

SensIT Collaborative Signal Processing Scenario Discussions

v.7

Jim Reich, Xerox PARC

April 17, 2001



Collaborative Signal Processing: The Scenarios

The Goal:

Develop a set of scenarios to establish levels of capability and compare performance of techniques.

- Began development at August PI meeting
 - Outlined basic scenarios, no scaling, etc.
- Discussions at Collaborative Signal Proc. Workshop
- Scenario telecons March-April 2001
 - Defined scaling, parameters of each scenario
- Surveyed level of interest in solving each scenario
- Current Status
 - 12 Canonical Scenarios
 - 4 Combined Scenarios
- Ready to use, but may need to be modified to support real hardware and vehicles available











Scenario Notes

- Do not expect 100% of scenarios solved in '00-'02
 - Some intended as long-term challenges!
- Single vehicle unless otherwise shown
- Unless otherwise stated, vehicles attempt to maintain constant speed and do not shift gears
- Unless otherwise stated, vehicles start beyond the sensor field and arrive in sequence
- Scenarios specify mean node spacing, mix of sensor payloads, mix of vehicles.
 - Diagrams not to scale, correct number of nodes not shown, but correct sensor payload mix is.
- Unless otherwise stated, nodes position, payload, vehicle order of arrival are unspecified
- For single vehicle, "vehicle mix" implies allowable subset of vehicles



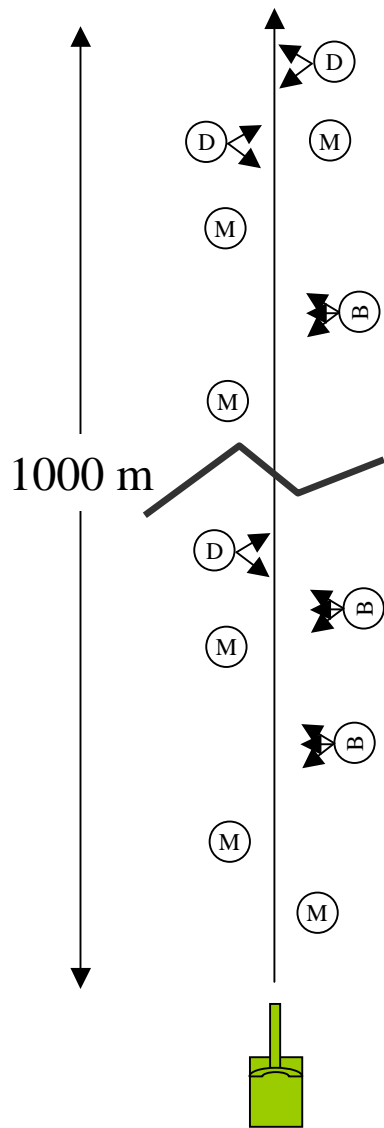
Sensor Payload Key

1D Scenarios \ 2D Scenarios

-  • **Omni Microphone Cluster**
 - 4 Omni Microphones (planar)
-  • **Directional Microphone Cluster**
 - 4 Crossed Dipoles
-  • **PIR Cluster**
 - 4 PIR Sensors
-  • **Mix A**
 - 2 Omnidirectional Microphones (dots along line shown)
 - 1 PIR Sensor
 - 1 Vertical Seismic
-  • **Mix B**
 - 1 Omnidirectional Microphone
 - 3 PIR sensors
-  • **Mix C**
 - 1 Omnidirectional Microphone
 - 1 Vertical Seismic
 - 1 Magnetometer (2 ch.)
-  • **Mix D (SITEX '00 Mix)**
 - 1 Omni Microphone
 - 1 Vertical Seismic
 - 2 PIR
-  • **Imager Node (imager only)**



1: Track Single Target



Task

- Estimate target position vs. time (continuous tracking)

Challenges

- Localize target
- Maintain accurate estimate in large gaps between sparse sensors
- Fuse data from multiple sensor types

Mean node spacing: 30 m

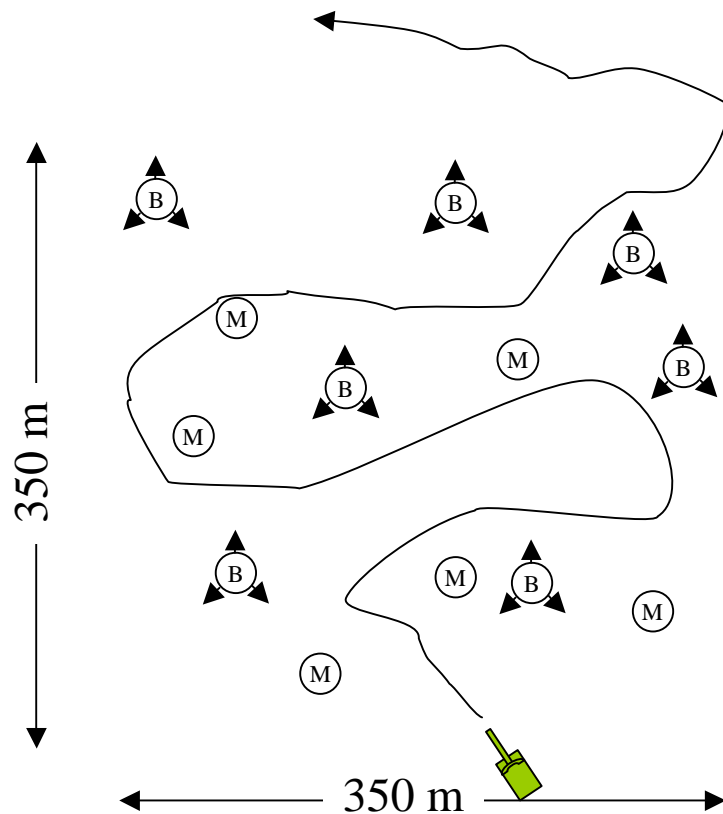
34 nodes total

Vehicles Allowable: Any

Vehicle Velocity: 10-30 m/s constant



2: Track Single Maneuvering Target



Task

- Estimate target position vs. time

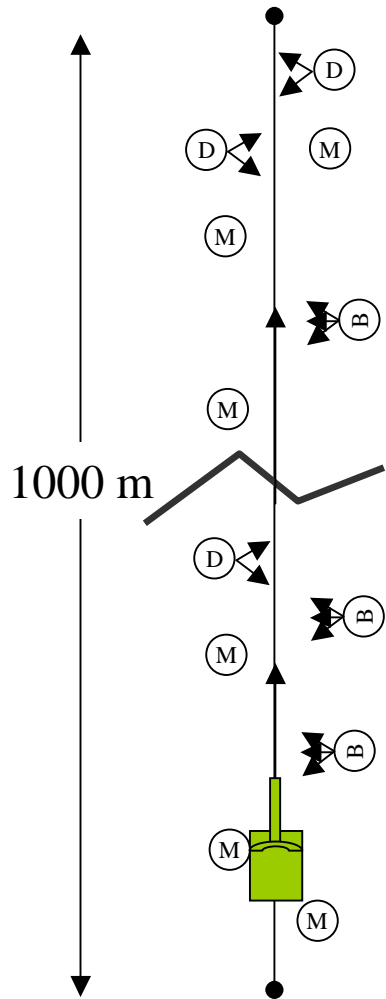
Challenges

- No road, hence no prior knowledge of vehicle trajectory
- Constant direction dynamics models no longer adequate
- Many sensors making simultaneous observations

Mean node spacing: 30 m
44 nodes total
Vehicles Allowable: Any
Vehicle Velocity: 10-30 m/s constant



3: Track Accelerating/Decelerating Target



Task

- Estimate target position vs. time

Challenges

- Vehicle signature time-varying
- Constant velocity dynamics models no longer adequate
- Gear shift requires maintaining internal discrete state (curr. gear)

Mean node spacing: 30 m

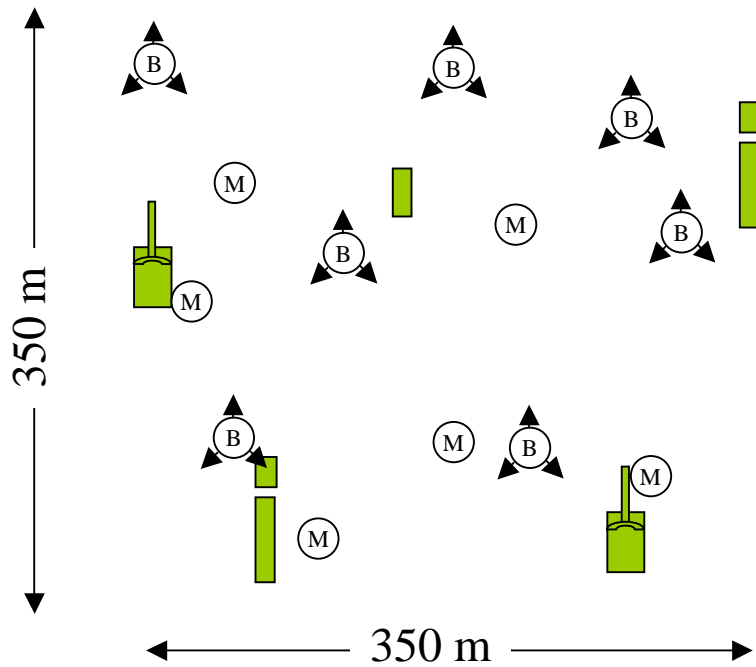
34 nodes total

Vehicles Allowable: Any

**Vehicle Velocity: 0-30 m/s variable
(w/gearshifts)**



4: Count Stationary (idling) Targets



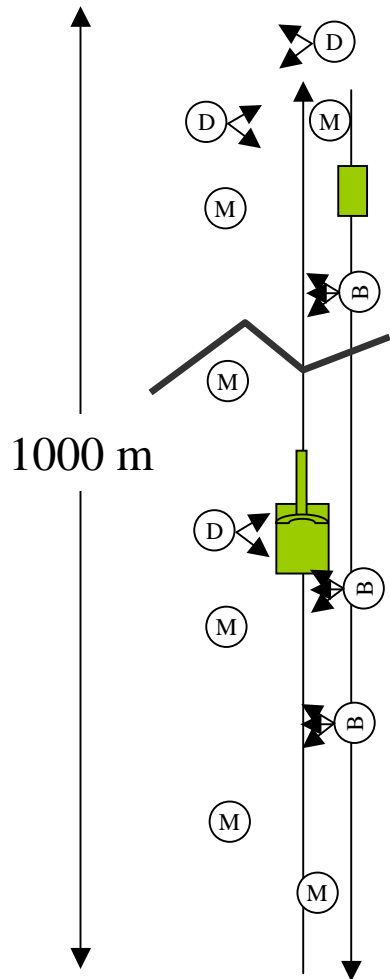
- Task
- Count number of targets
 - Locate targets

- Challenges
- Multiple vehicles
 - Unknown number of vehicles
 - Cannot depend on peak-finding (CPA) of acoustic signal

Mean node spacing: 30 m
34 nodes total
Vehicles Allowable: Any
Vehicle Velocity: 0



5: Two-way traffic



Task

- Track target positions
- Maintain target identity through crossover
- Estimate target crossing time

Challenges

- Vehicles in close proximity, need to use dynamics to keep identities separate

Mean node spacing: 30 m

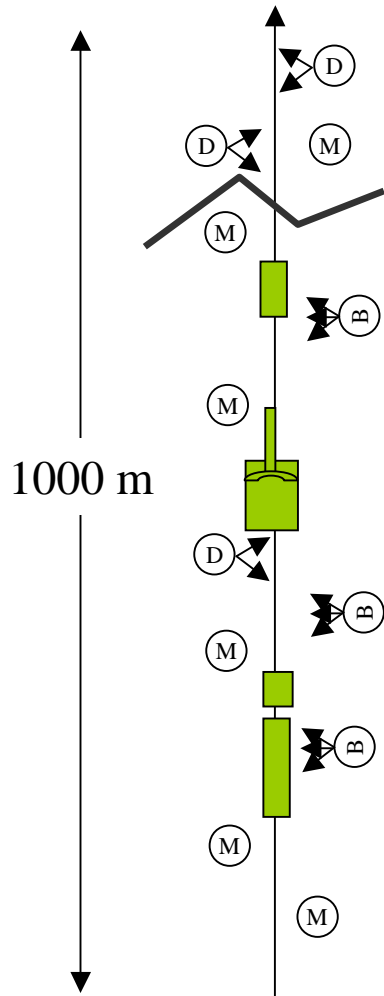
34 nodes total

Vehicles Allowable: Any

Vehicle Velocity: 10-30 m/s constant



6: Convoy on a Road



Vary inter-vehicle spacing to vary problem difficulty

Task

- Count number of vehicles of each type
- Determine order of vehicles

Challenges

- Initialization of new vehicles, count unknown a priori
- Multiple vehicles
- Classification and state information must follow vehicle along full length of road

Mean node spacing: 30 m

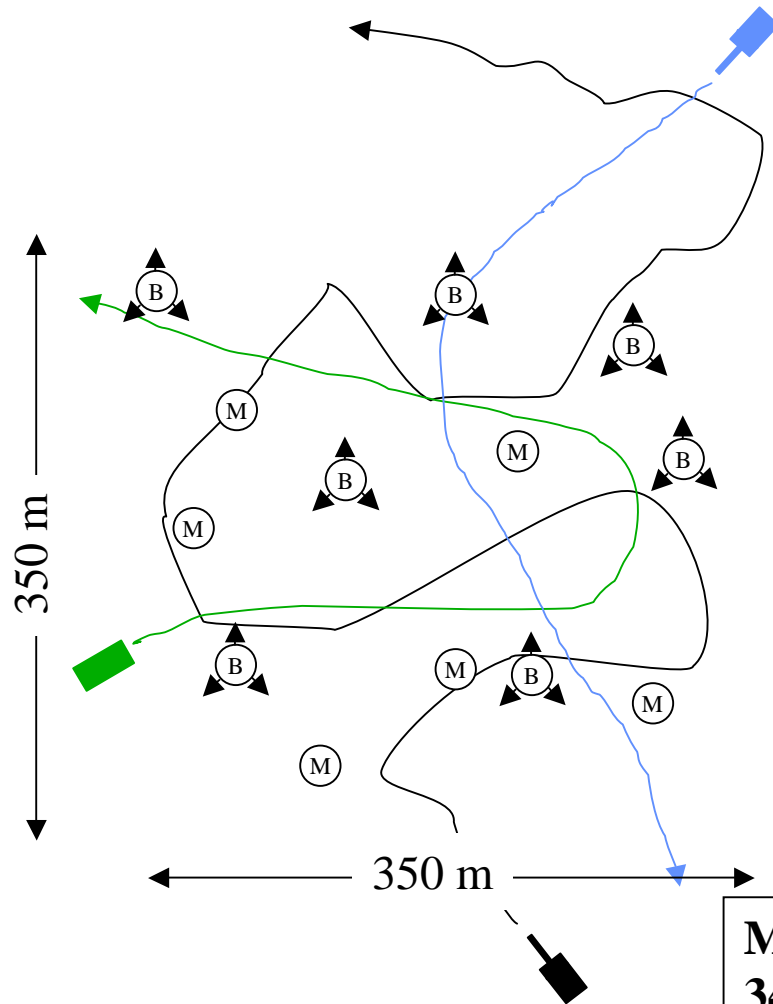
34 nodes total

Vehicles Allowable: Any

Vehicle Velocity: 10-30 m/s constant



7: Track Multiple Maneuvering Targets



Task

- Setup same as #2
- Vehicles maneuvers at const. speed
- 2 vehicles same class, one different
- Estimate target positions vs. time

Challenges

- 2D Data association problem
- No a priori knowledge of paths

Mean node spacing: 30 m
34 nodes total
Vehicles Allowable: Any
Vehicle Velocity: 10-30 m/s variable

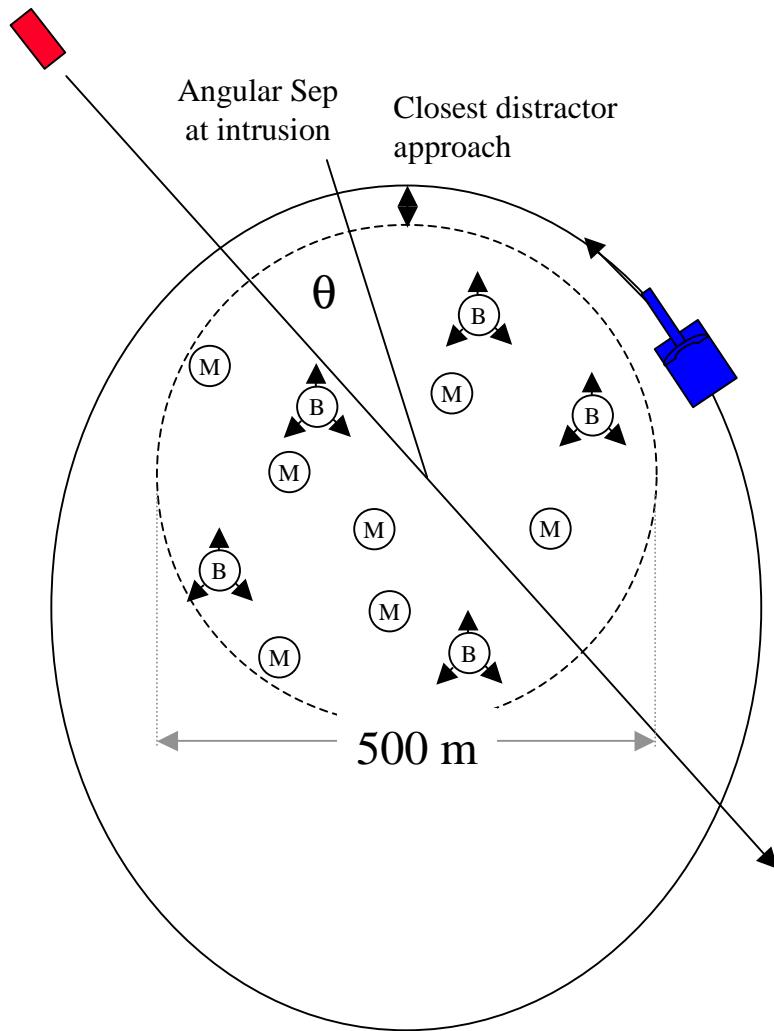
7: Track Multiple Maneuvering Targets

- Special Parameters
 - Closest approaches

Difficulty	Same vehicle type	Different vehicle type
Easy	100	50
Medium	50	20
Difficult	20	10



8: Perimeter Violation Sensing



- Task
- Alert on violation of perimeter
 - Ignore activity outside of perimeter (distractors)
 - Identify intruder type and track location

- Challenges
- Filter out distractor
 - Respond quickly while minimizing quiescent activity

Mean node spacing: 30 m
69 nodes total
Vehicle Velocity:
Distractor 10 Intruder 30
Veh. Types: by SPL ratio

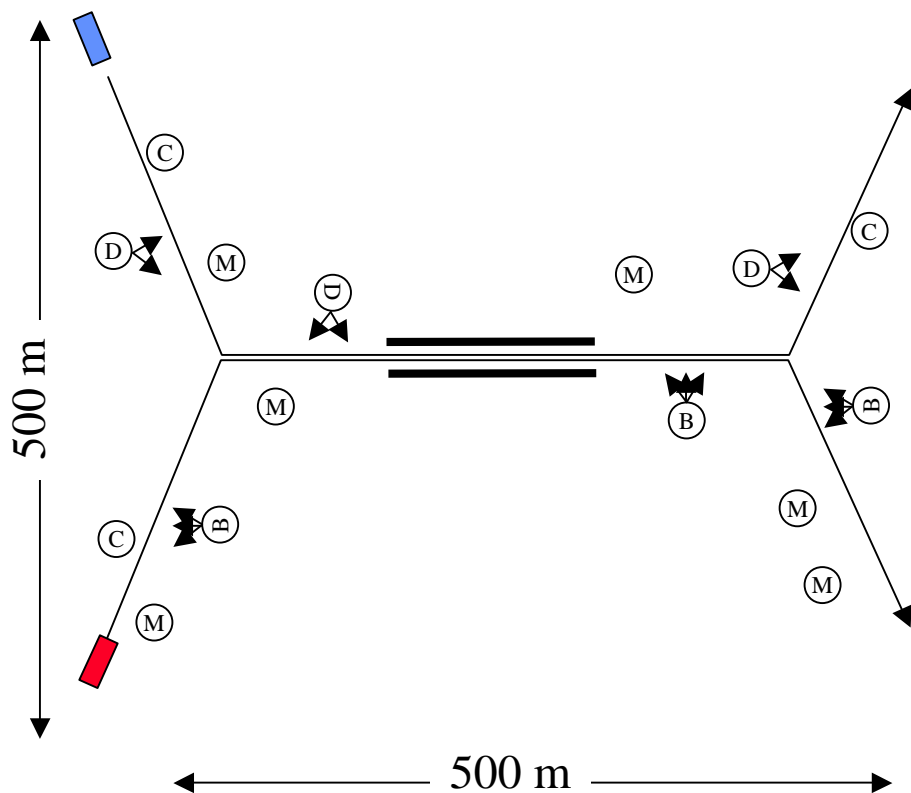
8: Perimeter Violation Sensing

- Special Parameters:
 - Time elapsed between distractor arrival and perimeter violation: up to 4 hours

Difficulty	Closest distractor Approach	Min. Angular sep. at violation (deg)	Source Amplitude Ratio (dB SPL @ 10m, intruder/distractor)
Easy	50	45	20
Medium	20	25	0
Difficult	10	15	-40



10: Identity Tracking & Mutual Exclusion using One-Time sensor



Targets can only be distinguished from each other by magnetometers (shown), which give one-time “red/blue” output when the vehicle passes over them.

Task

- Track targets
- Maintain target identities
- Re-establish identity of both targets when right-hand magnetometer is crossed

Challenges

- Need to conserve number and type of targets as they pass through tunnel.
- Need to reason about targets – Seeing blue at top right mag. guarantees red at bottom.

Mean node spacing: 30 m
72 nodes total
Vehicle Velocity: 10-30 const.



10: Identity Tracking & Mutual Exclusion using One-Time sensor

- Special Parameters
 - Desired time (secs) for propagation of exclusion constraint after magnetometer sees a vehicle after split

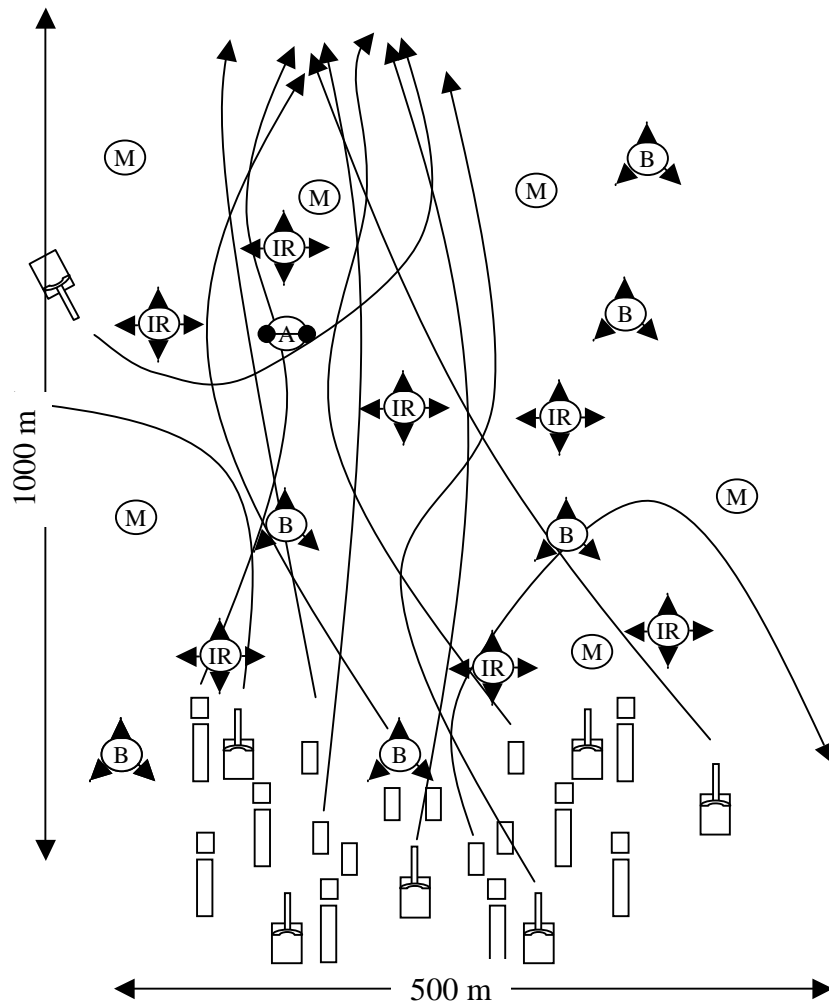
Easy: 10

Medium: 5

Difficult: 2



11. Cluster Behavior



Task

- Track cluster centroid
- Keep count of vehicles in cluster adjusting as some leave and join

Challenges

- Large number of targets
- Coalescing many similar targets, limiting exponential hypothesis blowup
- Measuring global properties of cluster (centroid, count) rather than properties of single target

Mean node spacing: 30 m
254 nodes total
Vehicle Velocity: 10-30
variable



11: Cluster Behavior

- Special Parameters
 - Mean vehicle spacing: 50m
 - Mean arrival time (s): 20
 - Mean departure time (s) : 40
 - Sphere of influence (m): 100m



12. Multiple Target Clusters

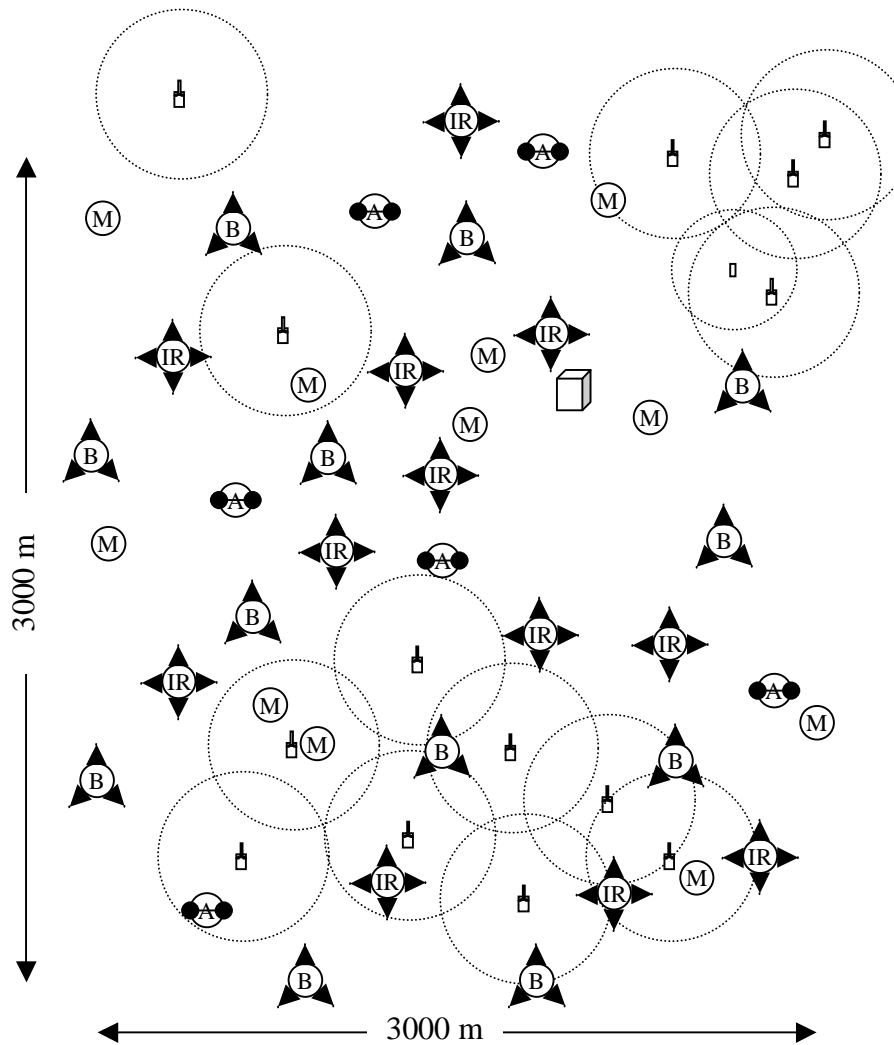
Task

- Sphere of influence defined for each vehicle type.
- Cluster defined as set of vehicles whose spheres intersect.
- Determine number of clusters, vehicle count by type of each.
- Track cluster centroids, cluster merges and splits over time

Challenges

- Too much data, delays too long to centralize cluster formation
- Cluster maintenance requires dynamic reconfiguration of node collaboration

Mean node spacing: 100 m
~1000 nodes total
Vehicle Velocity: 10-30
variable



12: Multiple Clusters

- Special Parameters
 - Mean vehicle spacing: 50m
 - Mean arrival time per cluster (s): 20
 - Mean departure time per cluster (s) : 40
 - Sphere of influence (m): 100m



CSP Canonical Scenarios: Who's Working on What, and When?



		2002					
#	Scenario	BaE Austin	BaE Sanders	PennSt ARL	PARC	UWisc	Lincoln Labs
1	Track Single Target	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
2	Track Single Maneuvering Target	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
3	Track Accel/Decel Target	Yellow	Yellow	White	Yellow	Yellow	Yellow
4	Count Idling Targets	White	Yellow	White	Yellow	Yellow	Yellow
5	Two-Way Traffic	Yellow	Yellow	White	Yellow	Yellow	Yellow
6	Convoy on Road	Yellow	Yellow	White	Yellow	Yellow	Yellow
7	Track Multiple Maneuvering Targets	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
8	Perimeter Violation Sensing	Yellow	White	White	White	White	White
9	Tracking in an Obstacle Field	White	White	White	Yellow	White	White
10	Identity Tracking/Mutual Exclusion	White	White	White	Yellow	White	White
11	Cluster Behavior	White	White	White	Yellow	White	White
12	Multiple Clusters	White	White	White	White	White	White

• Filled-in box indicates planned work at some level, could be simulation, lab experiment or field demo.

• Some scenarios may not be field demoable in 2000-2002 (i.e. simulation only)



1: Gathering Intelligence on a Convoy

Easy: All enemy vehicles

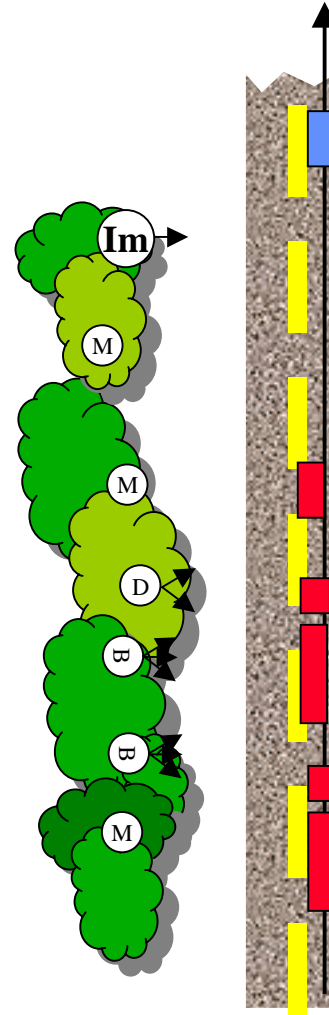
- Enemy convoy, S-N, Const. Speed.
- Track & Image all of them.

Medium: Mix of civilian and enemy vehicles

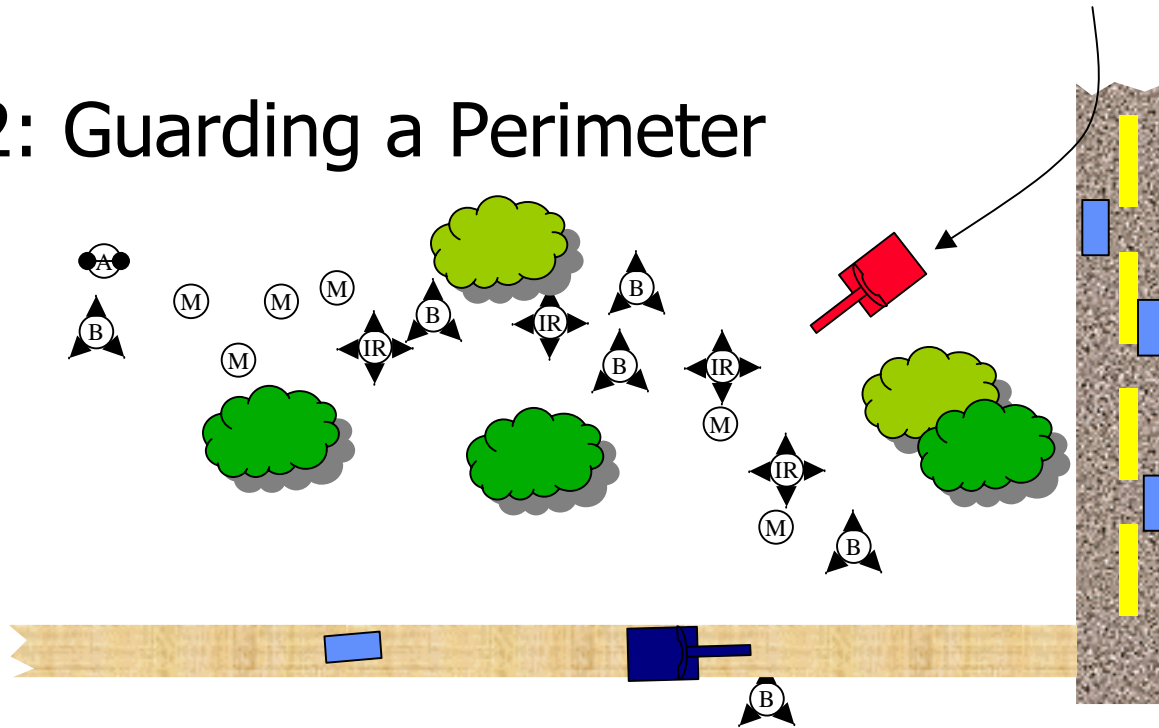
- Dwell 5 hours w/civilian vehicle transits
- Enemy column passes S-N, Const. Speed
- Simultaneous civilian transit N-S
- Image enemies, ignore civilians
- Conserve power

Hard: Civilian & Military Vehicles Maneuver

- Multi-day dwell w/civilian traffic
- Ubiquitous 2-way civilian traffic, 2 directions.
- Enemy convoys transit S-N, stopping to split and merge by side of road.
- Track & Image enemies
- Alert on arrival of TELs



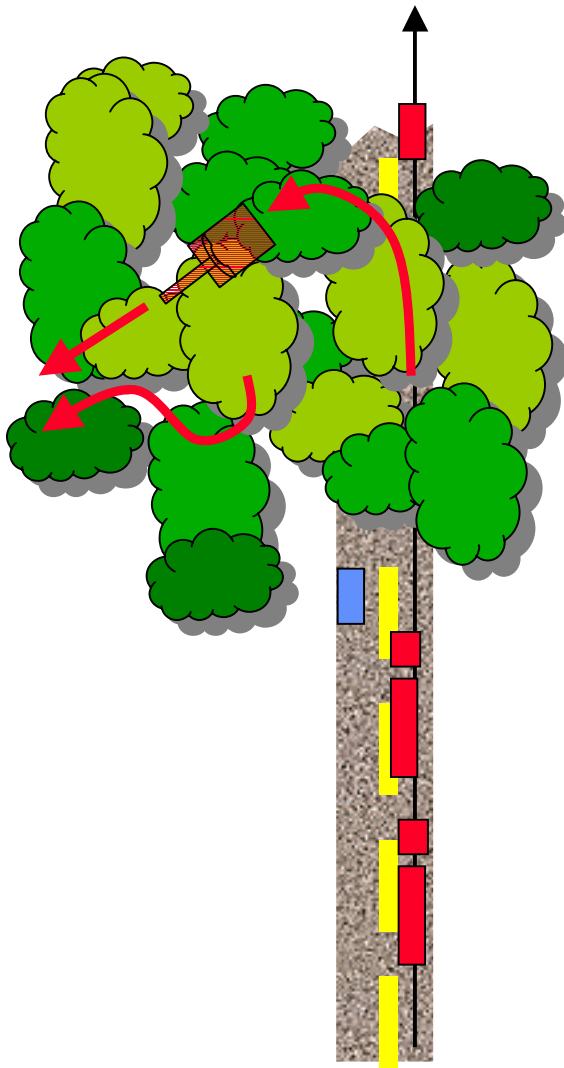
2: Guarding a Perimeter



- Monitor incoming/outgoing friendly traffic on dirt road
- Ignore Civilian traffic on main road to maintain long dwell
- Enemies may break off from main road and attempt to violate perimeter. Sound alarm.



3: Targets Under Trees



Easy

- Track vehicle under tree cover on road

Medium

- Track multiple vehicles maneuvering under tree cover

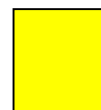
Hard

- Civilian and enemy vehicles on road
- Enemy vehicles pull off road under tree cover
- Shut off engines
- Rendezvous with pre-positioned vehicles, some leave area under cover
- How many of the original vehicles were left behind?

Combined/Canonical Scenario Mapping Matrix



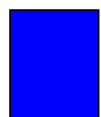
Operational Scenario ↑ Requires → Benchmark Scenario	1	2	3	4	5	6	7	8	9	10	11	12
1. Convoy Intelligence	Easy		Hard	Hard	Medium	Easy						
2: Guarding a Perimeter	Easy	Easy	Hard	Hard	Medium		Hard	Easy	Medium			
3: Targets Under Trees	Easy	Medium	Hard	Hard		Hard	Medium		Medium	Hard		
4. Large Battle	Easy	Easy	Easy	Medium	Easy	Easy	Easy		Hard		Easy	Medium



Easy version



Medium Version



Hard Version