# A Corpus-Guided Framework for Robotic Visual Perception

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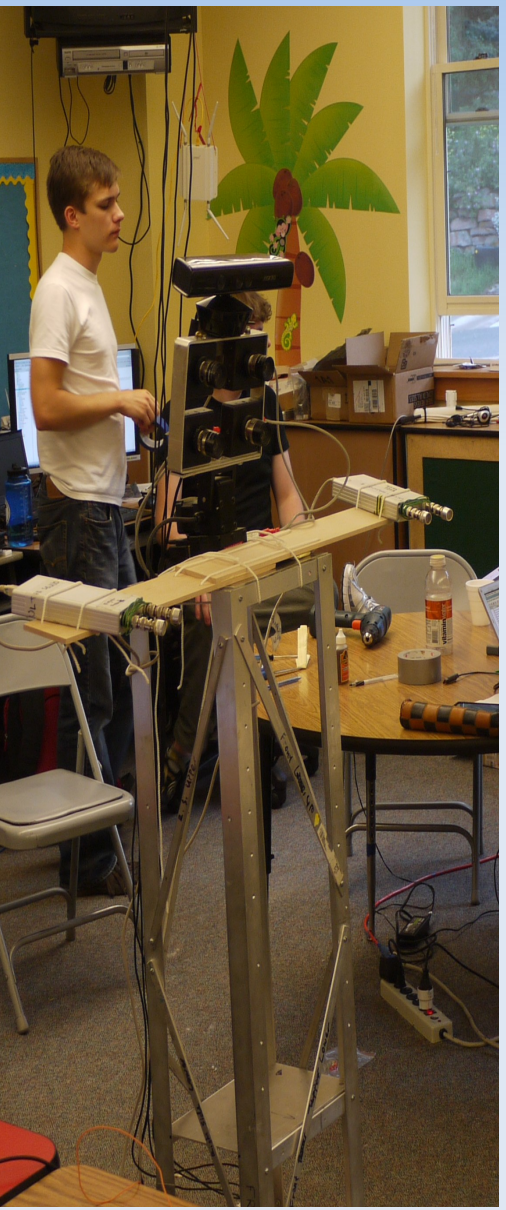
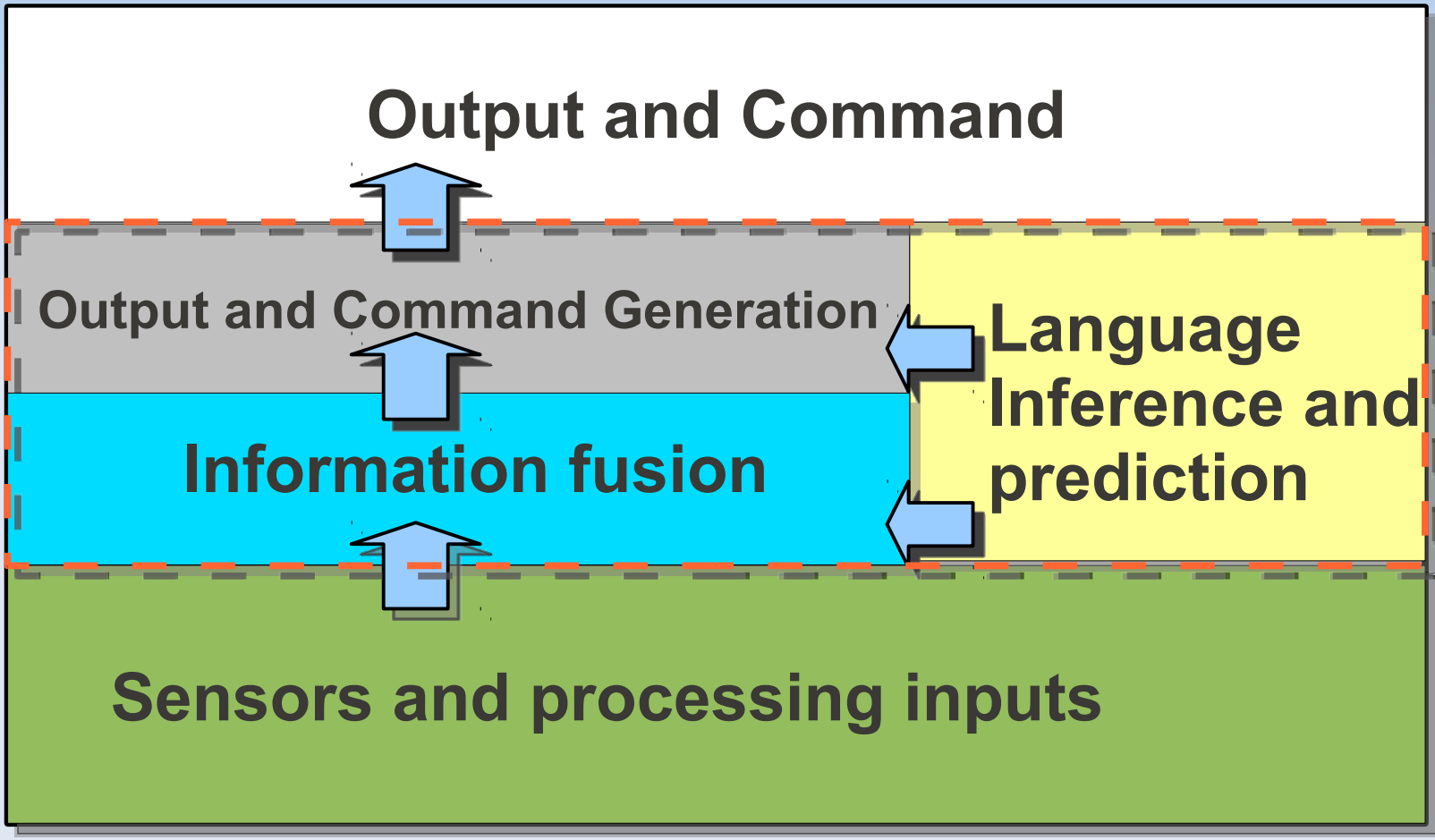
# Robot Perception Control Unit (RPCU)





# The Functions of RPCU

- 1) fuse (noisy) information from various sensors and process inputs;
- 2) perform inference and predictions using language;
- 3) eventually generate a useful output or command that show that the robot has truly perceived the world with all its complexity and richness.

# Our example of RPCU for Visual Perception

- 1) Using Language: We use language (large corpora) as a prior in guiding other modules;
- 2) Information Fusion: We use state-of-art object detectors to detect hands, tools and direct-objects, then predict actions using an EM framework;
- 3) Output (Command) Generation: We model the sentence generation process as a HMM;
- 
- Both 2) and 3) are language guided.

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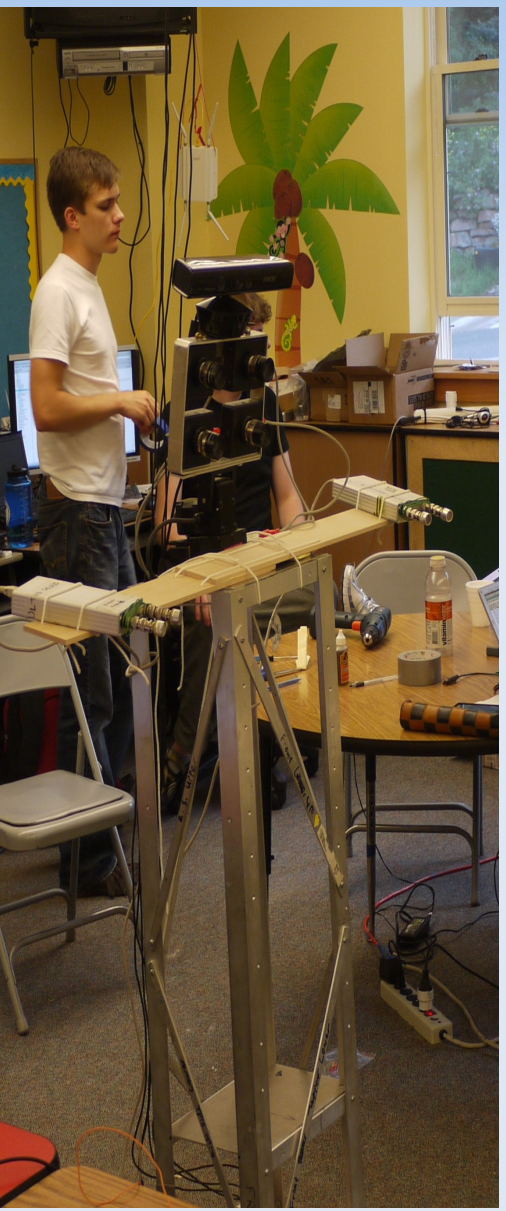
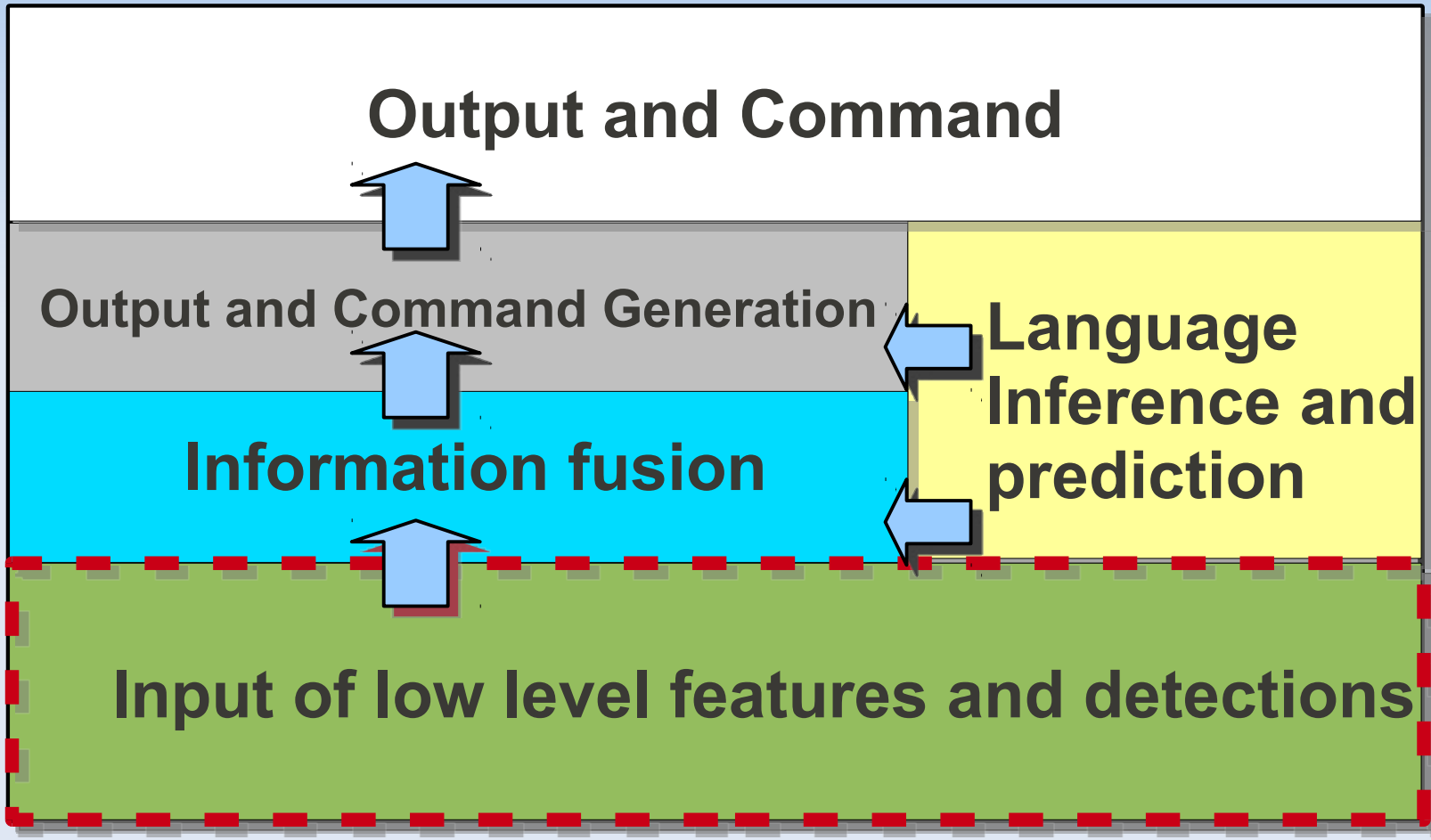
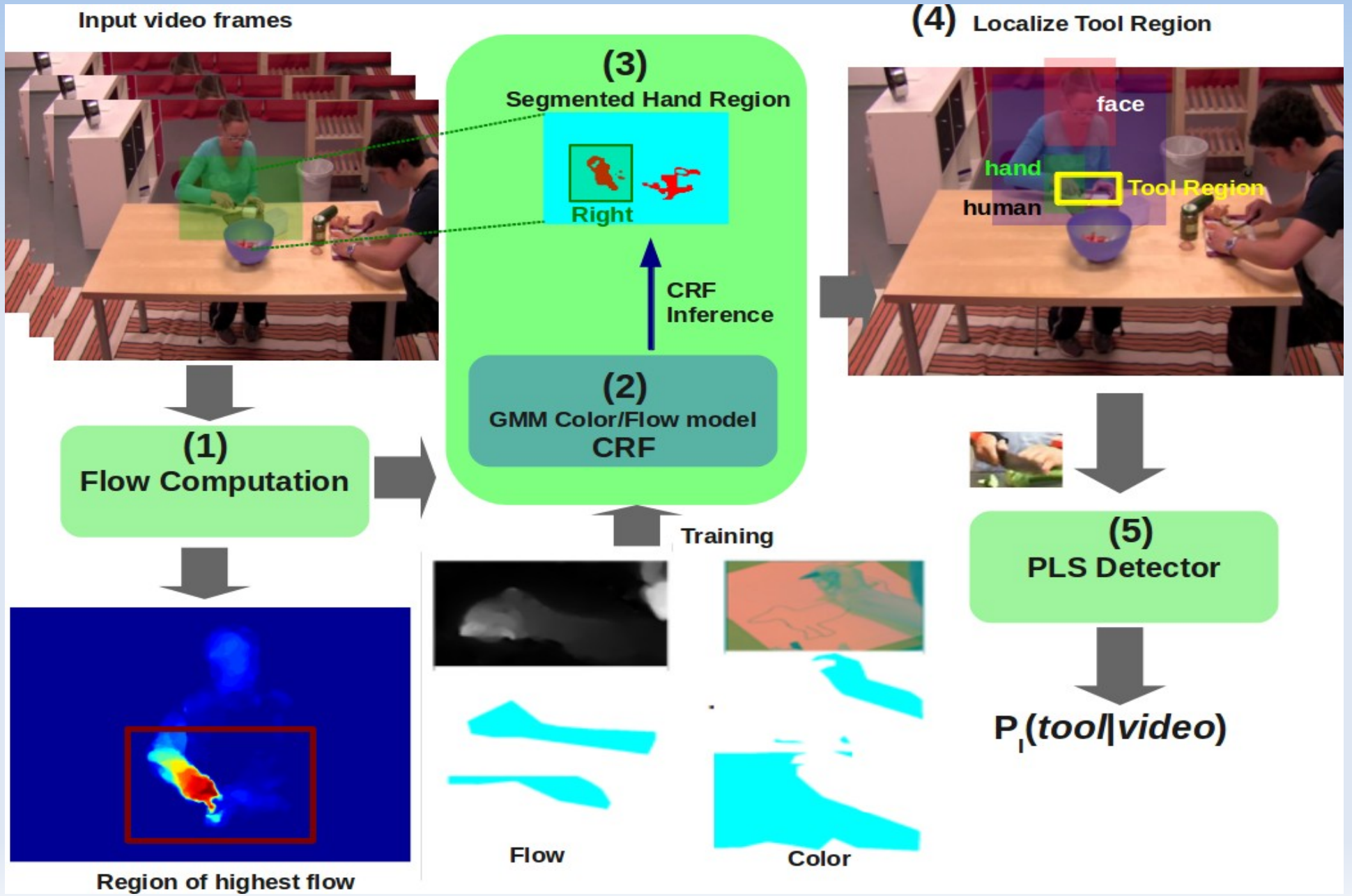
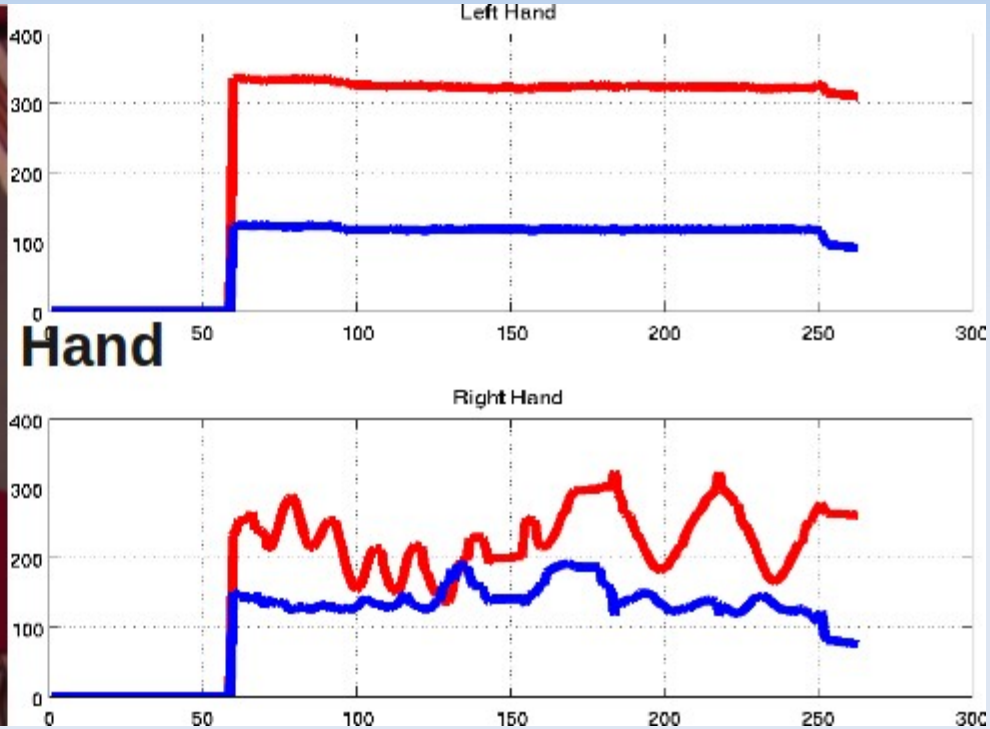




# Hand, Tool and Object Detections



# Action Features



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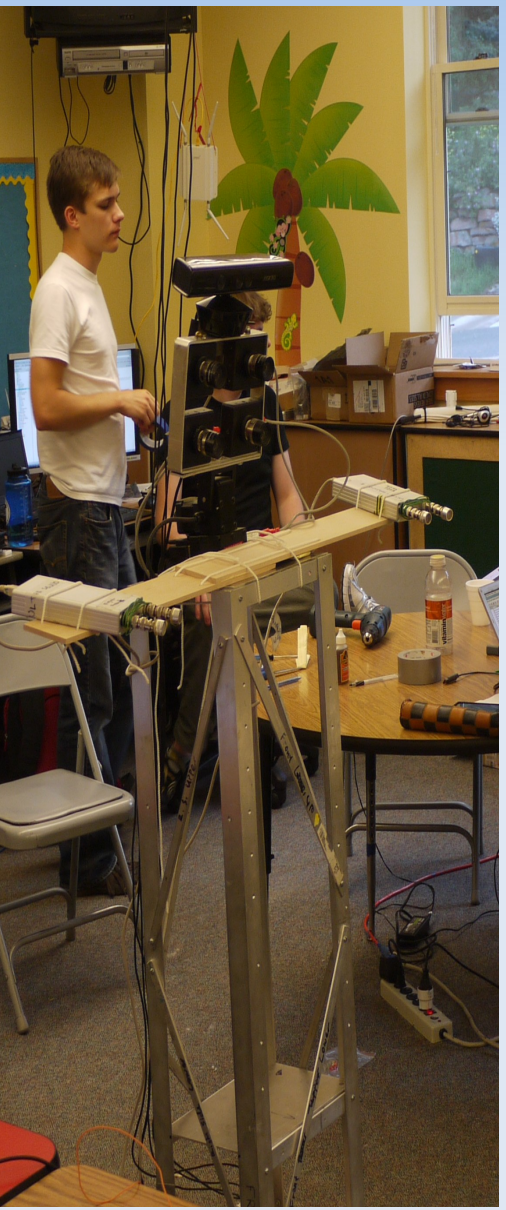
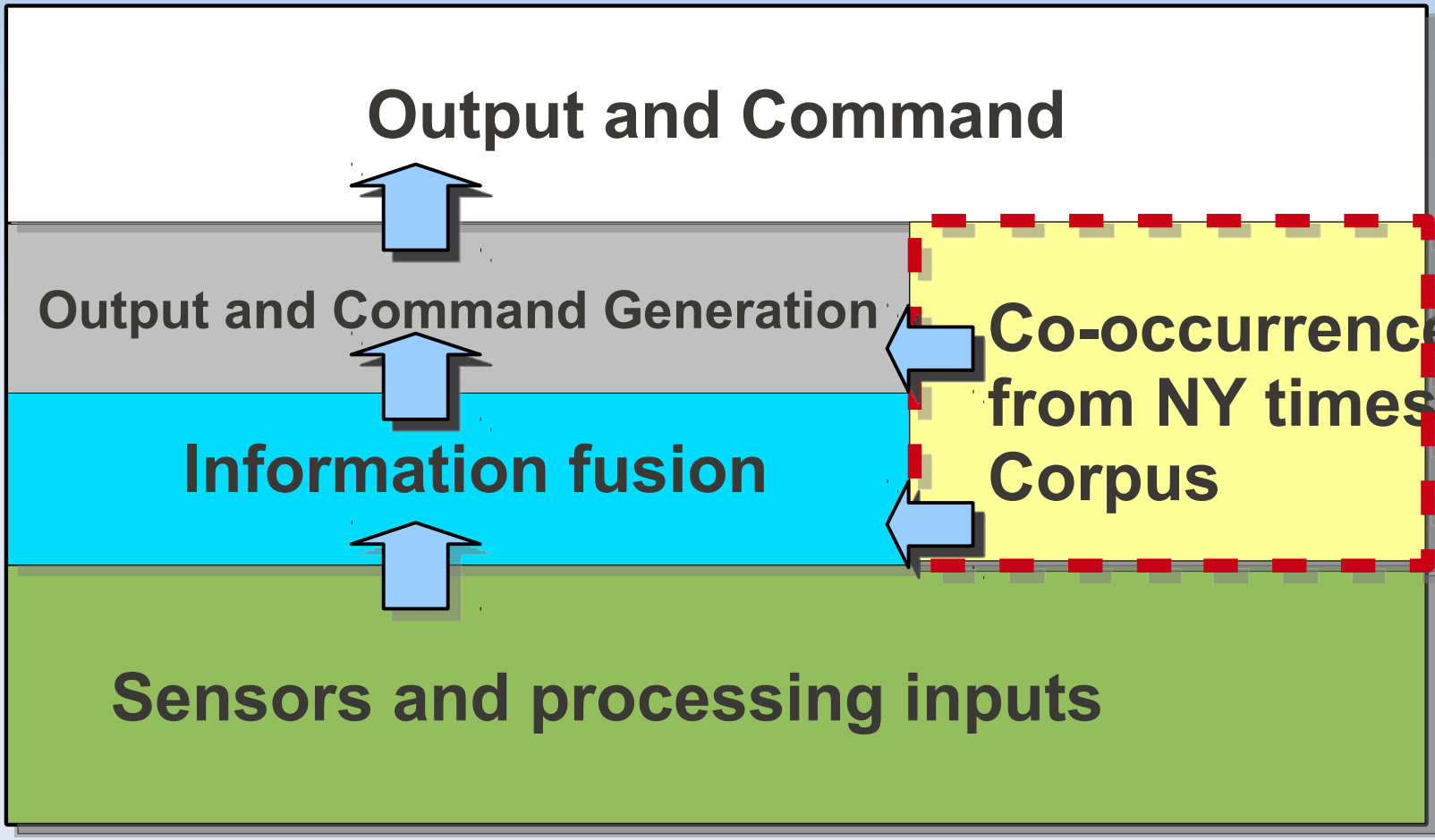
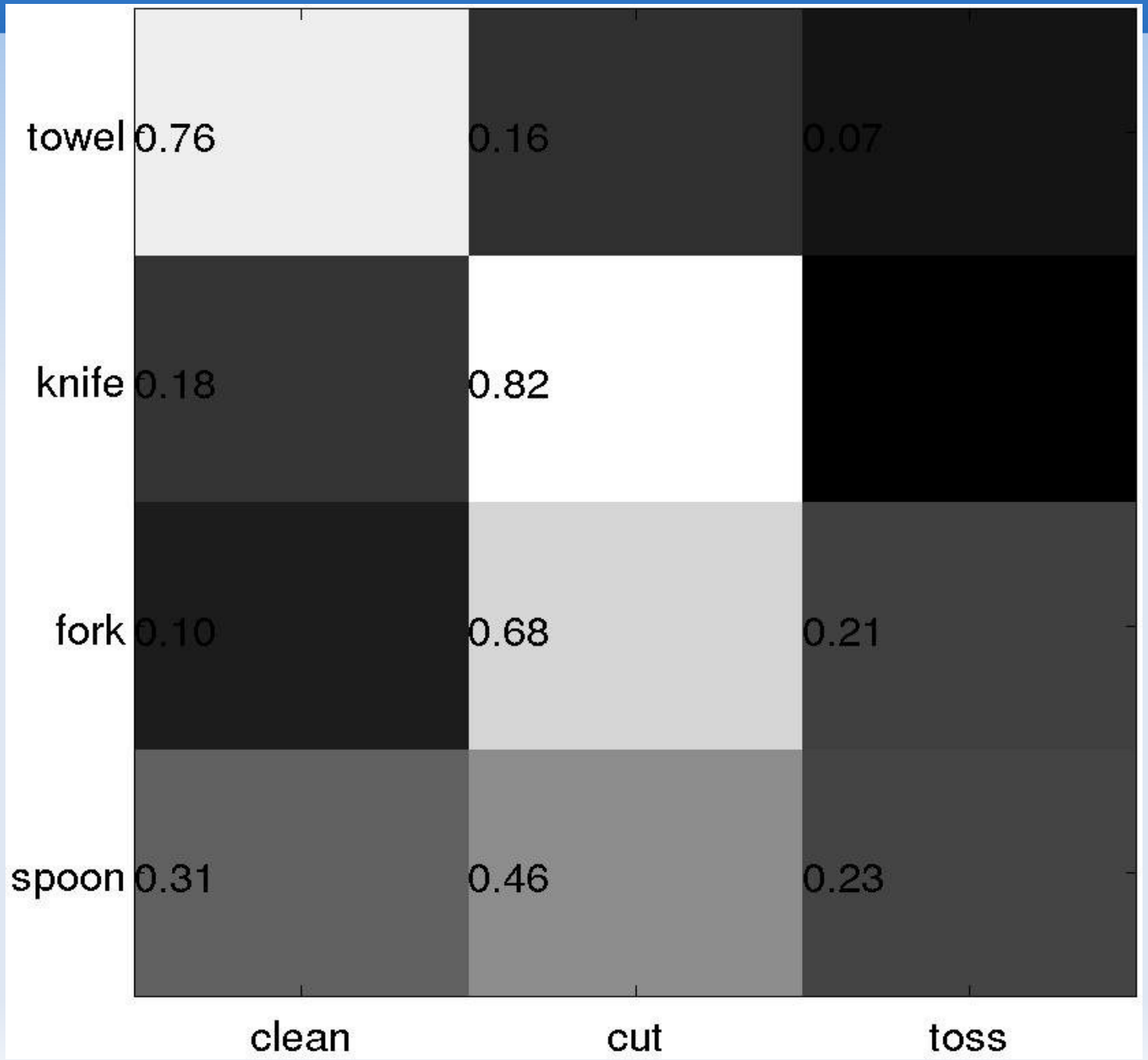




# RPCU: Language Model



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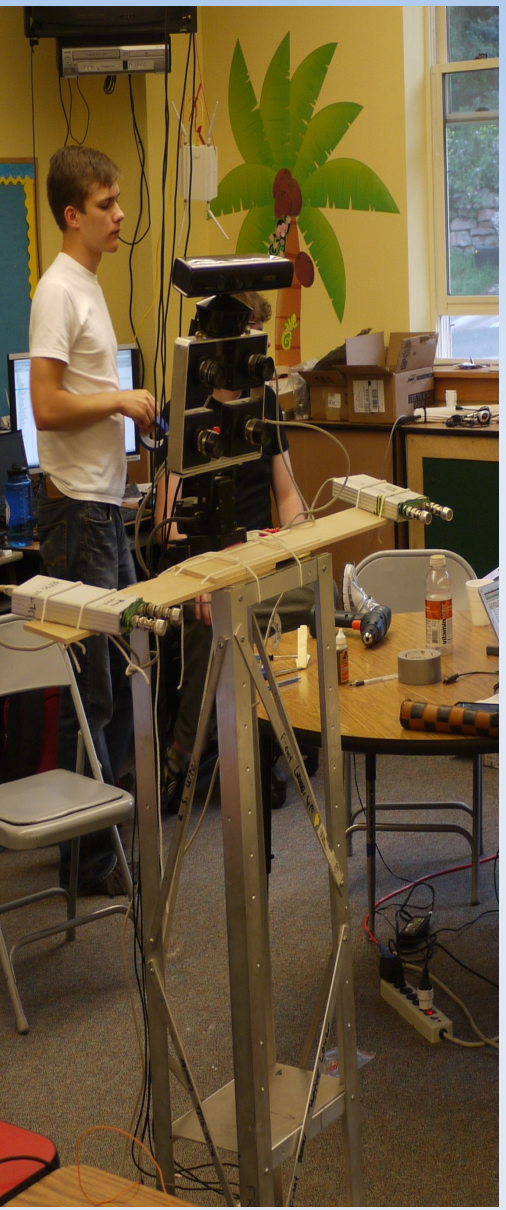
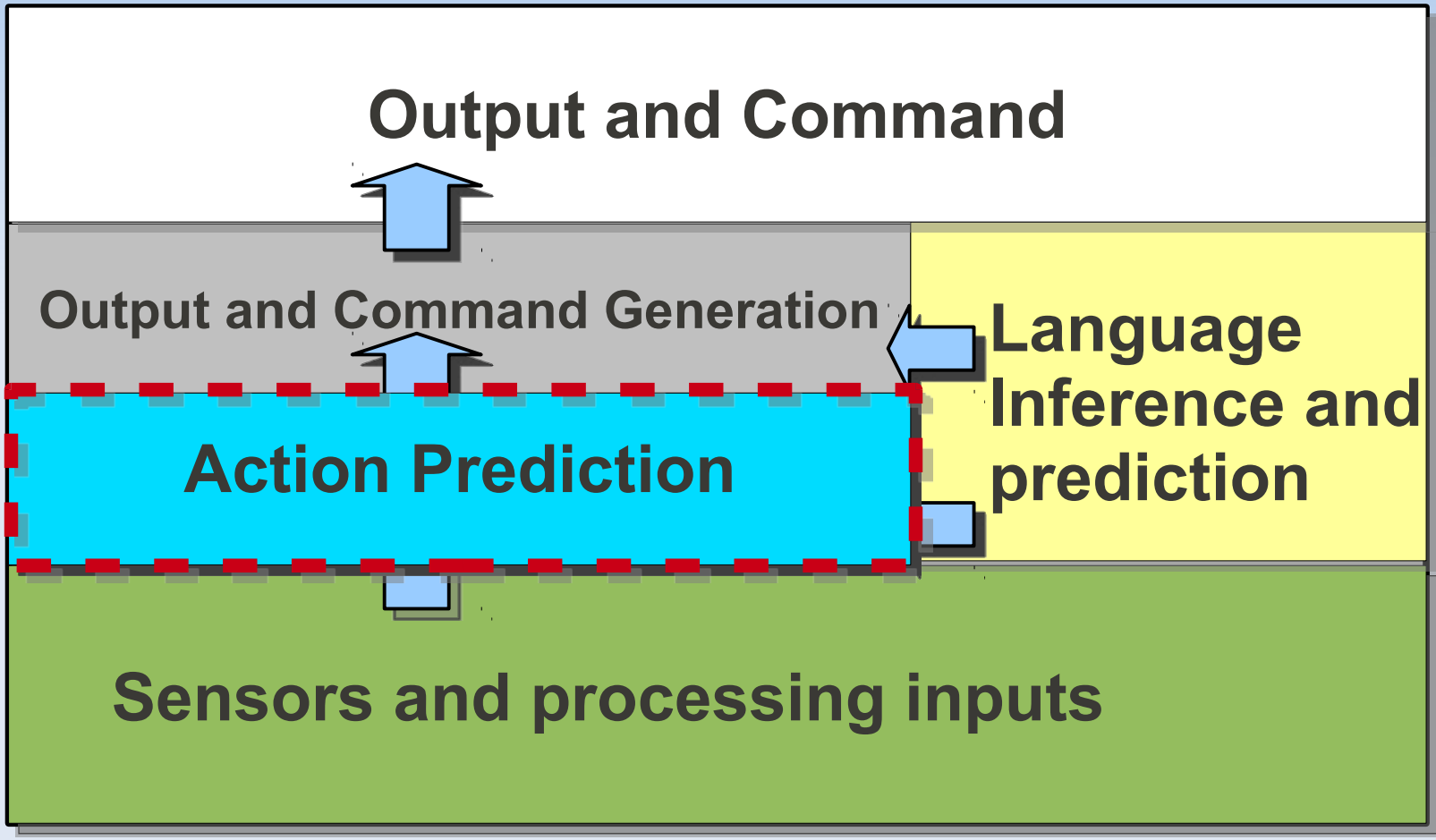
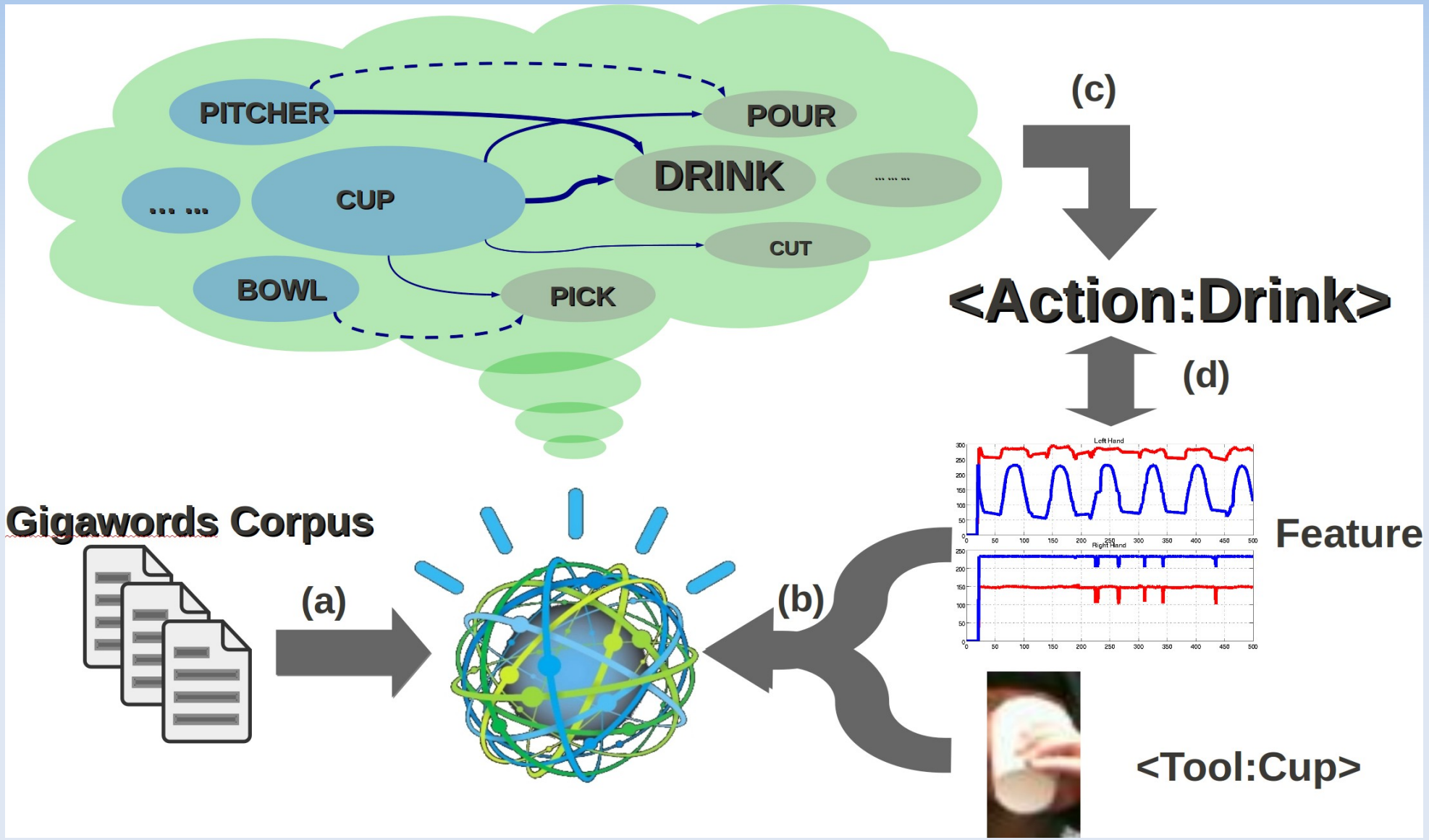




# RPCU: Predicting Actions



# RPCU: Predicting Actions

- Define a latent assignment variable A:

$$A_{ijd} = \begin{cases} 1 & j \text{ is performed using } i \text{ during } d \\ 0 & \text{otherwise} \end{cases}$$

- Expectation Step:

$$\mathcal{W} = \mathbb{E}_{\mathcal{P}(A)}[A]$$

$$W_{ijd} \propto \mathcal{P}_I(i)\mathcal{P}_L(j|i)Pen(d|j)$$

# RPCU: Predicting Actions

- Maximization Step:

$$\hat{\mathcal{C}} = \arg\max_{\mathcal{C}} \mathbb{E}_{\mathcal{P}(A)}[\log \mathcal{P}(A|\mathcal{D},\mathcal{C})\mathcal{P}(\mathcal{D}|\mathcal{C})]$$

$$\hat{\mathcal{C}}_j = \frac{\sum_{i\in\mathcal{N}_1, j\in V, d\in M} \mathcal{W}_{ijd} F_d}{\sum_{i\in\mathcal{N}_1, j\in V, d\in M} \mathcal{W}_{ijd}}$$

- Action Prediction:

$$\mathcal{Z} = \sum_{j\in V}\sum_{i\in\mathcal{N}_1} \left(\mathcal{P}_I(i|d)\mathcal{P}_L(j|i)Pen(F_t|\mathcal{C}_j^*)\right)$$

$$\mathcal{P}_I(j|d) = \frac{\sum_{i\in\mathcal{N}_1} \left(\mathcal{P}_I(i|d)\mathcal{P}_L(j|i)Pen(F_t|\mathcal{C}_j^*)\right)}{\mathcal{Z}}$$

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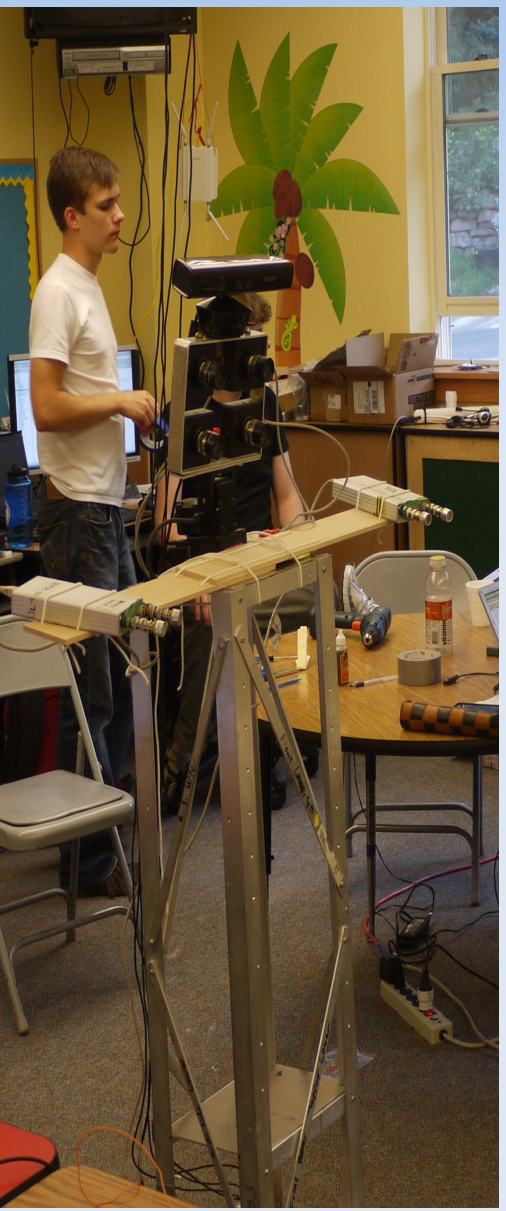
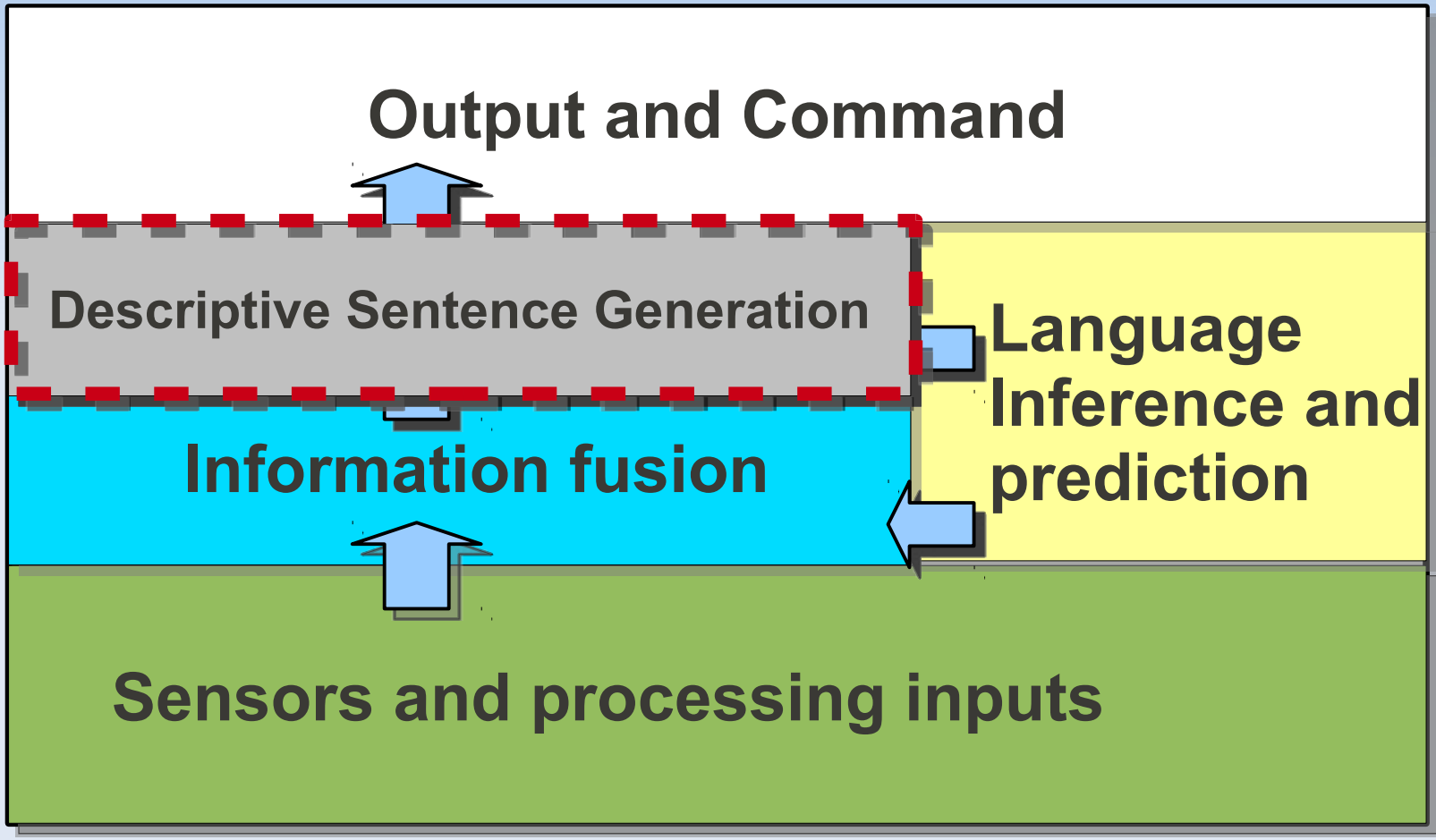
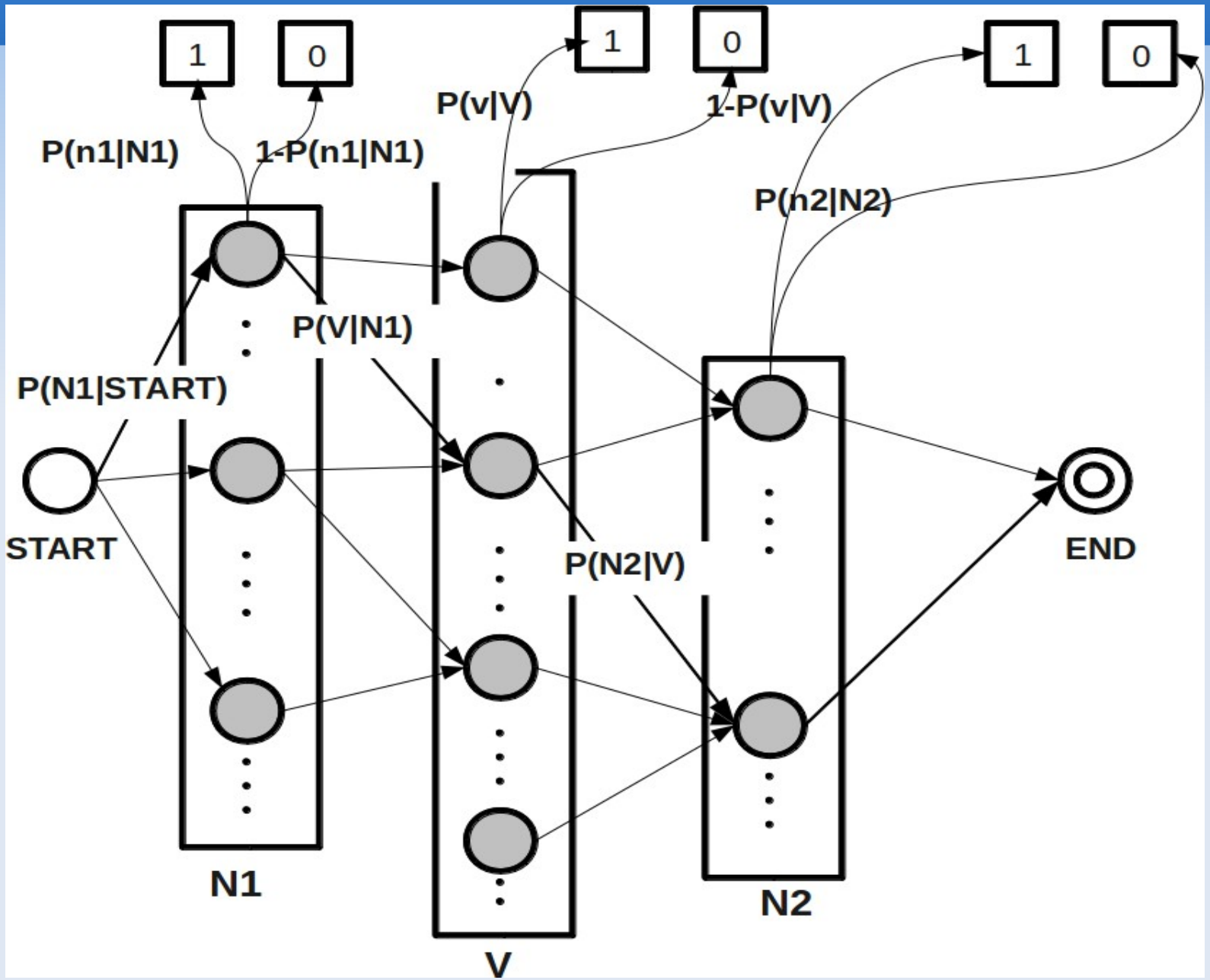


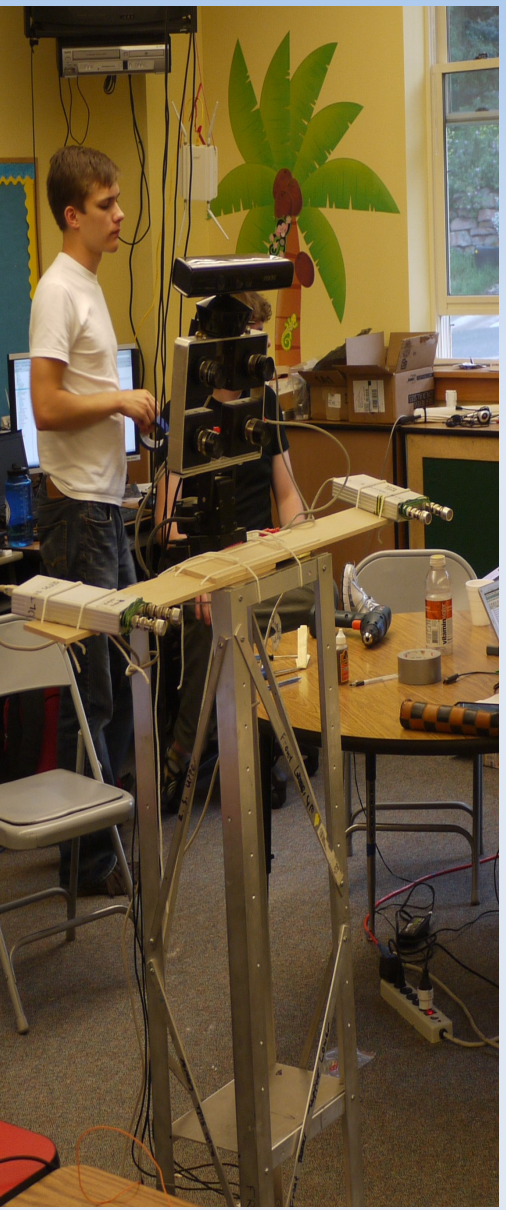


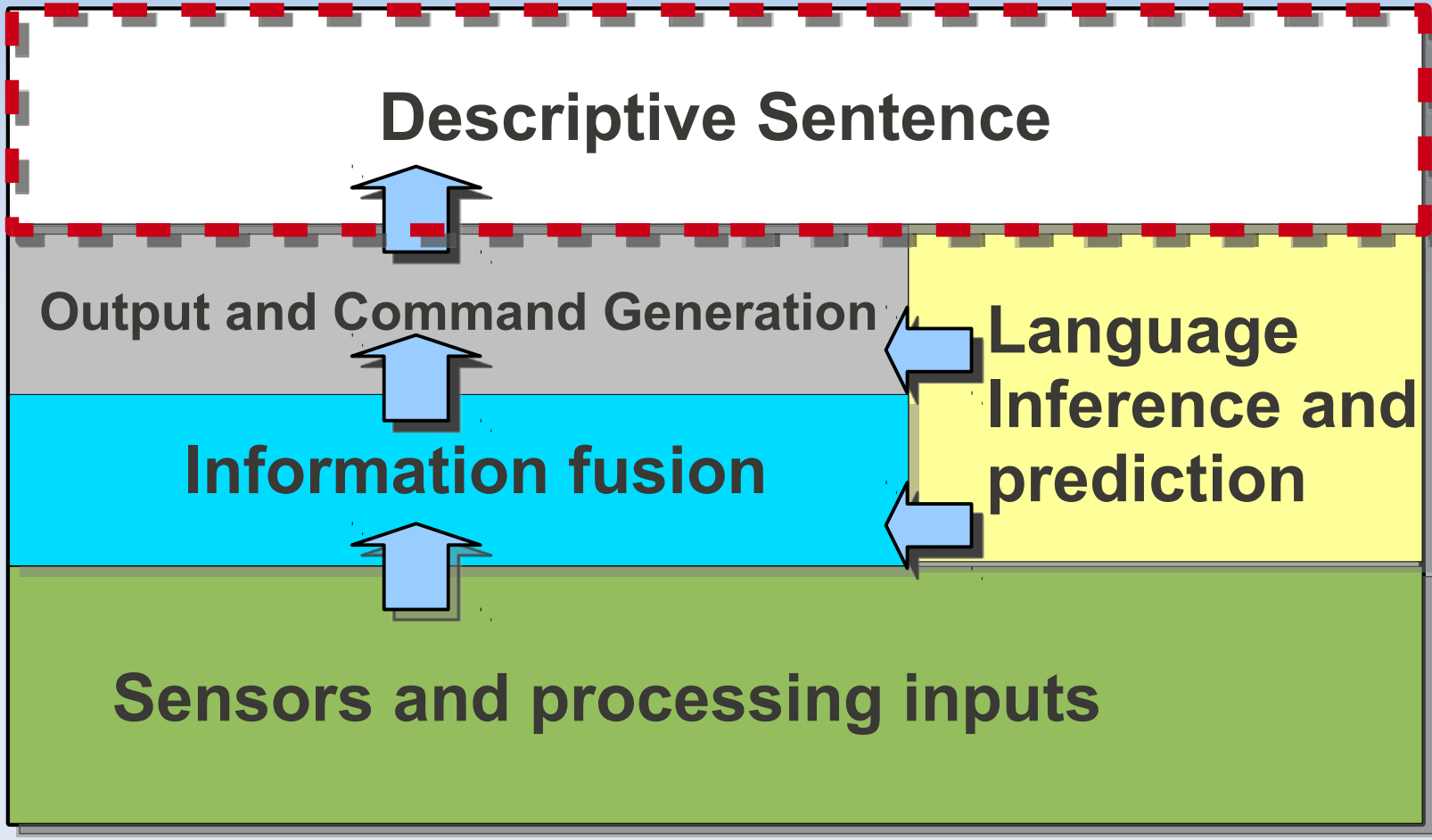
# RPCU: Sentence Generation




Corpus-Guided Sentence Generation of Natural Images, EMNLP. 2011

# Robot Perception Control Unit (RPCU)





# Dataset and Results

{towel,clean,table}

The person is cleaning the table with the towel.

{knife,cut,cheese}

The person is cutting the cheese with the knife.

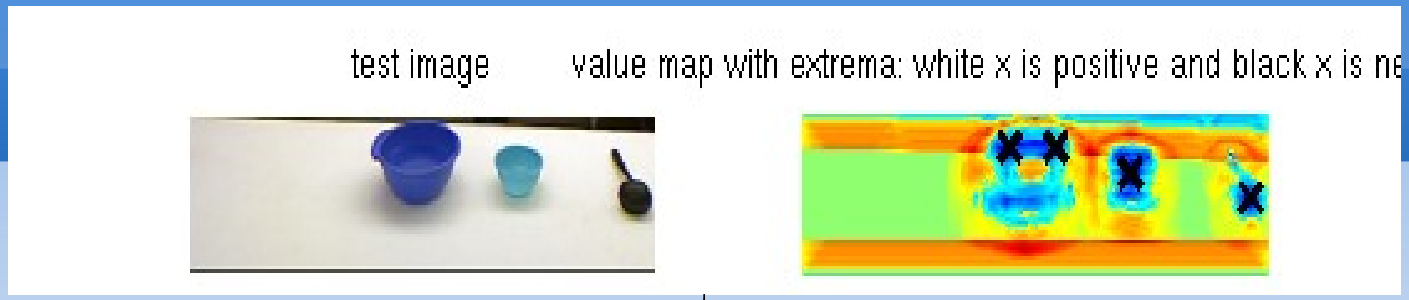
{knife,cut,tomato}

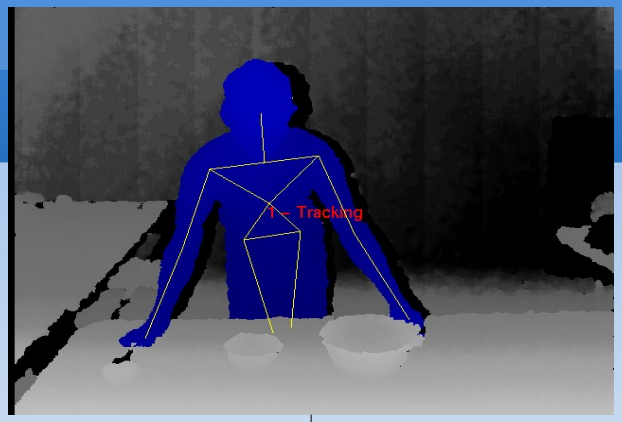
The person is cutting the tomato with the knife.

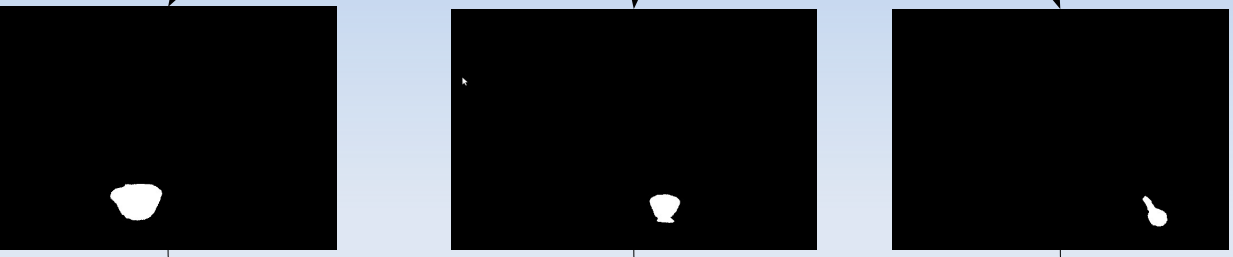
{spoon,toss,salad}

The person is tossing the salad with the spoon.

# Telluride Experiments

Big Bowl

Small Bowl

Ladle

Pour

A person is using ladle to pour water into the bowl.

# Future Work

- Expand to more sensors input, such as Sound.
- Discover from language, the co-located set

  of such tools, objects and actions via attributes, rather than pre-defined sets.
- Extend the language generation module to generate even more complicated sentences that involves, for example, adjectives and adverbs.
- ...

# Thank You!