# MRUI Adaptation in the Presence of Uncertainty

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# Structure

- Motivation
- Intent-based Model
- Representations of Uncertainty
- Adaptation coupling input and output uncertainty
- Conclusions

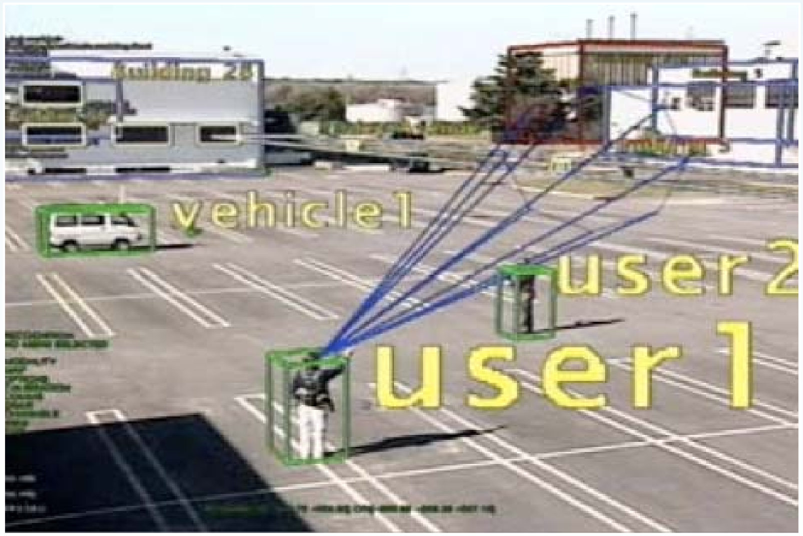
# The Keypoints

- Uncertainty is ubiquitous and we need to deal with it with adaptive interfaces

- Successful adaptation
  - *Requires* a suitably expressive model of uncertainty
  - *Exploits* the coupling between input and output uncertainty

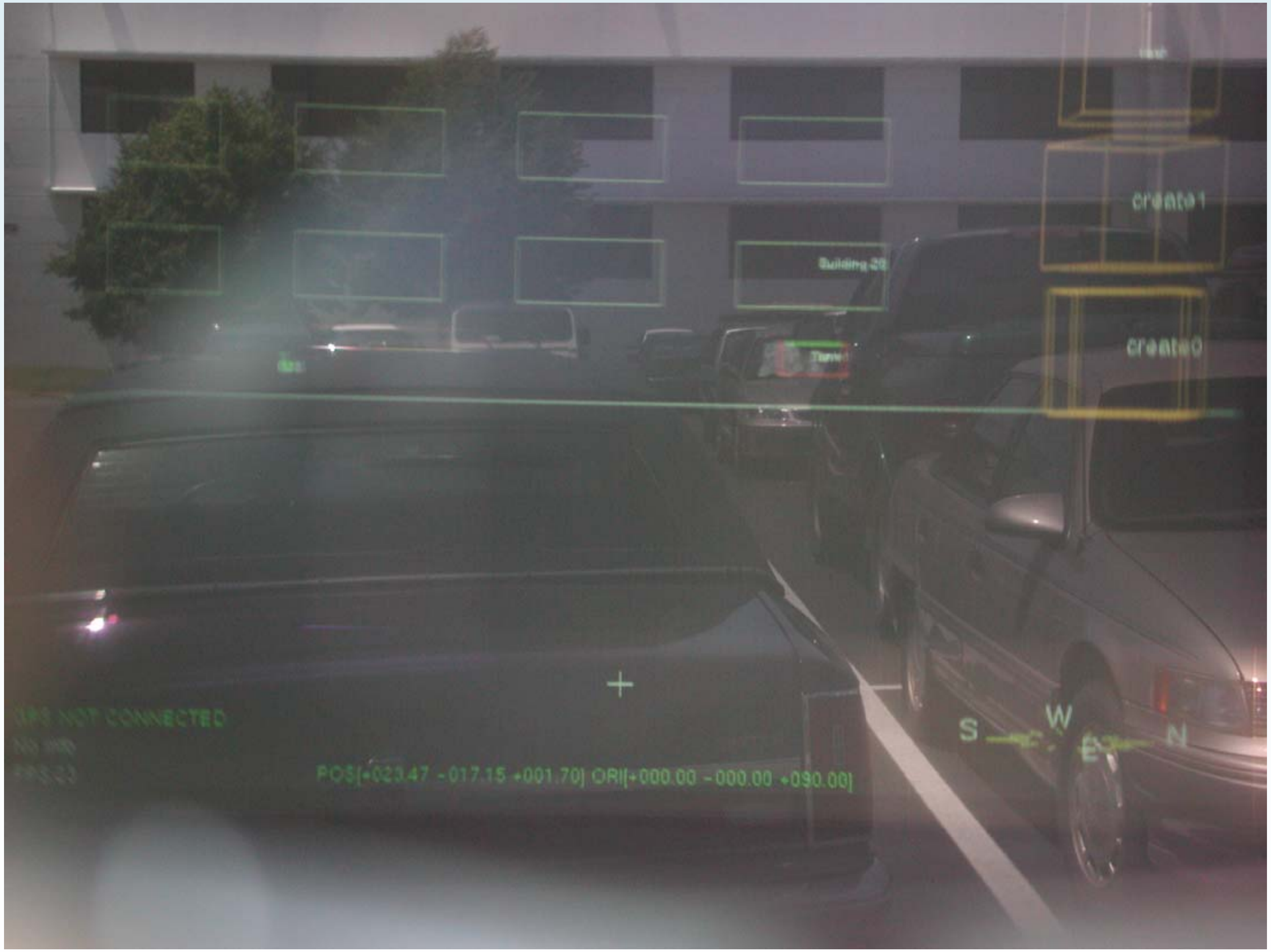
# Motivation

- Consider the problem of development of user interfaces for mobile systems
- Uncertainty is prevalent:
  - User inputs
    - Measured by tracking system and / or deduced by pattern recognition software
  - Context
    - Entered manually by the user
    - Inferred from user inputs
- We need to develop interfaces which can adapt to these errors

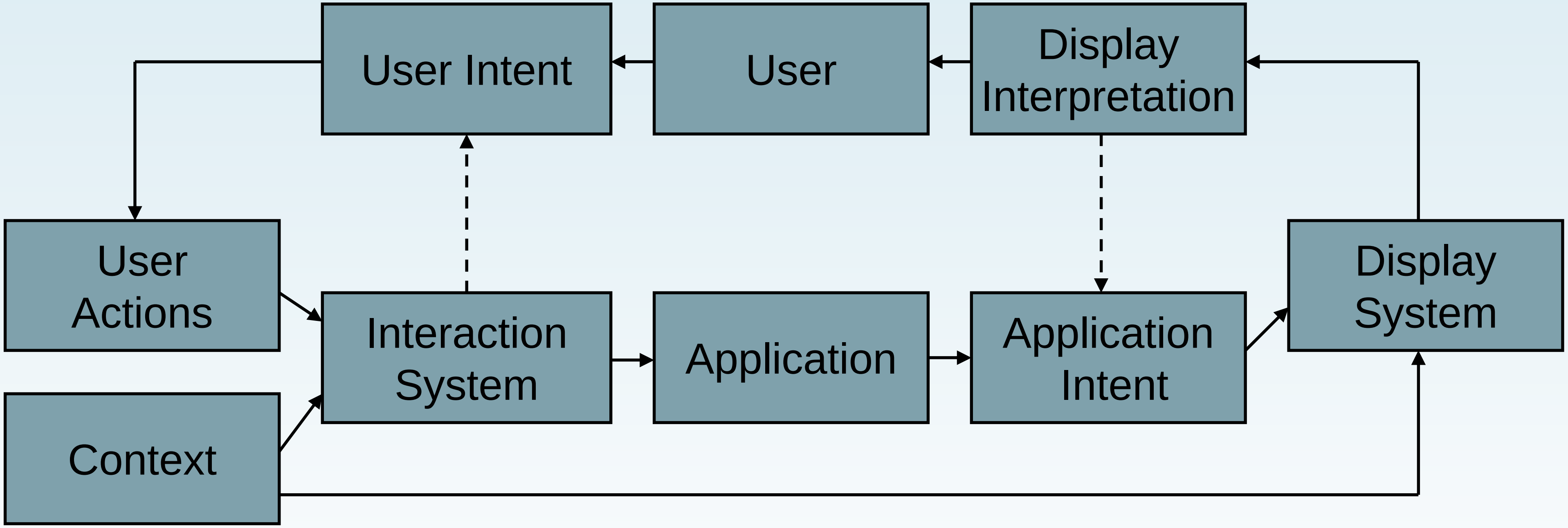



Naval Research Laboratory BARS / VIeWHUD mobile AR system

# Good Registration…

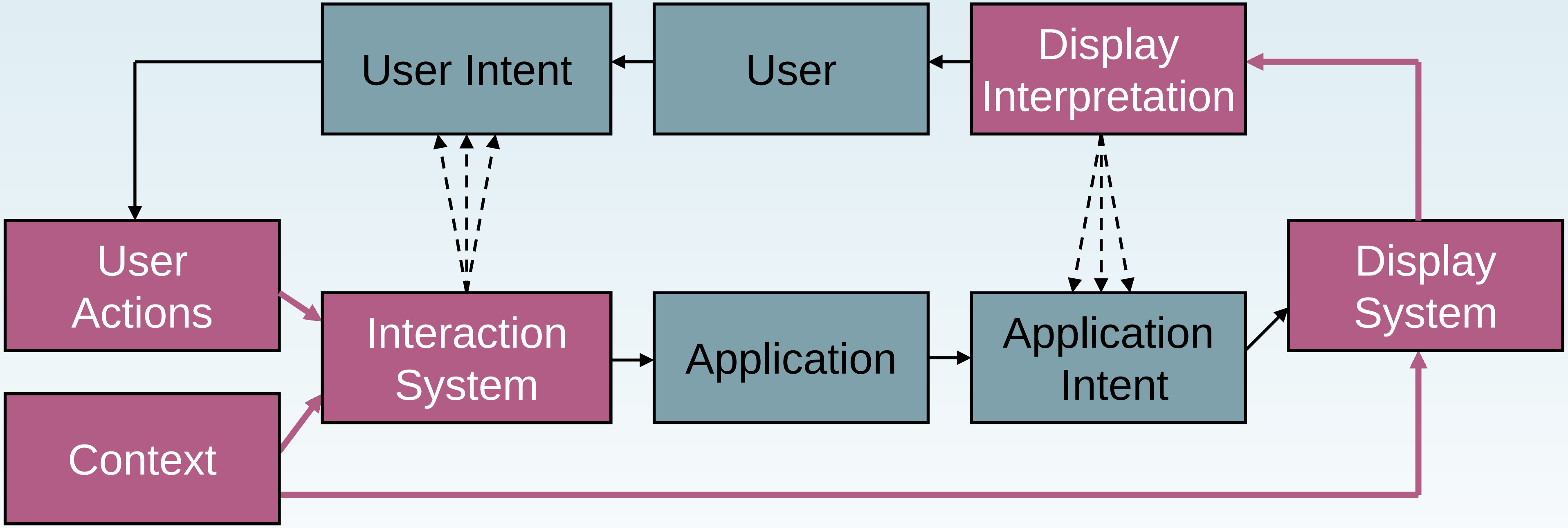


# Interaction Model




- Consider the user interface using a model of *communicative intent*
  - User wants to convey request to system
  - System wants to convey result to user

# Uncertainty in the Interaction Model




- Uncertainty leads to a family of *hypotheses* of communicative intent
- The purpose of the adaptive MRUI is to collapse these down to a *single* (correct) hypothesis

# MRUI Adaptation Schemes

- Various input and output disambiguation schemes have been developed
  - Input typically considered in context of multi-modal interaction
  - Output considered in terms of adaptive AR displays

# Adaptive Intent-Based Displays


- “Adapting to Registration Error in an Intent-Based Augmentation System”, Robertson *et al.*

# MRUI Adaptation Schemes

- Various input and output disambiguation schemes have been developed
  - Input typically considered in context of multi-modal interaction
  - Output considered in terms of adaptive AR displays

- However, for succesful adaptation:
  - The correct hypotheses *must* be generated
  - The fact that input and output disambiguation are *dependent* upon one another must be used

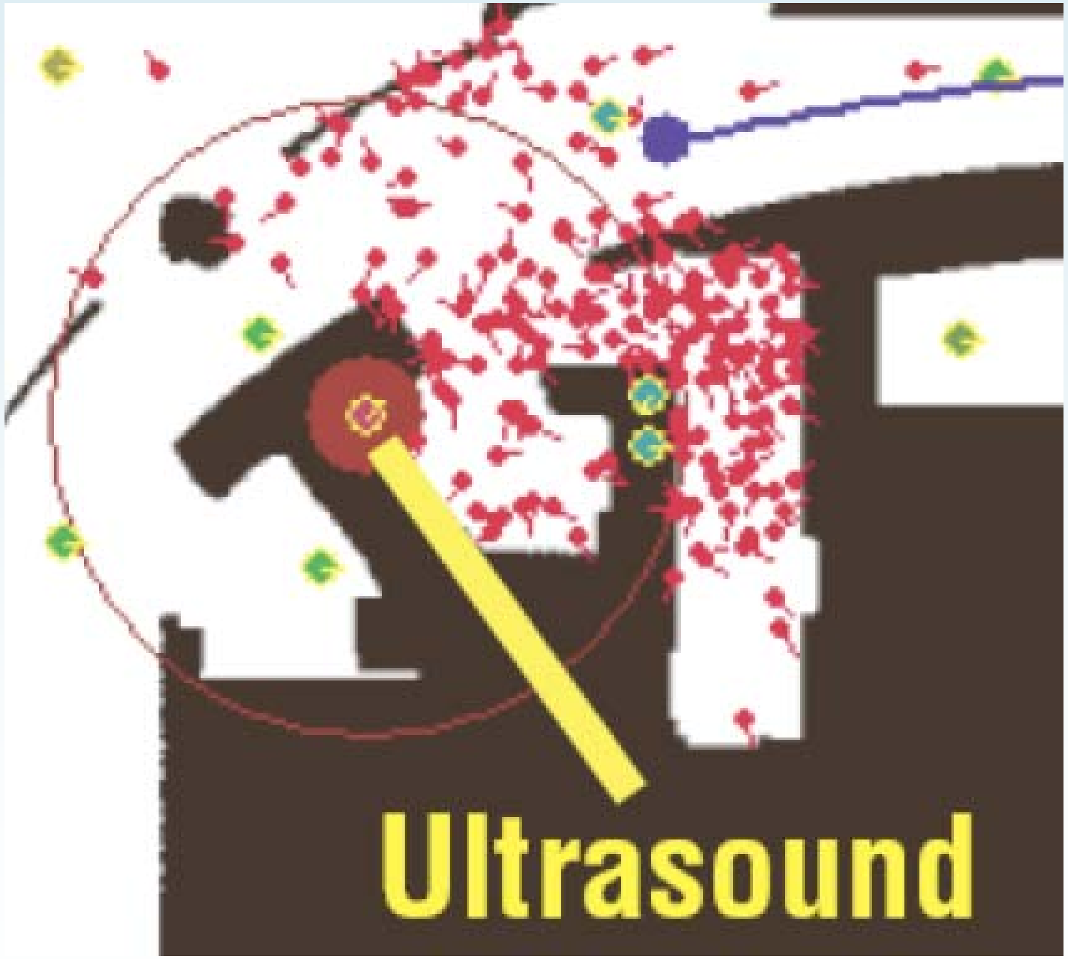
# Inducing Hypotheses

- The hypotheses arise from the fact that uncertain context and user actions are driven into the interaction system

- Therefore we must
  - Use sufficiently rich representations of uncertainty to drive into the system
  - Use sufficient techniques to stochastically model how the interaction system reacts to this uncertainty

# Representing Uncertainty

- Tracking systems can have very complicated models of uncertainty
  - Vary both temporally and spatially
- Therefore, simple fixed upperbounds aren't sufficient
- Also simple geometric bounds (e.g., GDOP) aren't typically good enough either



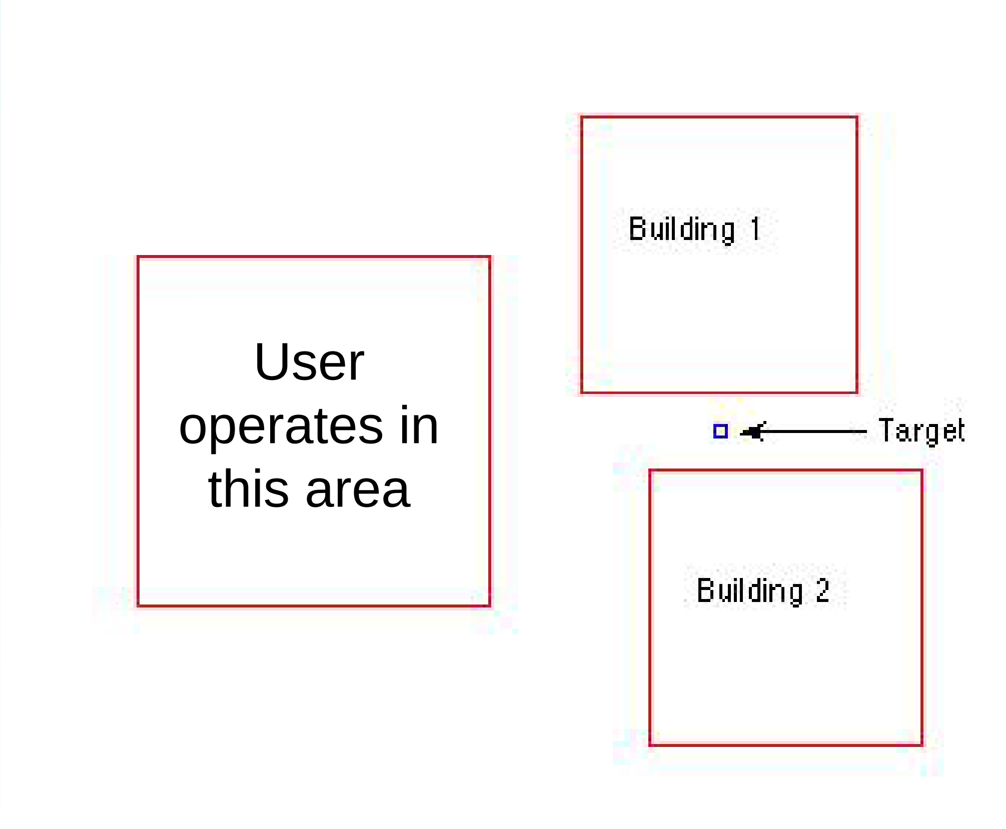

Distribution of position of wearable computer, Hightower and Fox

# Representing Uncertainty

- Particle filters represent uncertainty using finite set of weighted points or particles
  - Often considered the “gold standard”
  - Can be used in practically any kind of system in almost any way

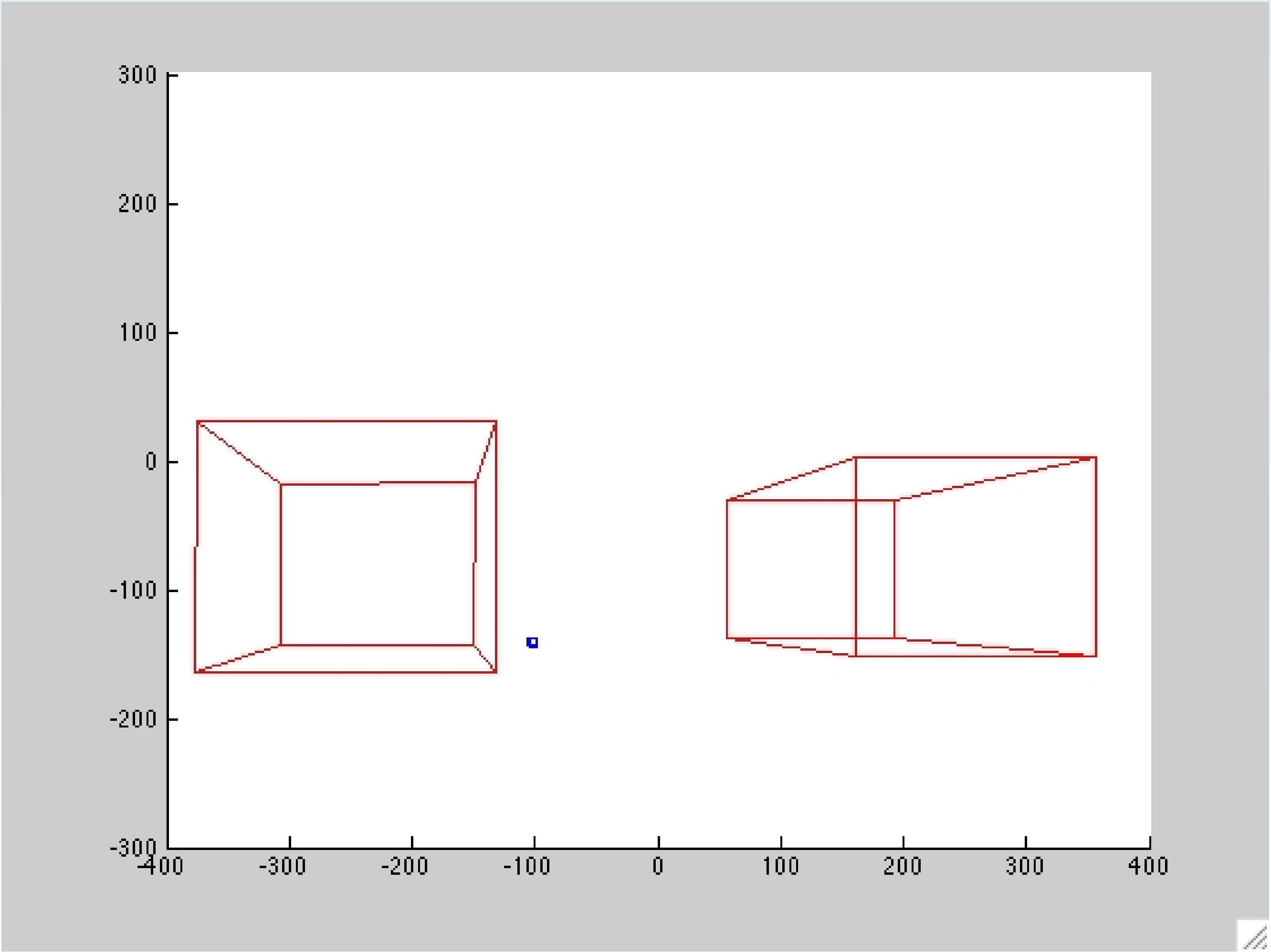
- However, a key element is to have a random number generator
  - This can lead to high frequency noise which can be *very* distracting

# Concrete Example




- Scenario consists of two large buildings and small target
- Uncertainty standard deviation is [2m,2m] position, 10º orientation

# Sampling Noise



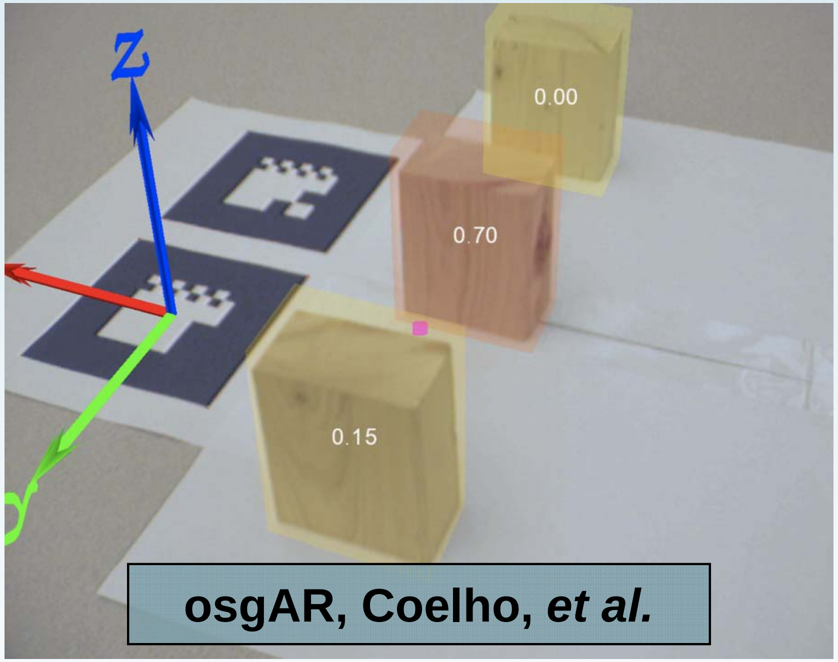

Viewpoint calculated from mean of 1600 particles

# Representing Uncertainty

- Kalman filters represent uncertainty using means and covariances
- Kernel estimators provide good compromise between the two

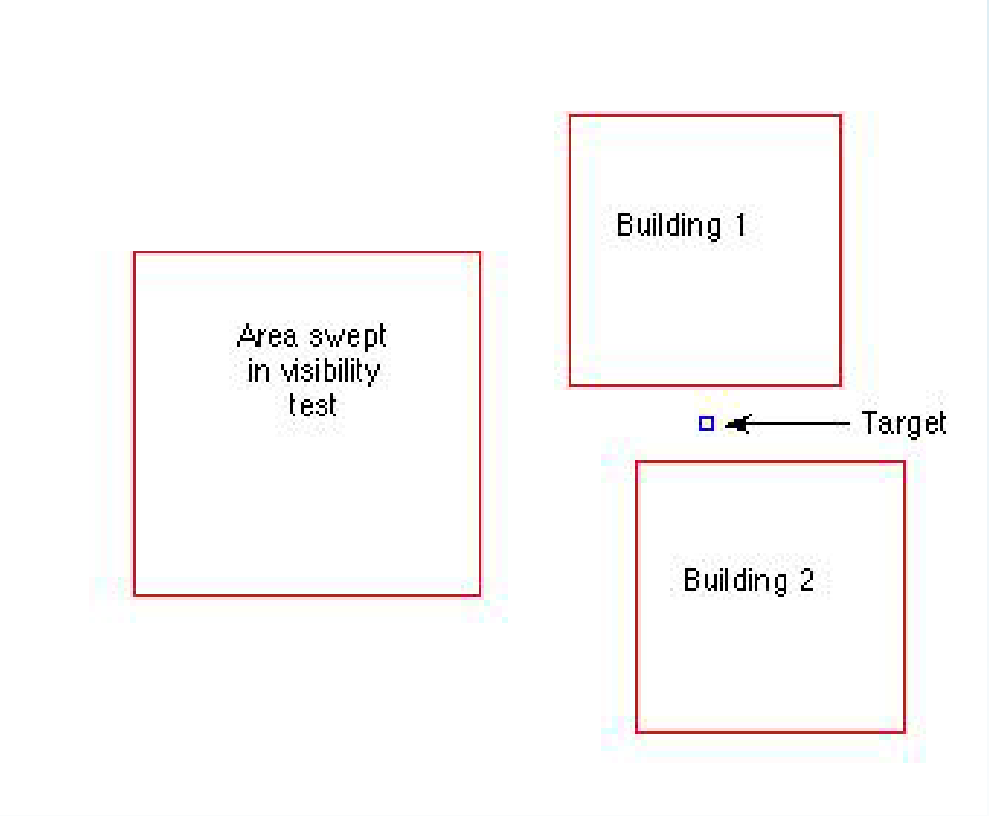
- However, you need to use the uncertainty properly
  - Monte Carlo techniques can be used to drive *any* data-driven interface, even if it's implemented using high-level framework languages

# Ray-Based Selection With Uncertainty

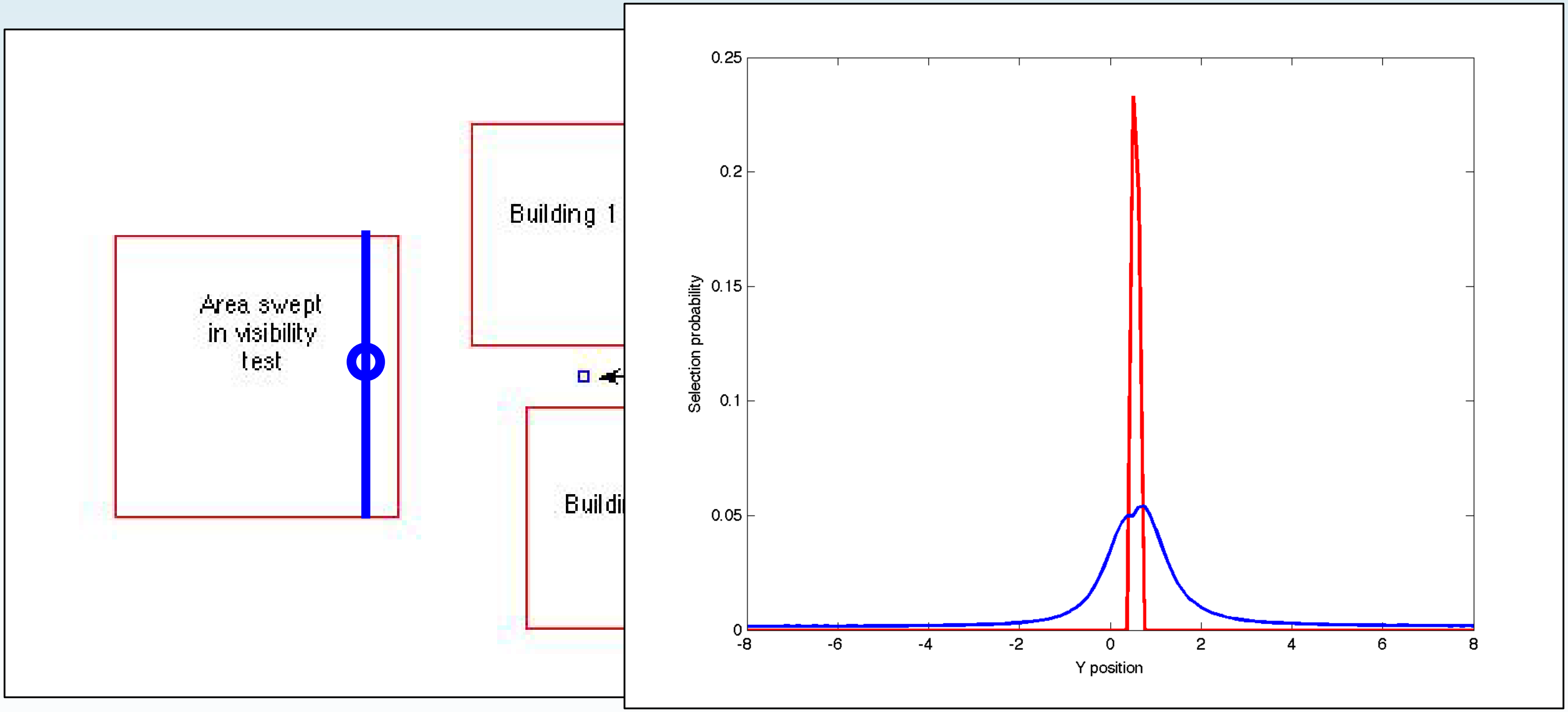

- Many current uncertain selection algorithms account for angular errors *only*
  - Fine if position uncertainty is *small*
  - Does not handle occlusion relationships

# Estimating Visibility Probability



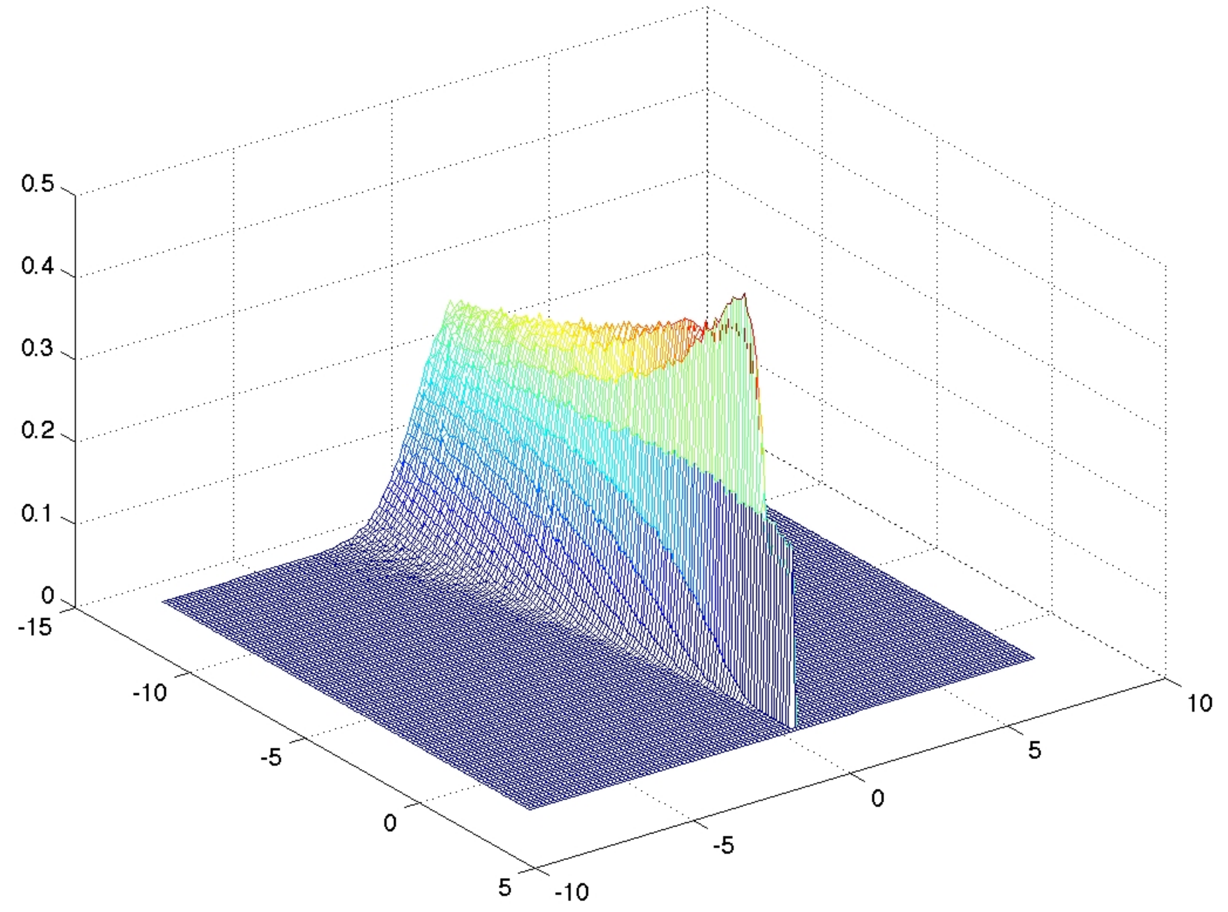

- Iterate through swept visibility test region to determine probability that user is looking at the target

# Estimating Selection Probability



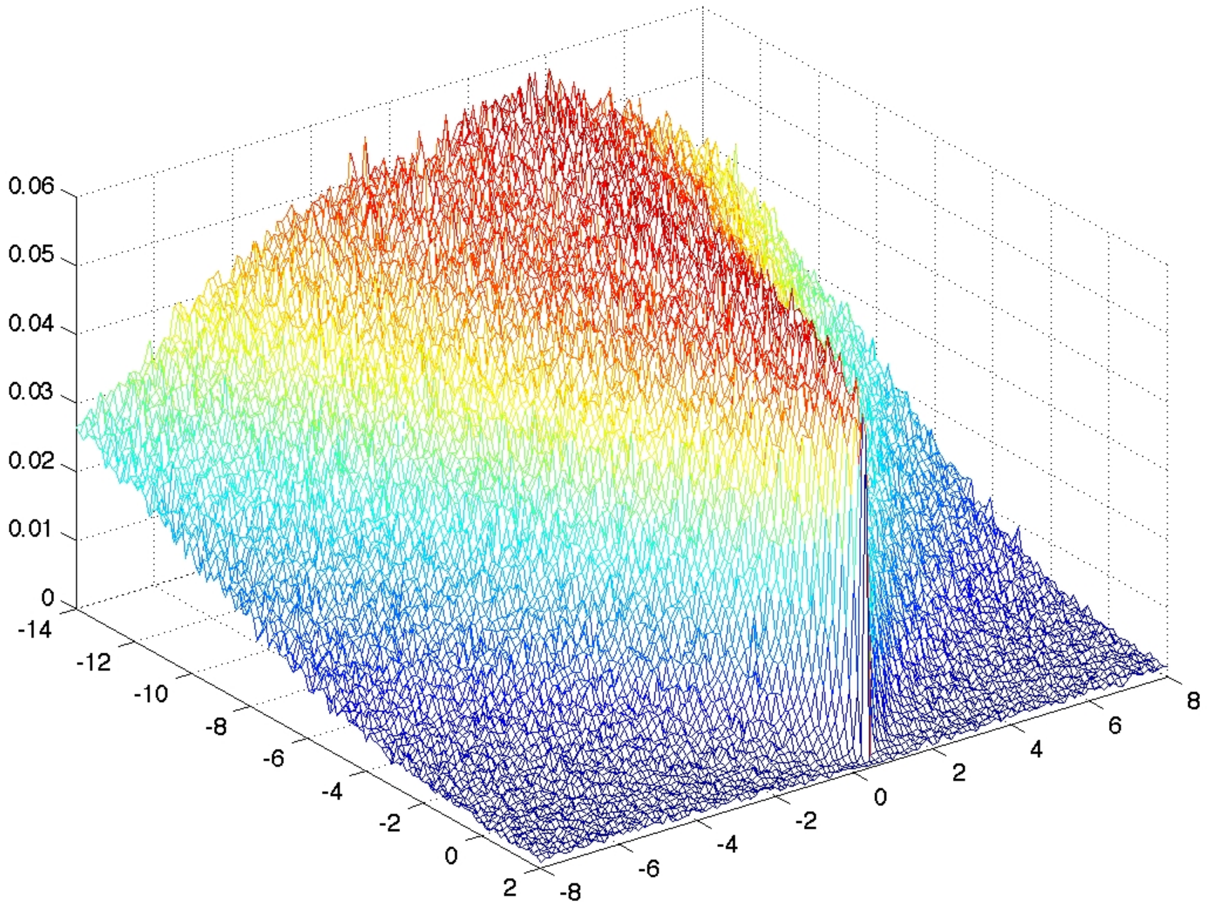

- Without position uncertainty P(selected) ≈0.25
- With position uncertainty P(selected) ≈0.05

# Estimating Selection Probability




No occlusion

# Estimating Selection Probability



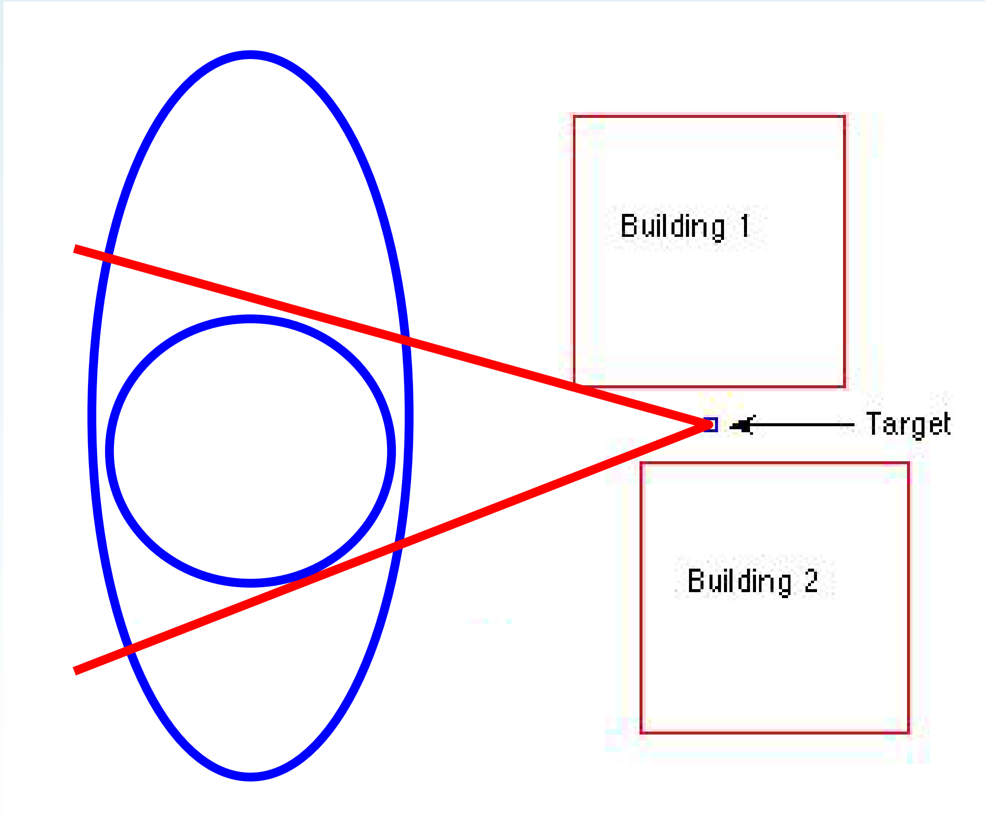

With occlusion

# Coupling Tracking Uncertainty with the UI

- In the mobile AR case, the *same* uncertainty leads to input and output ambiguity means that addressing one can be used to address the other
- Disadvantage:
  - The input disambiguation schemes need to be aware of the error in the output
- Advantage:
  - Resolving uncertainty in output can resolve uncertainty in user inputs

# Coupling Tracking Uncertainty with the UI

- Consider the uncertain location scenario again
- If the user selects the target object, they have to be in a position where the target is selectable
- Cast rays from the target object back into space




User

Position

# Summary and Conclusions

- Uncertainty is prevalent in user inputs and context for mobile systems
- We can view these as generating multiple hypotheses of communicative intent
- To be properly adaptive, MRUIs should:
  - Use appropriate models of uncertainty
  - Exploit the commonality of uncertainty in the input and output of systems

# So How Does This Relate to Standards?

- Representing uncertainty
  - Schemes such as SensorML are developing sophisticated sensor classifications
- Representing system architecture
  - Uncertainty couples *all* parts of the system together in a seemingly monolithic way
  - One solution is to make all parts aware using  Monte Carlo methods to drive the systems
  - Is the standards problem then coming up with the hypothesis resolution schemes?
- We haven’t even asked the question: what are the right cues to use?