

SLAM with a Prior Map

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SLAM

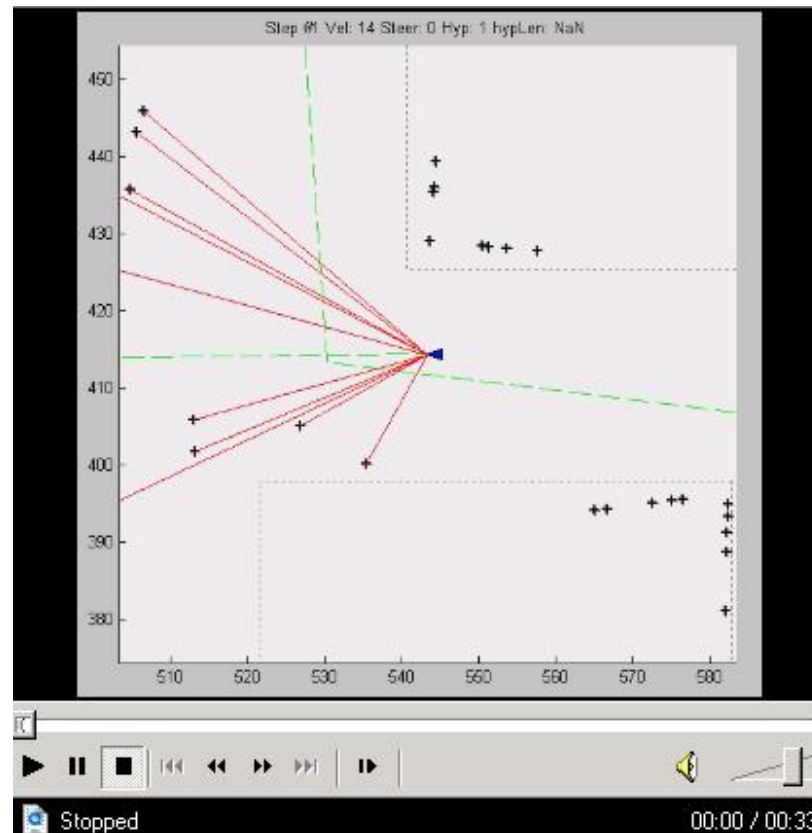
“A moving vehicle attempting to recover a spatial map of its environment, while simultaneously estimating its own pose relative to the map”

SLAM gives more accurate vehicle localisation than odometry alone

“Chicken and egg” problem:

- To get a robot pose need to know map
- To build a map, need to know robot pose

EKF-SLAM Example



Reasons for Problem with SLAM

- Can show will be mathematically inconsistent
- Linearisation and other approximations do not model cumulative effects of models properly
- However, a key assumption is that the environment is unknown

The Unknown Environment Assumption

- Conventional SLAM solutions eschew knowledge about the global environment
 - Some work generates and exploits local constraint information only
 - Global constraints are mentioned but have not been used
- However, *lots* of global prior information can be obtained and *very easily*

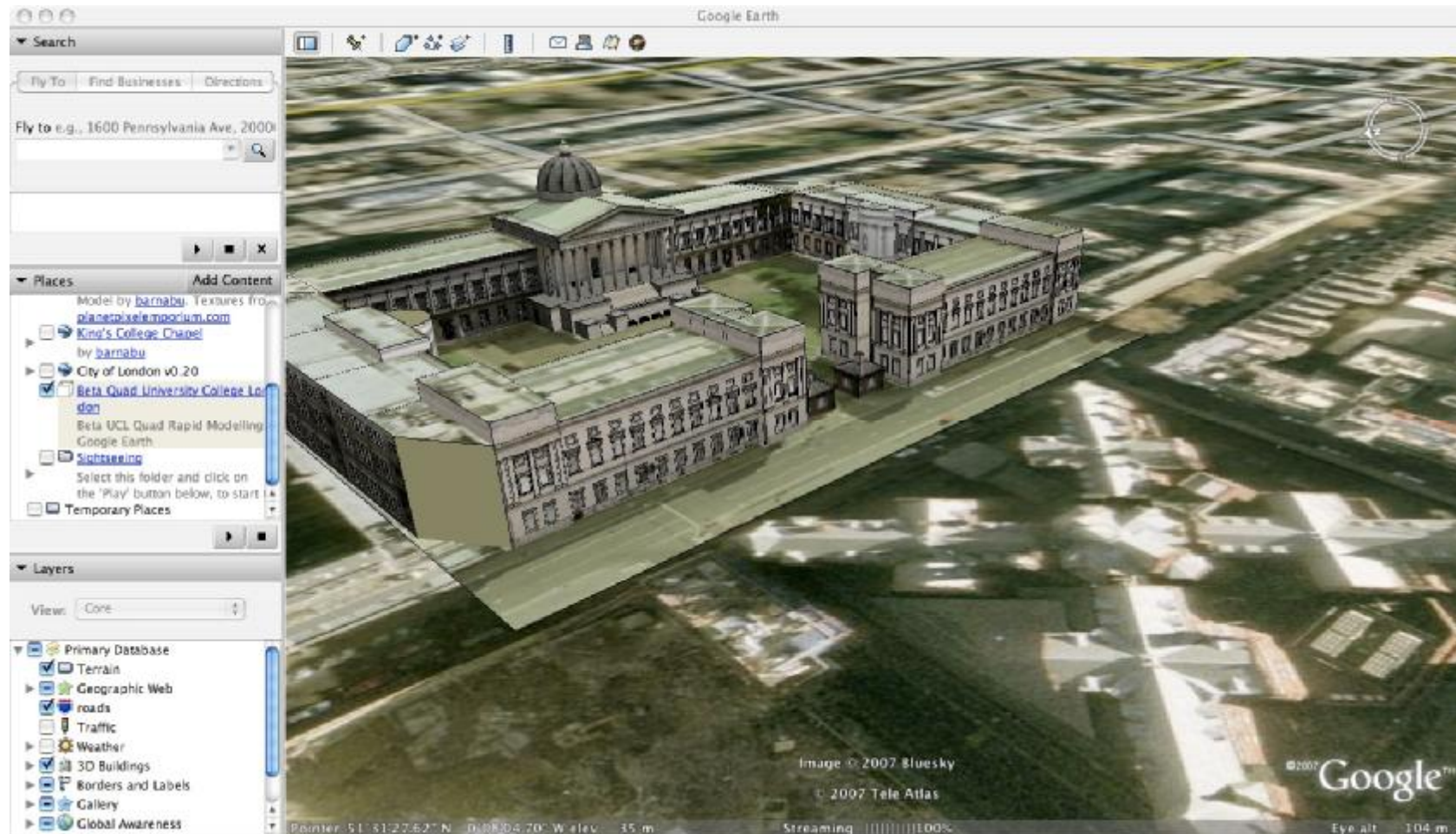
COTS Aerial Imagery



COTS LIDAR



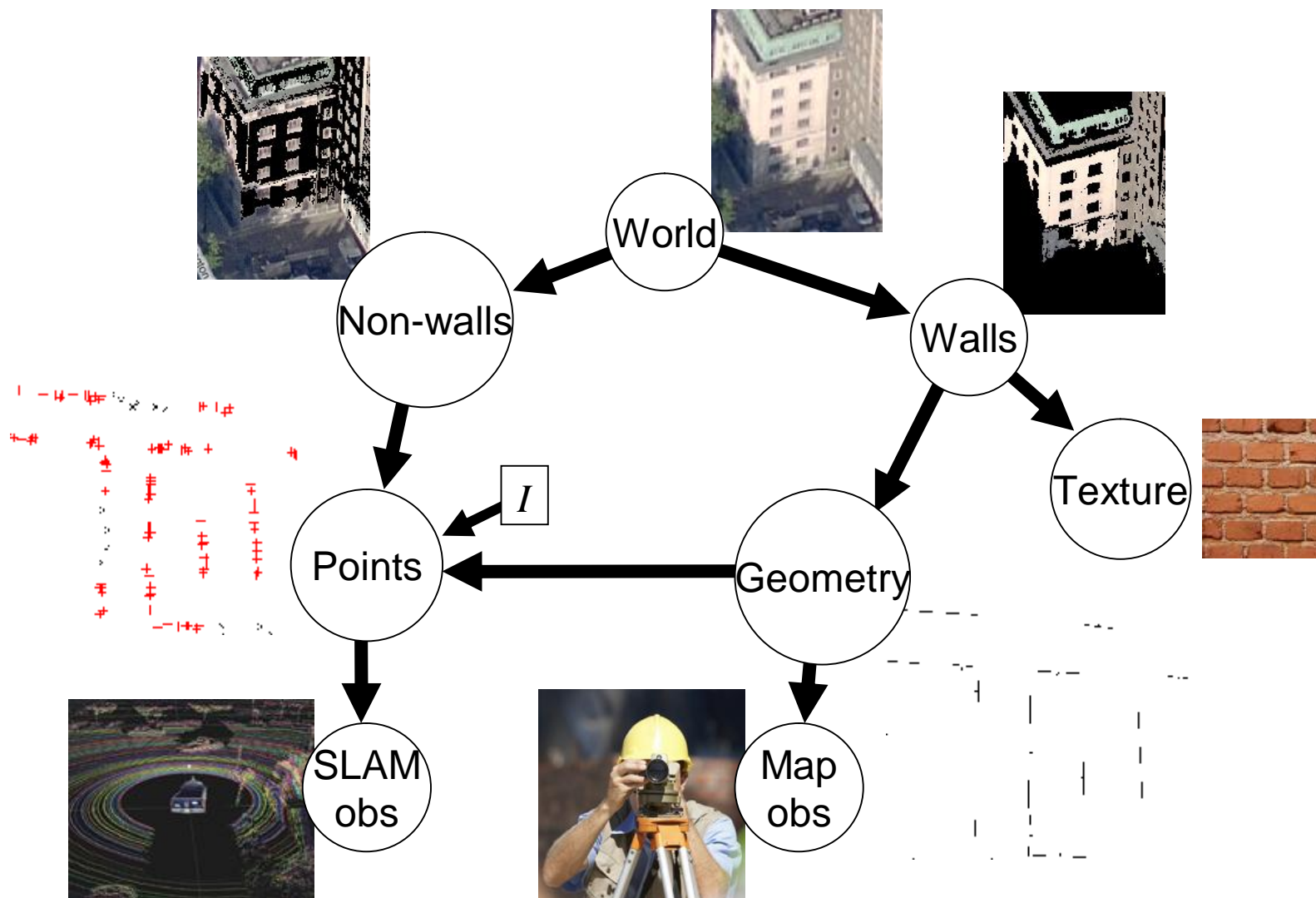
And Various Other Sources...



Modelling Multiple Information Sources

- We consider multiple map sources to arise from multiple agents
- Most would have used SLAM to some extent
- Different agents use different sensors and processing algorithms
- They see correlated, but different, views of the same world

Prior Information Network

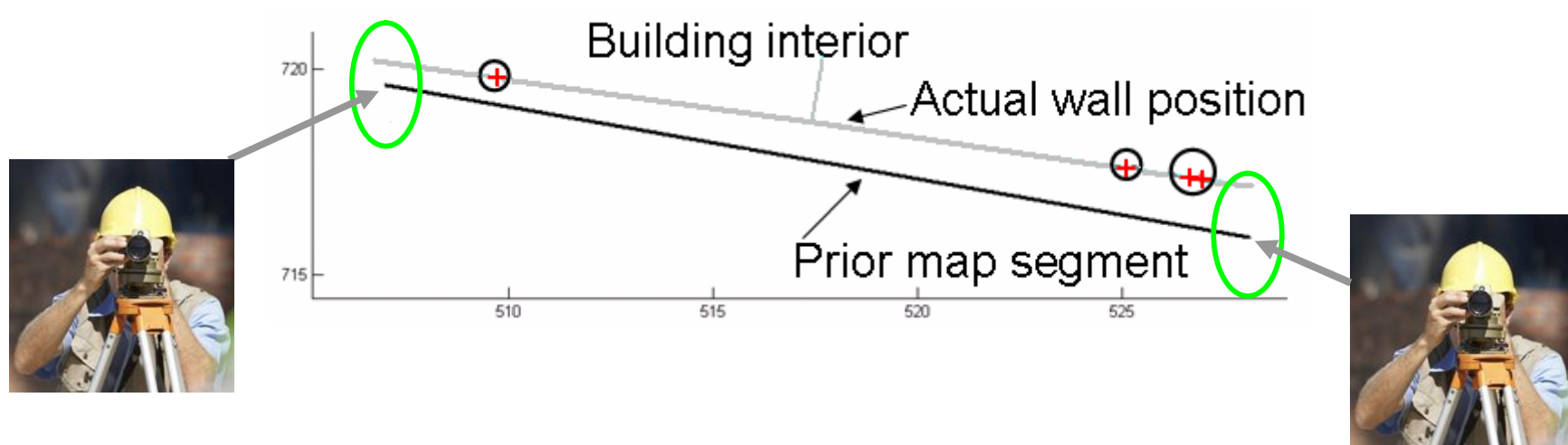


Using Multiple Maps

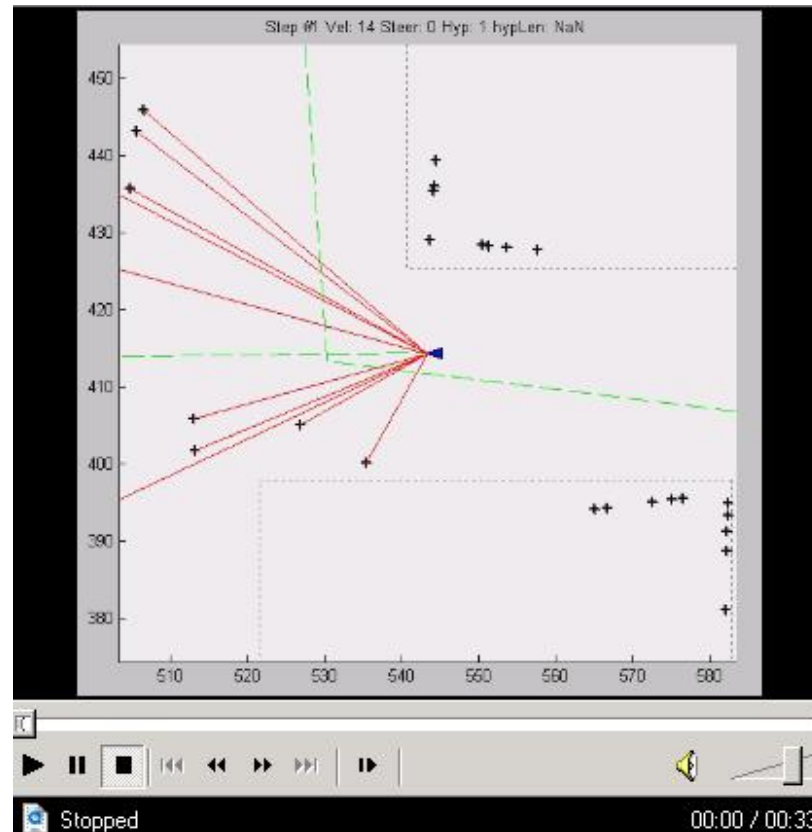
- There are three main challenges:
 - Modelling everything together
 - Performing data association to work out common features in maps
 - Fusing common features when they have been identified
- Using a prior map *effectively* is non-trivial
- We consider the problem of applying point and line features

Introducing a Prior Map

- 1 m std. dev. line segment prior map
- All beacons lie on the walls
- They can be parameterised in terms of the prior map

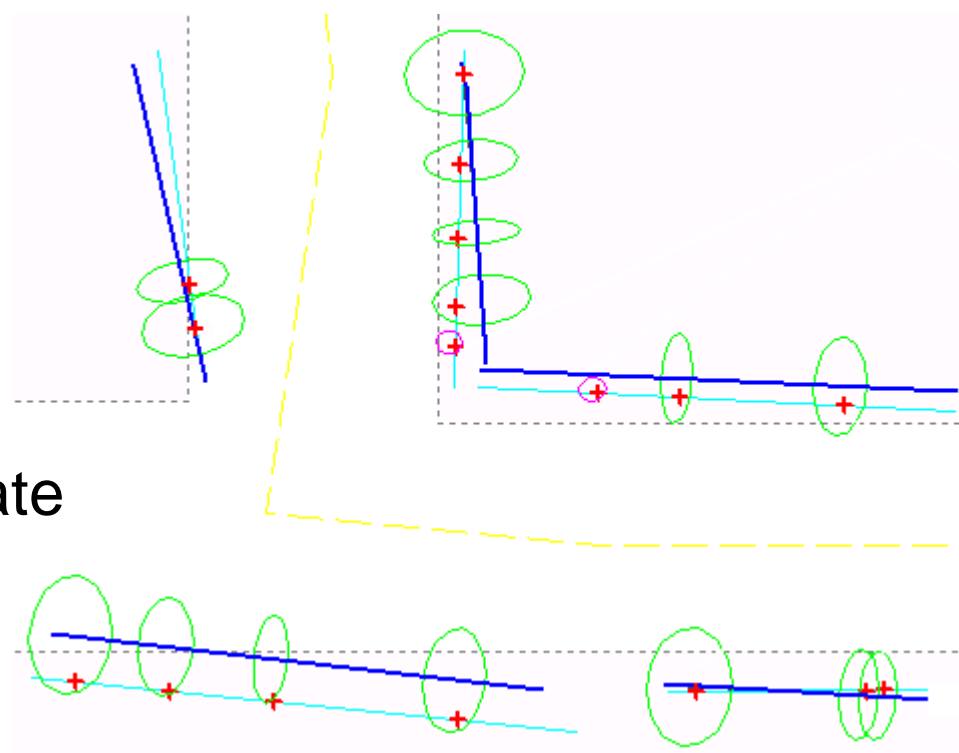


Using a Prior Map is Non-Trivial



Mitigating Errors with a Prior Map

- Fix the prior map using a Schmidt-Kalman update
- Resistant to SLAM errors
- Beacon uncertainty estimate is suboptimal



Free beacons (do not use prior map)

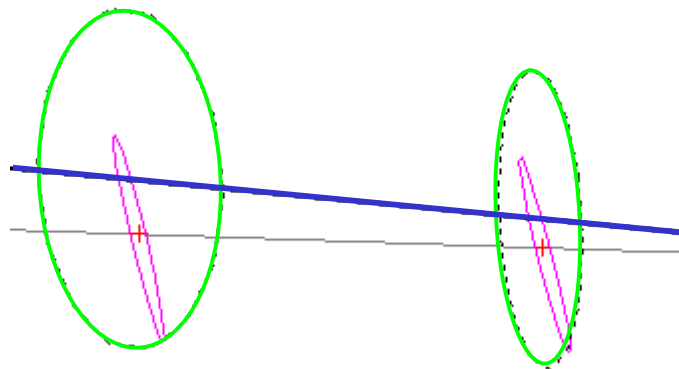
Beacons expressed through prior map

Fixed prior map (not updated)

$$\begin{bmatrix} \hat{\mathbf{x}}_u \\ \hat{\mathbf{x}}_c \\ \hat{\mathbf{x}}_m \end{bmatrix} \begin{bmatrix} \mathbf{P}_u & \mathbf{P}_{uc} & \mathbf{P}_{um} \\ \mathbf{P}_{uc}^T & \mathbf{P}_c & \mathbf{P}_{cm} \\ \mathbf{P}_{um}^T & \mathbf{P}_{cm}^T & \mathbf{P}_m \end{bmatrix}$$

The Dual Representation

- Maintain **constrained** & **unconstrained** estimates at the same time
- **Unconstrained** estimate gives more precise estimate
- **Constrained** estimate mitigates EKF errors

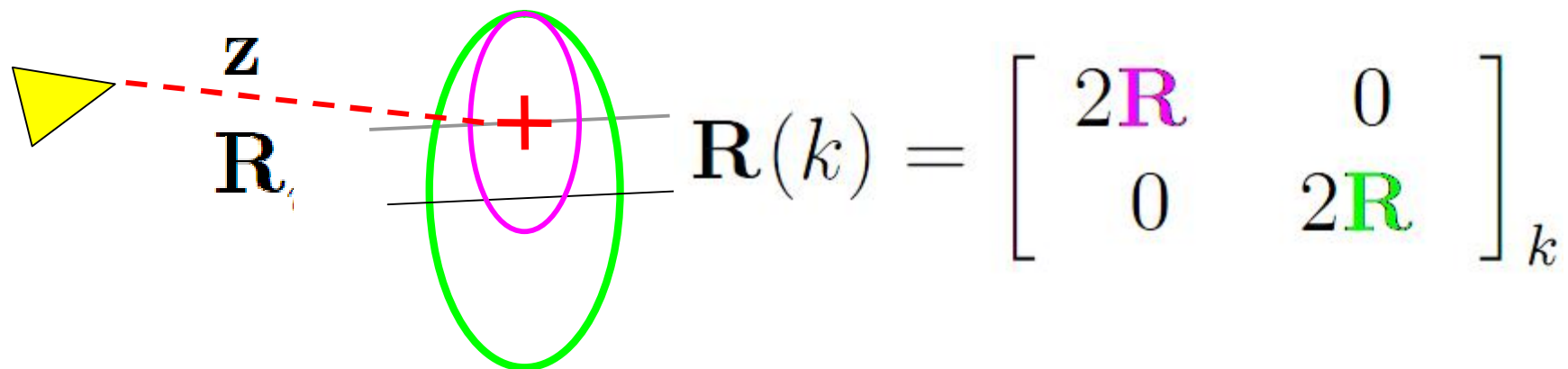


$$\begin{bmatrix} \hat{\mathbf{x}}_u \\ \hat{\mathbf{x}}_c \\ \hat{\mathbf{x}}_m \end{bmatrix} \begin{bmatrix} \mathbf{P}_u & \mathbf{P}_{uc} & \mathbf{P}_{um} \\ \mathbf{P}_{uc}^T & \mathbf{P}_c & \mathbf{P}_{cm} \\ \mathbf{P}_{um}^T & \mathbf{P}_{cm}^T & \mathbf{P}_m \end{bmatrix}$$

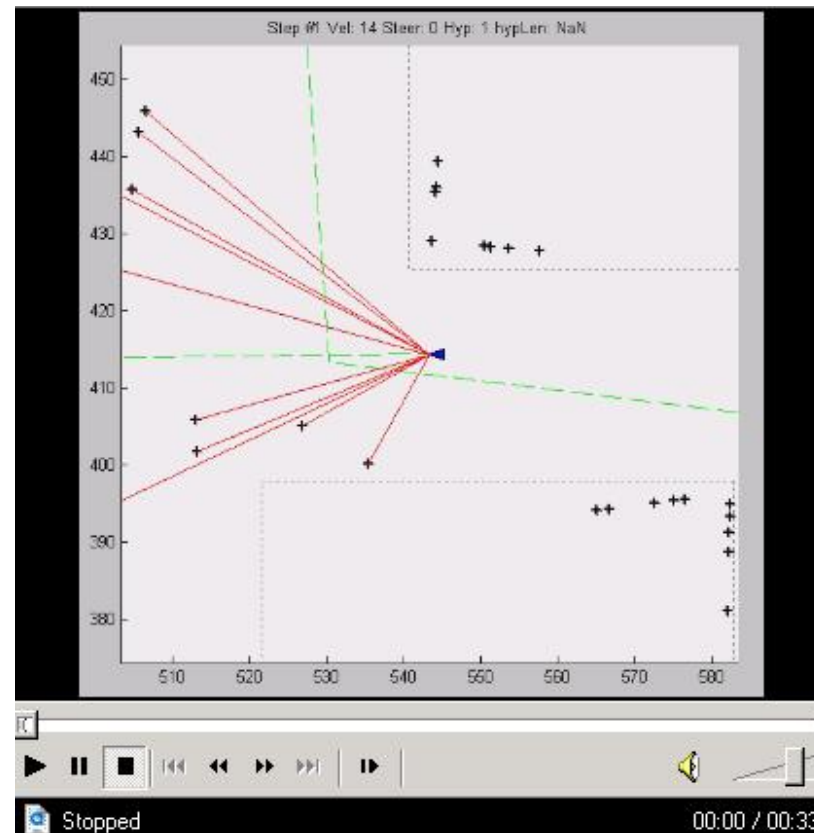
Updating Dual Representation Beacons

- Duplicate the observation \mathbf{z} for the beacon and its corresponding observation uncertainty \mathbf{R}
- Account for the shared information

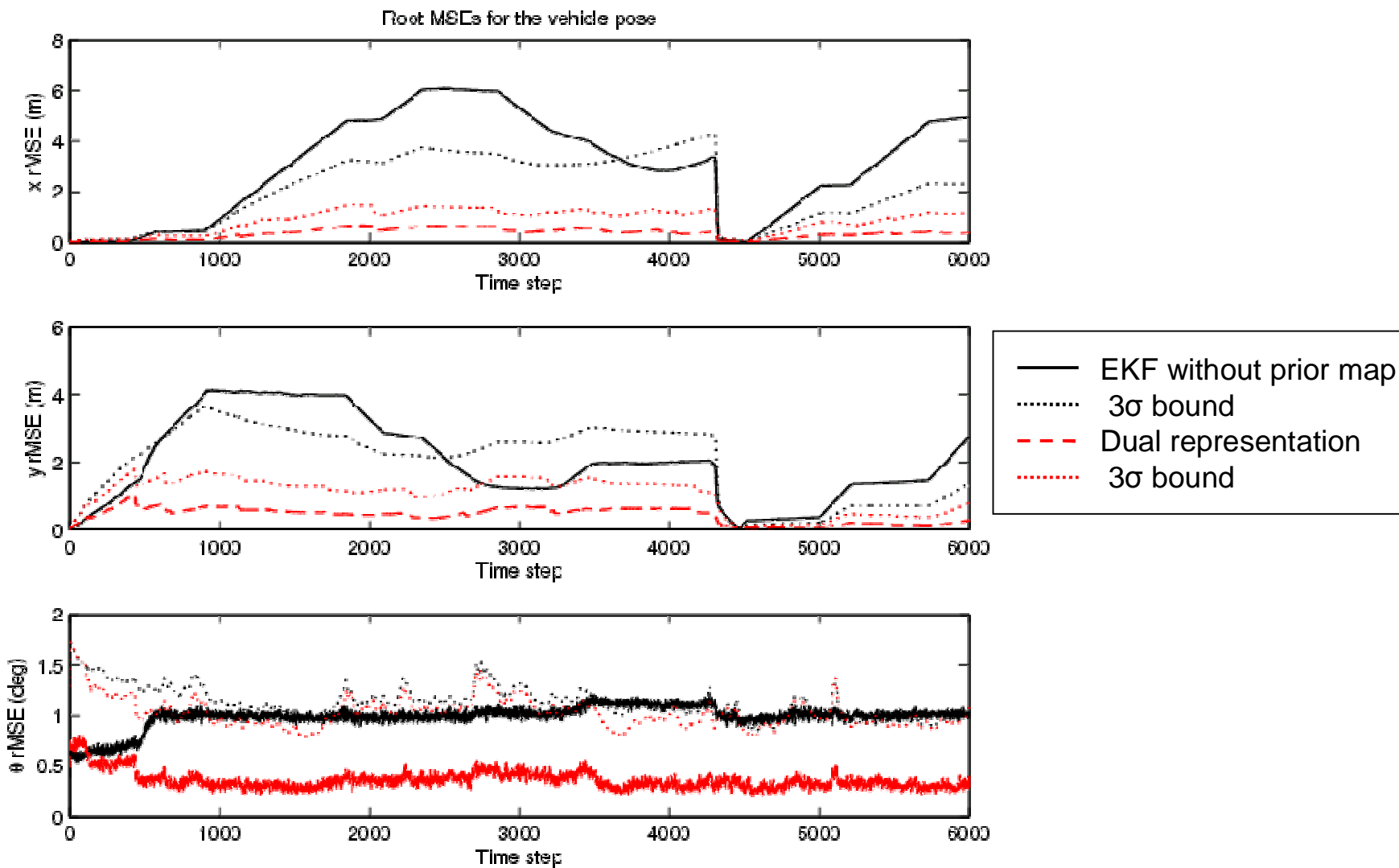
$$\mathbf{z}(k) = \begin{bmatrix} \mathbf{z} \\ \mathbf{z} \end{bmatrix}_k \quad \mathbf{R}(k) = \begin{bmatrix} \mathbf{R} & \mathbf{R}^T \\ \mathbf{R} & \mathbf{R} \end{bmatrix}_k$$



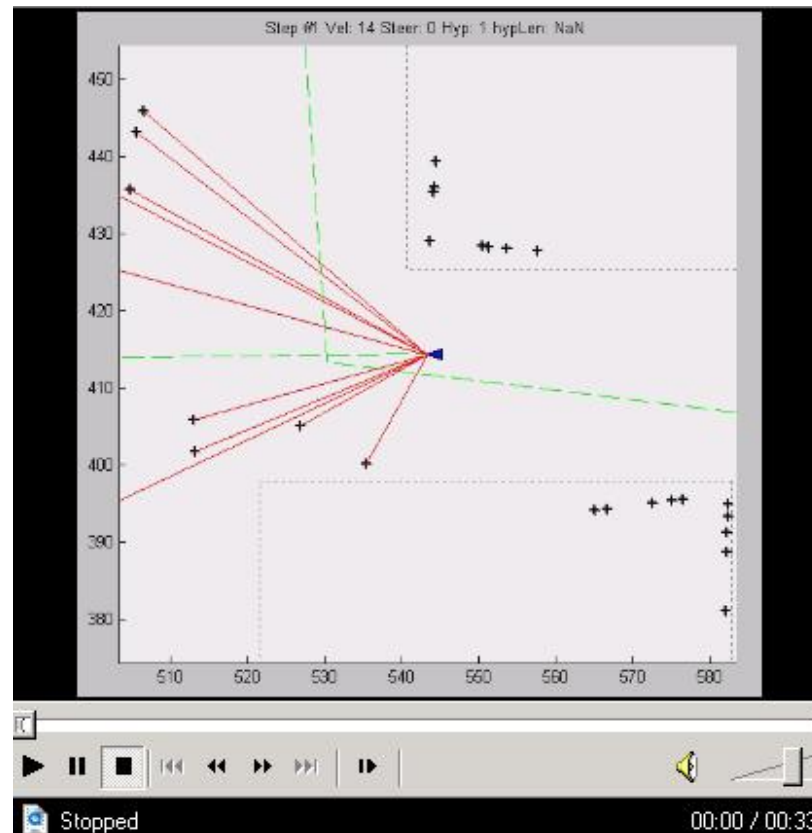
Example Run



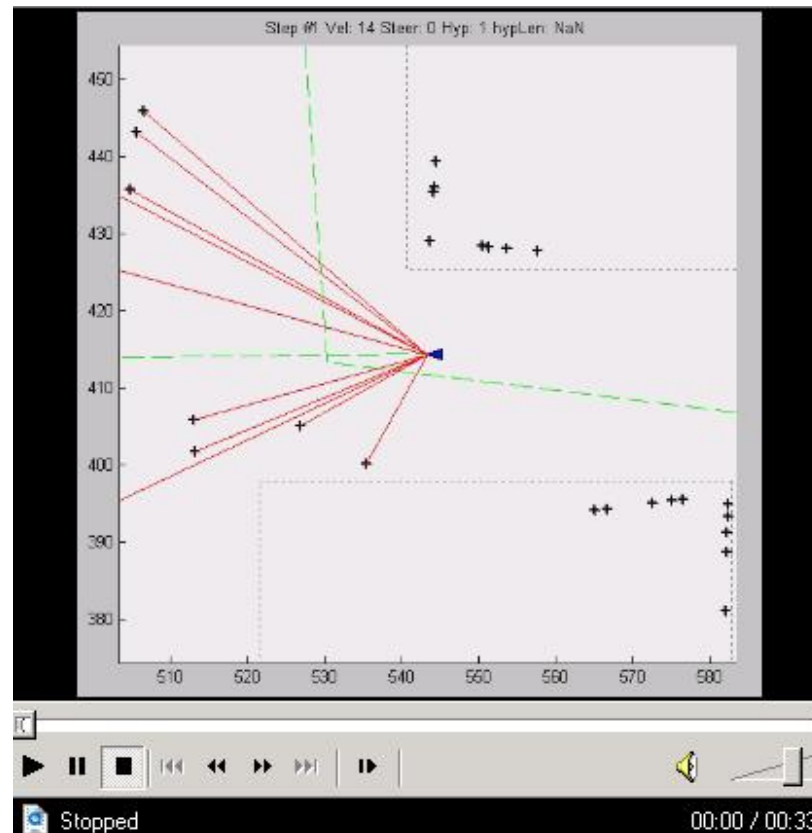
Monte Carlo Simulations



Bearing-Only SLAM: No Prior Map



Bearing-Only SLAM: Prior Map

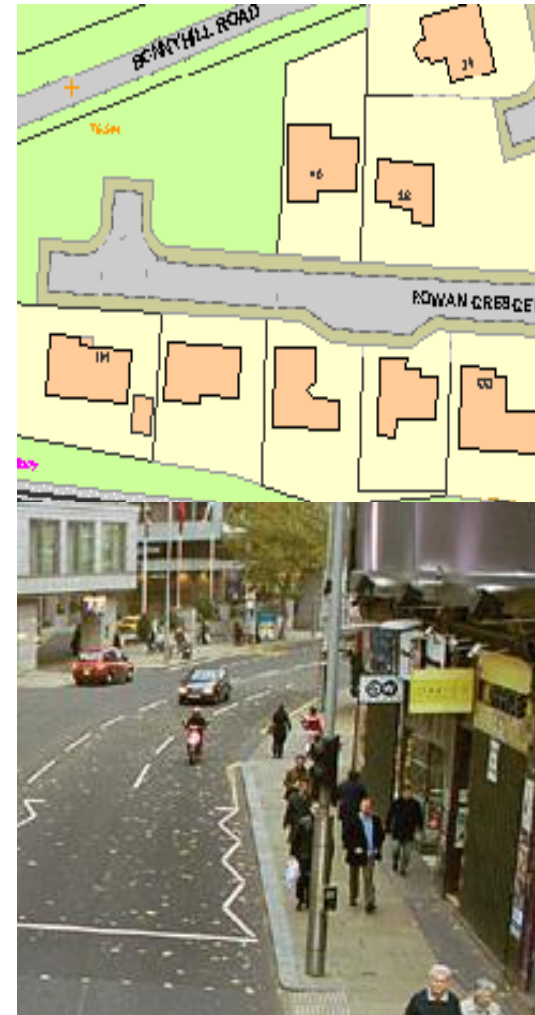


The Real World

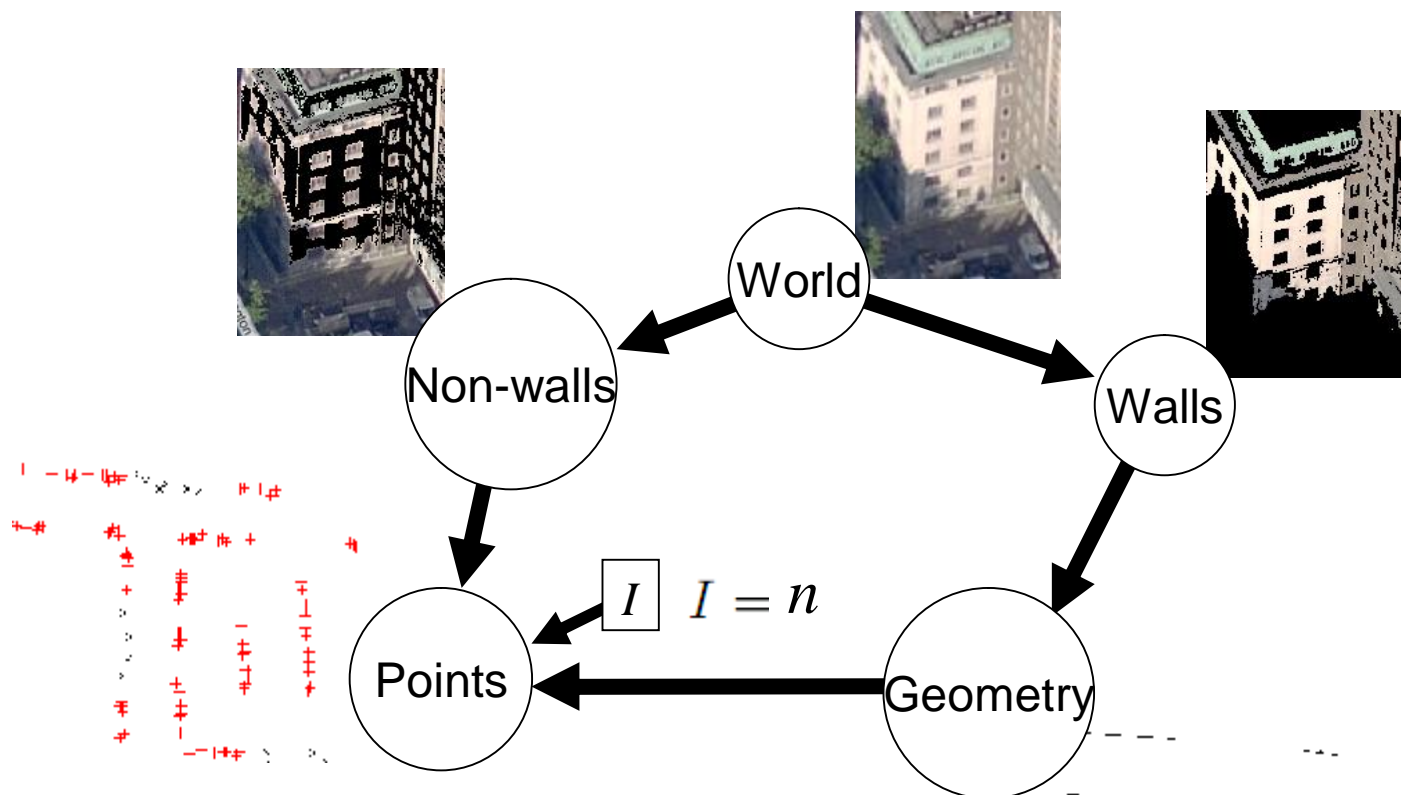
- Real world is more complex than any prior map

For a map of building walls,
“clutter” caused by:

- Trees
- Signs
- Lamp posts
and many more...



Network Representation



- $I \in \{\emptyset, 1 \dots n\}$
- $I = \emptyset$ is the clutter case
- Need to determine I

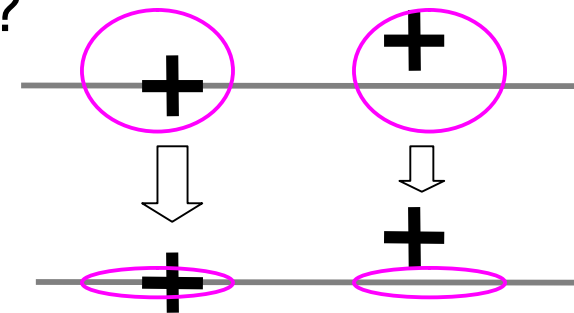
Association between Features

Is a beacon part of a prior map feature?

Yes: prior map feature gives information about this beacon

No: using the prior map feature would corrupt the state

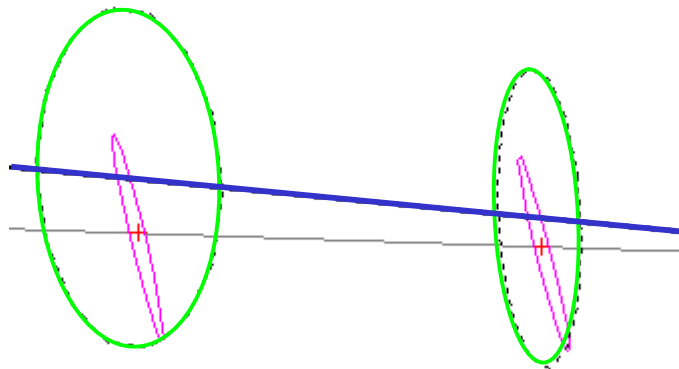
- Estimated beacon position incorrect?
- Clutter?
- Incorrect prior data?



Can we distinguish between the two cases?

Clutter with Dual Representations

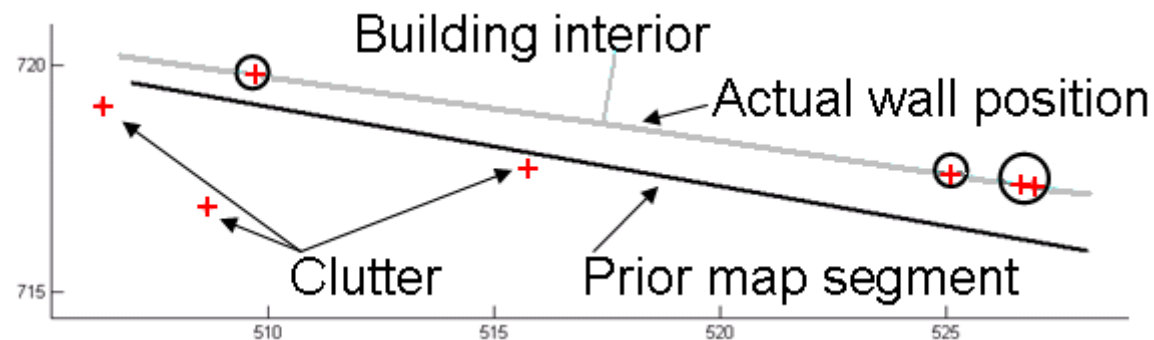
- Offers a convenient method of resolving clutter
- Compare unconstrained vs. constrained estimates
- Can use max likelihood, posterior probability etc.
- Can even revise data association decisions (to a certain extent) – throw out $\hat{\mathbf{x}}_c$



How likely are $\hat{\mathbf{x}}_c$ and $\hat{\mathbf{x}}_u$ to correspond to the same beacon?

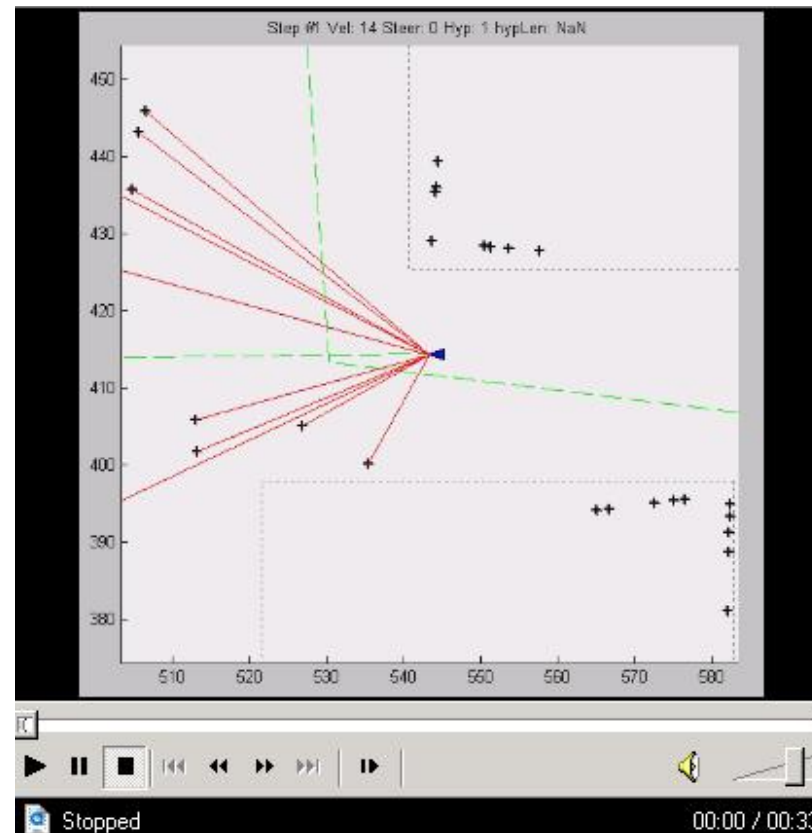
Monte Carlo Simulations - Prior Map

- 1 m std. dev. line segment prior map
- Some beacons lie on the wall, some in front of it (the “clutter”)

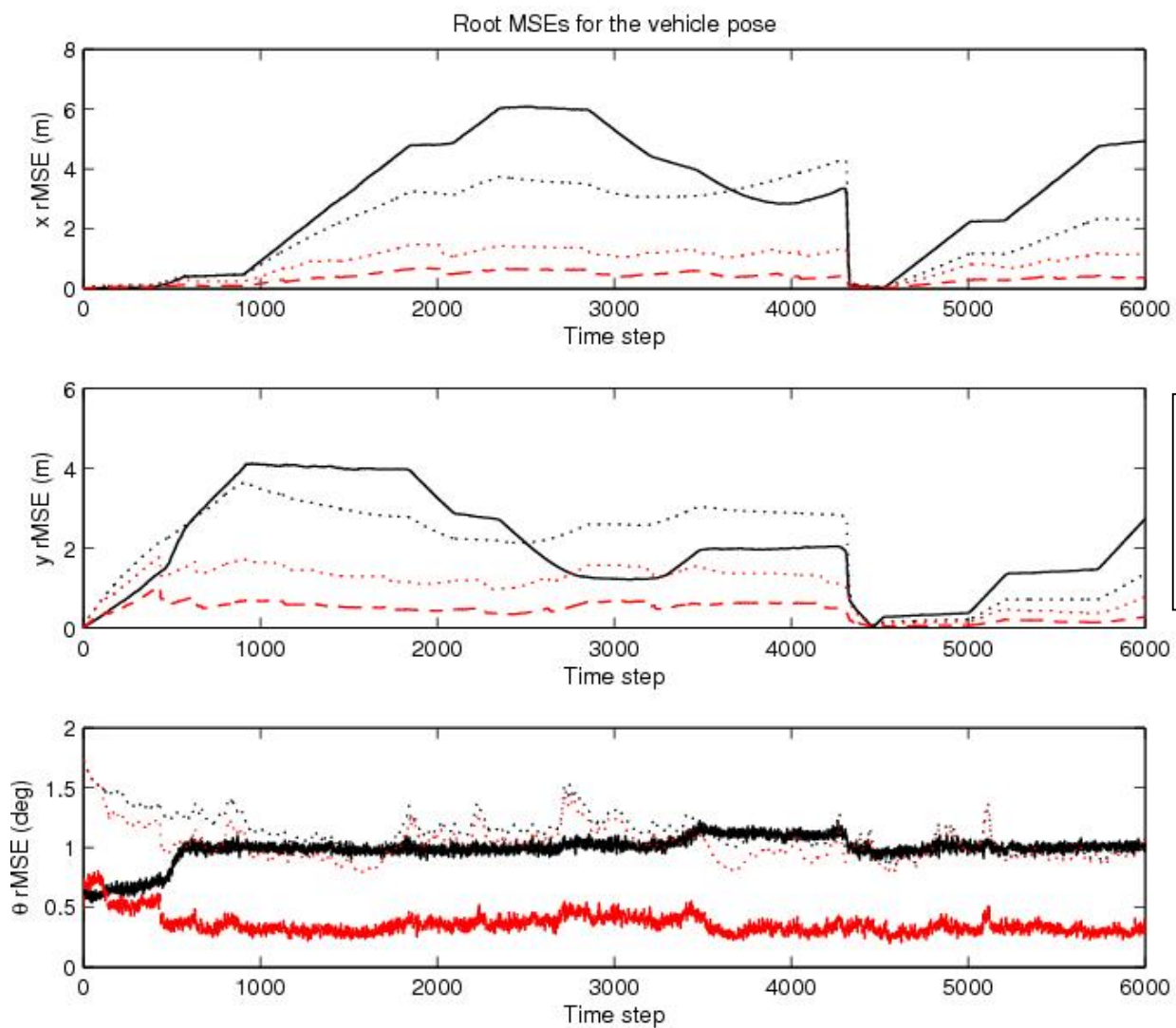


Beacons that are not clutter are circled

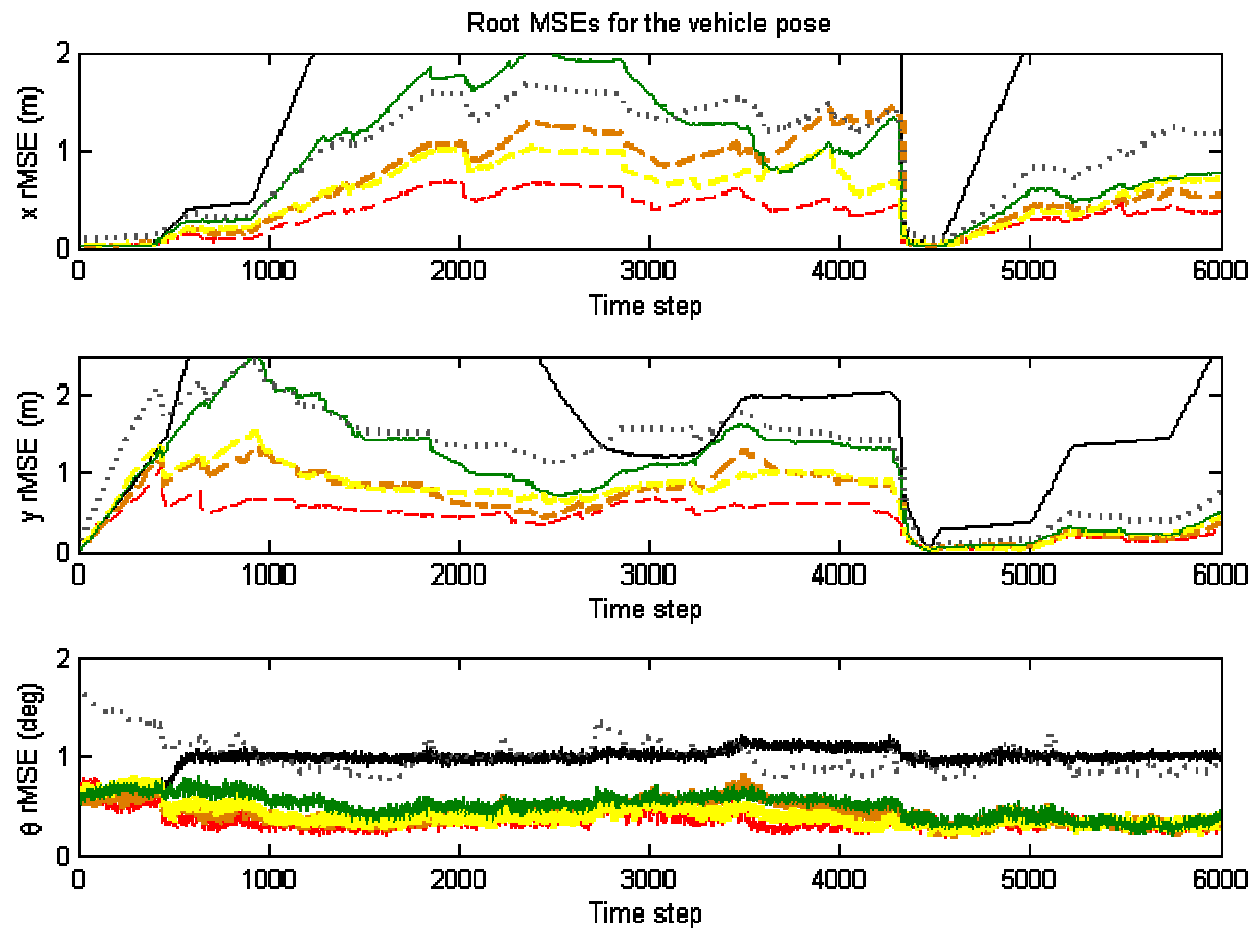
Example Run with Clutter



No Clutter Reminder



Increasing Clutter



Conclusion

- The Dual Representation mitigates EKF errors when using information from a prior map
- Simple and computationally fast
- Flexible: can use multiple prior maps with different representations
- Determine beacon-map associations (and thus detect clutter)
- Heuristically detect and revise incorrect associations