Active Sensing in an Urban Environment: Closing the Loop

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Objective

Demonstrate through Monte Carlo simulations an active sensing platform with waveform design and scheduling for multitarget tracking, that simultaneously:

- reduces missed-detection probability
- reduces the uncertainty ellipse for a tracked target
- increases the time devoted to surveillance

Motivation

When compared to tracking airborne targets, tracking ground targets on urban terrain brings a new set of challenges:

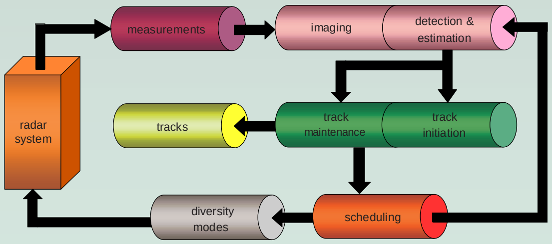
- target mobility is constrained by road networks
- dense clutter
- multipath
- limited line-of-sight
- multiple other interferers

In order to improve the accuracy of track estimates under such complex scenarios, it is important to use prior knowledge of the environment, and exploit the integration of detection, signal processing, tracking, and scheduling.

Overall System

Common approaches to tracking are based on suboptimal decoupling of radar system and tracker. Our innovative solution includes:

- use of statistics from current scan to design waveform to be transmitted on next radar scan
- use of pre-processed measurements instead of raw radar returns



Distinct levels of diversity are considered:

- spatial diversity through the use of coordinated multistatic radars
- waveform diversity by adaptively scheduling the transmitted radar waveform according to the scene conditions
- motion model diversity by using a bank of parallel filters, each one matched to a different maneuvering model

Complexities of the Urban Terrain

Core technical issues:

- multipath ambiguities
- multipath modelling
- continuous target visibility
- measurement-track association

Satellite images and city maps provide layouts for:

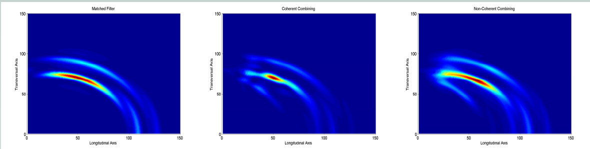
- streets map
- buildings
- vegetation

Above: Illustration of multipath reflections of radar returns. The two trucks are the intended targets, and measurements from clutter should not be validated by the system.

Sorting Through Clutter

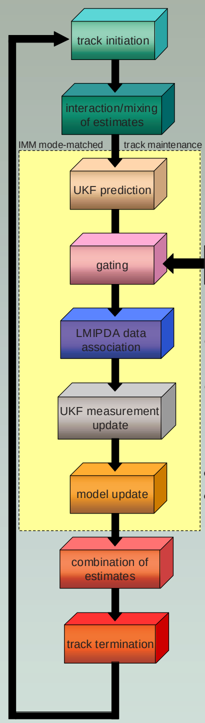
Target state and waveform-dependent covariance matrix are estimated from radar images polluted by clutter and multipath. Goals:

- high-resolution image that discriminates targets and suppresses clutter
- compromise between missed-detection and false alarm rates



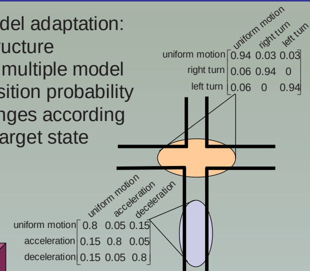
Above: Snapshot of a moving target at (x,y) = (50,70) using 3 distinct imaging schemes. Matched-filter is the baseline. Coherent combining is sensitive to fading and phase errors. Non-coherent combining is robust under fading, but shows blurring and estimation errors.

Multitarget Tracker Implementation



Motion model adaptation:

- variable-structure interacting multiple model
- model transition probability matrix changes according to current target state



	uniform motion	right turn	left turn
uniform motion	0.94	0.03	0.03
right turn	0.06	0.94	0
left turn	0.06	0	0.94

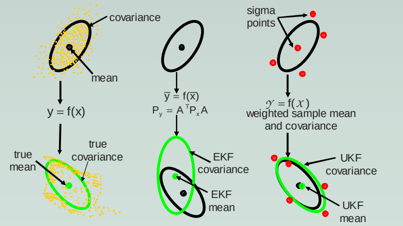
	uniform motion	acceleration	deceleration
uniform motion	0.8	0.05	0.15
acceleration	0.15	0.8	0.05
deceleration	0.15	0.05	0.8

Measurement-track association

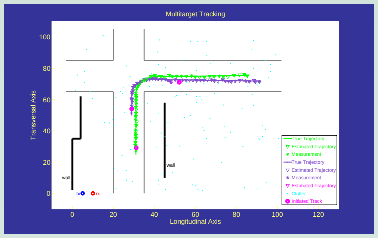
- integrated track initiation and termination using the probability of track existence (PTE)
- track is initiated (terminated) if PTE gets above (below) threshold

Unscented Kalman vs. extended Kalman filters

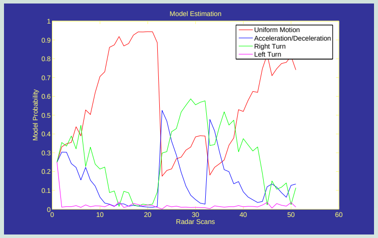
- EKF: filter divergence due to model linearization
- UKF: deterministic sampling, propagates sigma points through nonlinear model



Preliminary Results



- Left: Tracking 2 targets in urban terrain. Tracks are initiated and terminated according to threshold levels.
- Right: Target motion-model estimation. The correct model at each scan has the highest probability. Some delay in model-switching is expected.



Future Work

- MVDR imaging
  - minimizes power of interferers
- waveform scheduling
  - round-robin
  - myopic strategy
  - non-myopic strategy
- tracking people
  - motion models
  - indoor vs. outdoor environments