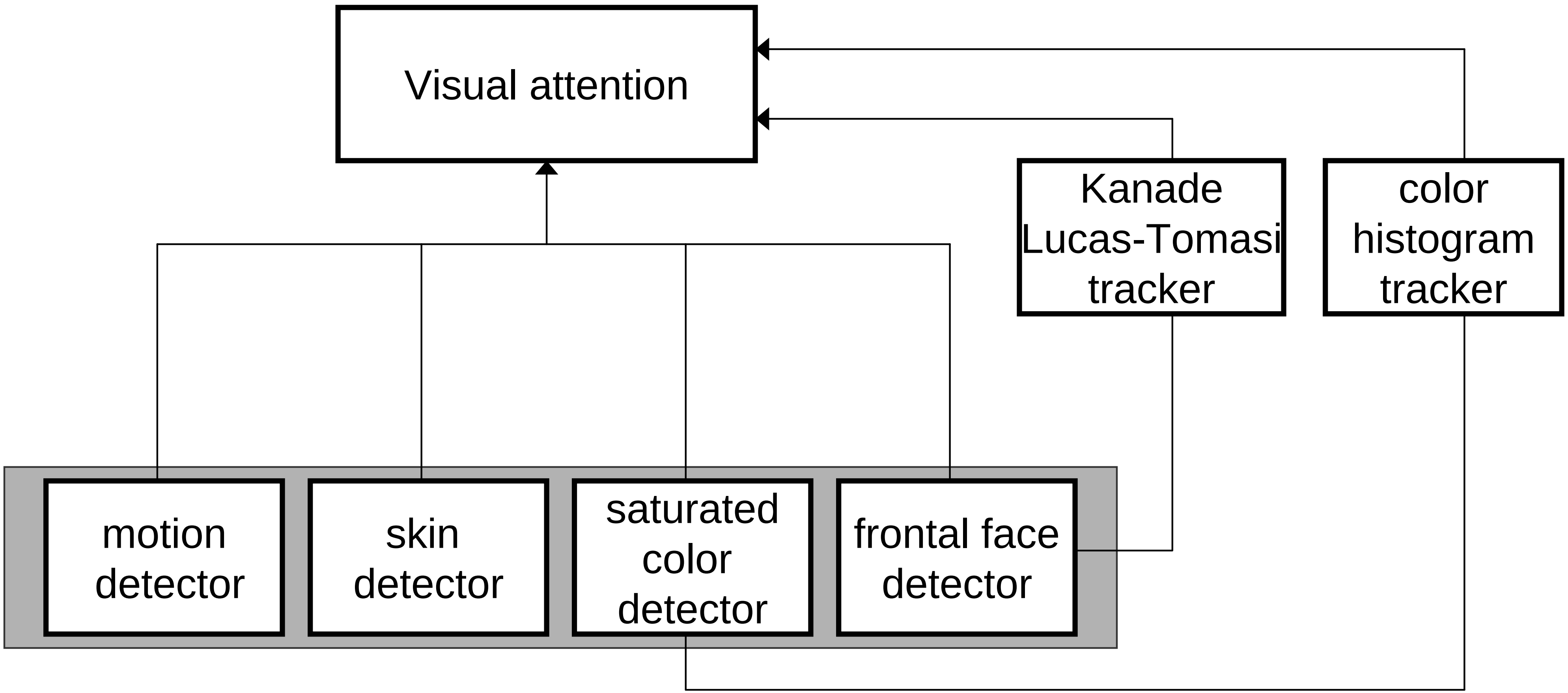
Modular control



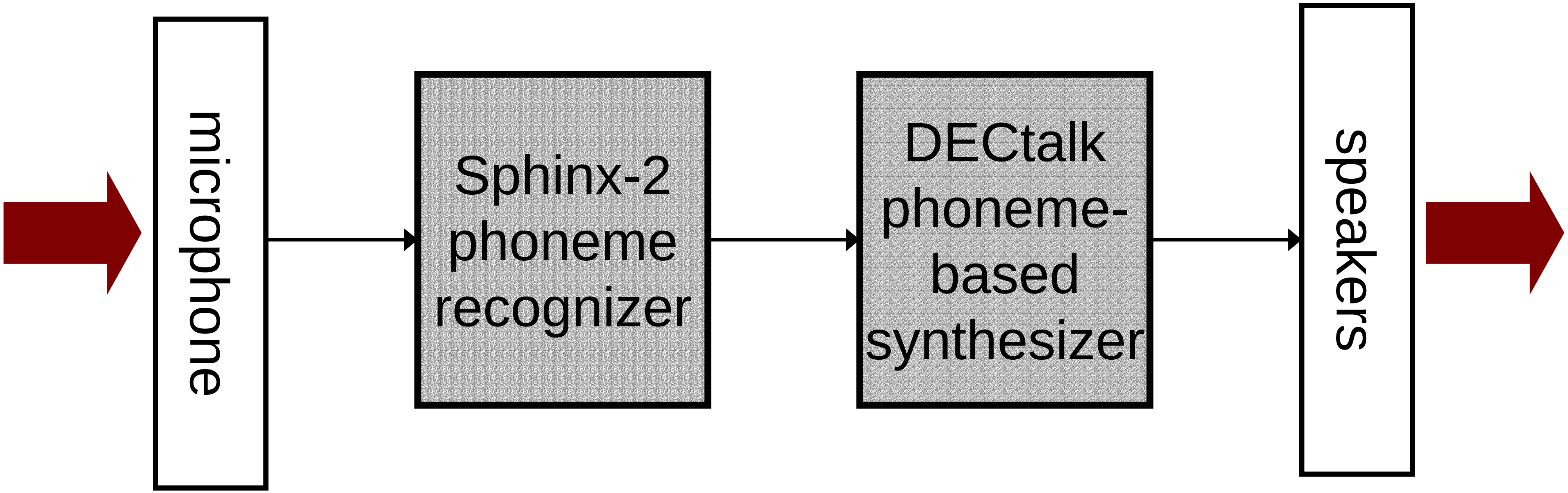


Vision

- Implemented in YARP (Fitzpatrick & Metta) & OpenCV
- Frontal face detector (Viola & Jones)

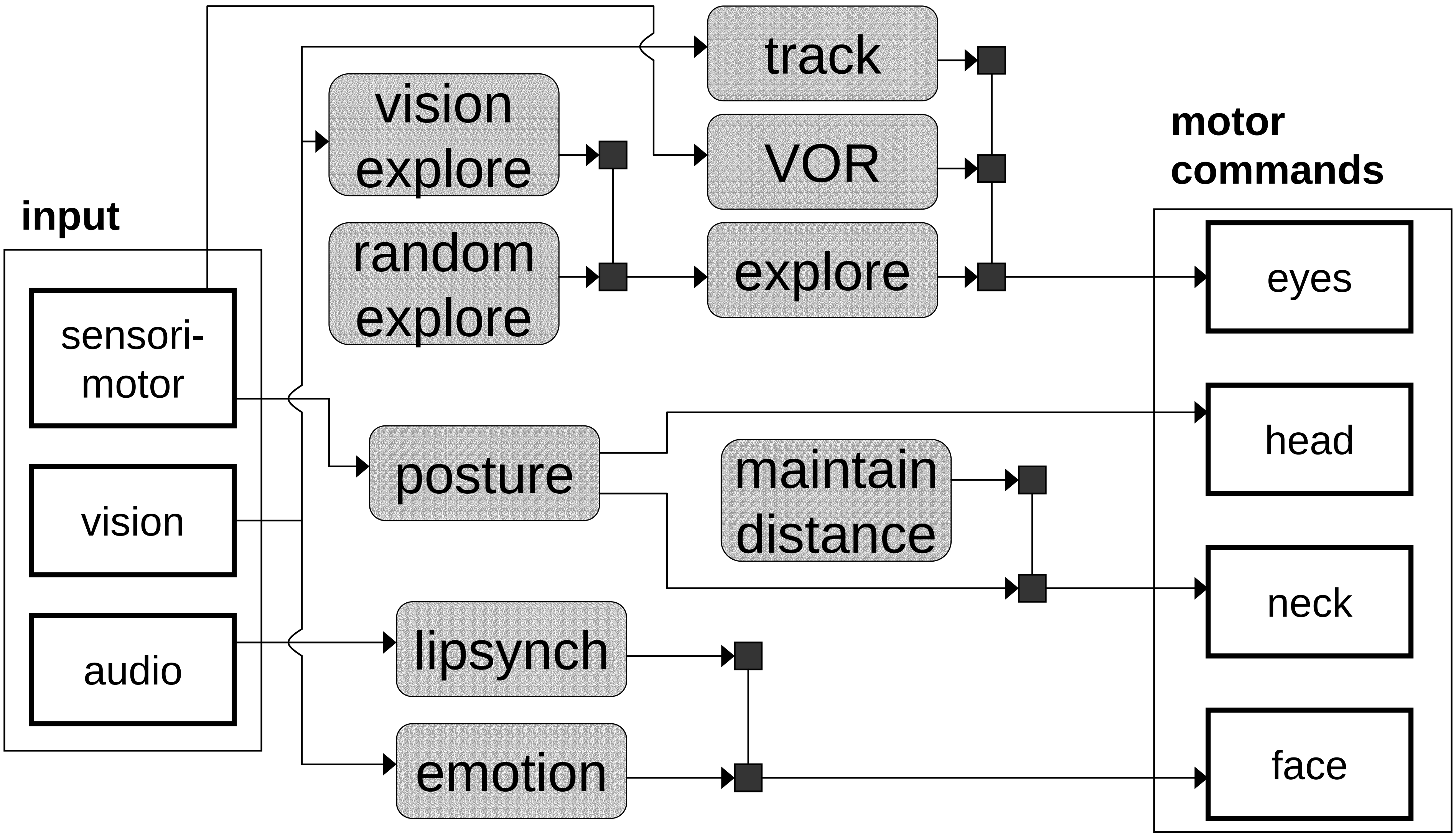


Audio



microphone
Sphinx-2 phoneme recognizer
DECtalk phoneme-based synthesizer
speakers

Behavior-based control



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Experiment: phase I

	Time	Duration	Location
Day 1	2pm – 10pm	8 hours	Laboratory
Day 2	12pm – 6pm	6 hours	Building Lobby
Day 3	10.30am – 11.30pm	13 hours	Balcony overlooking a student lounge
Day 4	9.30am – 4.30am	19 hours	Laboratory and moved to another area in the lab at 2 am

- Goals
  - Test current design
  - Study failure modes
  - Observe visual data across locations and times of day

Results: phase I

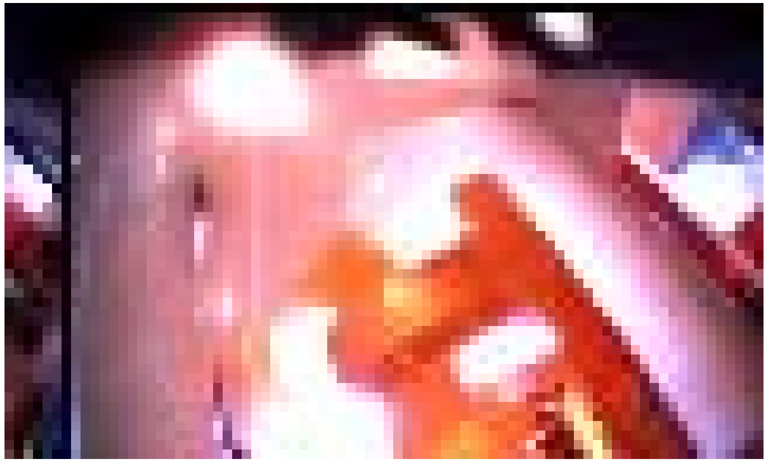
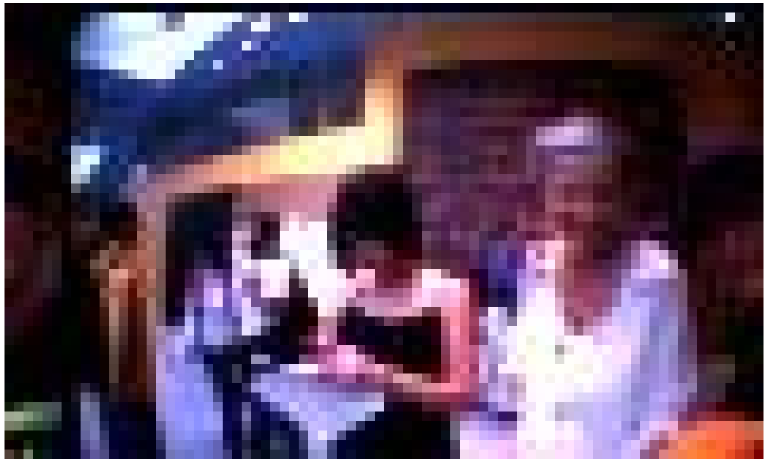
	Hours after startup	Failure
Day 1	2	The two motors actuating the neck's Series Elastic Actuators started heating up.
Day 2	1	One of the Series Elastic Actuators popped out of the neck joint because of a loose set screw.
Day 3	7	A wire connecting the linear potentiometer signal on the SEA to a signal conditioning board is loose.
	10	A screw was found missing in one of the SEAs, causing the motor to stall and heat up very quickly.
Day 4	0	At startup, we found that the potentiometer placed on the neck's differential tilt joint has been un-calibrated because of a loose screw. Each axis is relying on its potentiometer to calibrate itself to a default initial configuration upon startup.

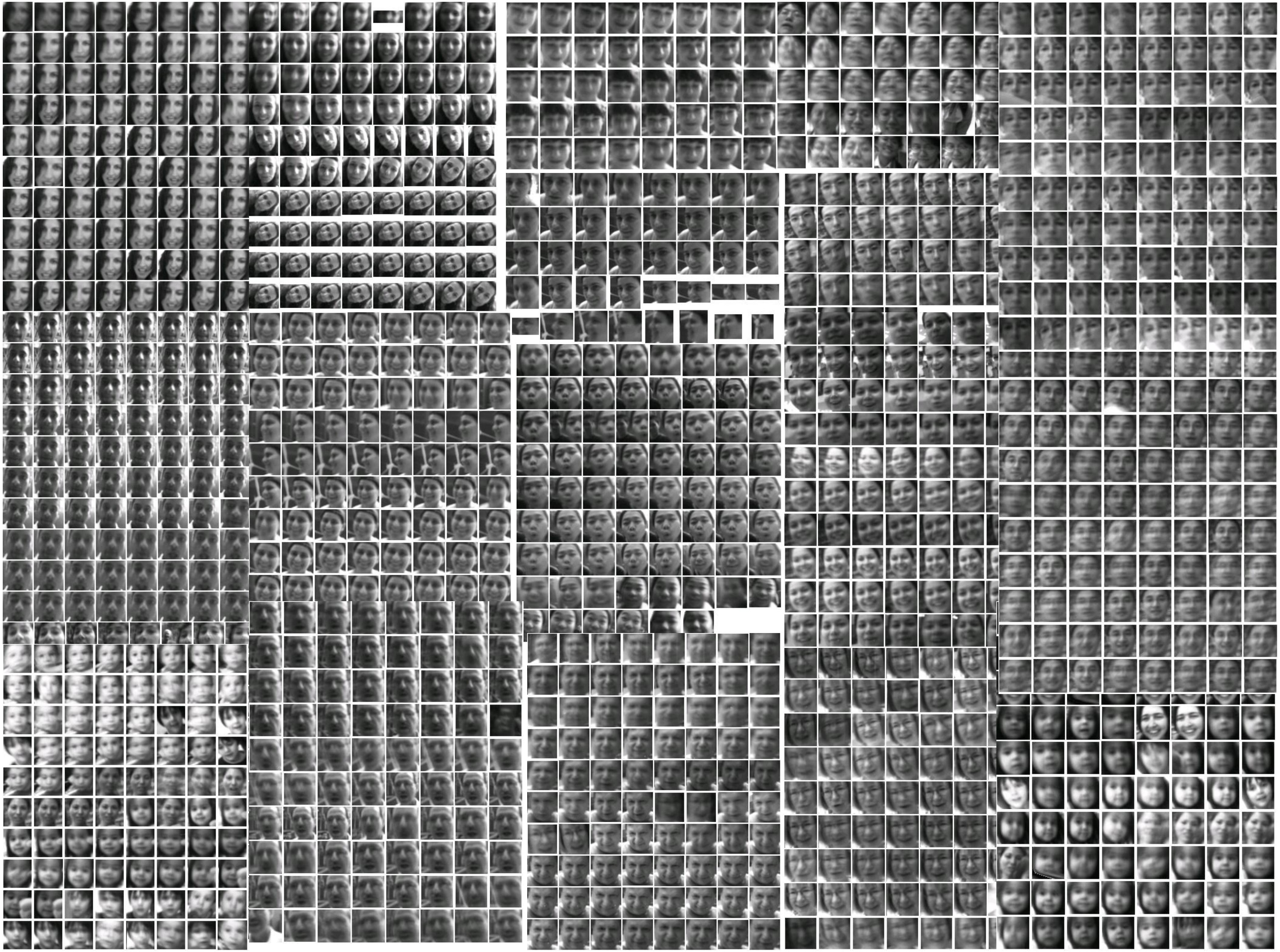
Experiment: phase II

- Lessons from phase I
- Goals
  - Further test robustness
  - Evaluate sociability
- Setup
  - 11 am – 6 pm
  - 5 days
  - different public spaces

Results: phase II

- ~ 140 people a day
- Tracked > 100,000 faces from > 600 individuals
- 6937 audio samples



Conclusion

- MERTZ, an active-vision head for exploring learning in social context
- The case for robustness
- Design criteria and implementation
- Experimental results