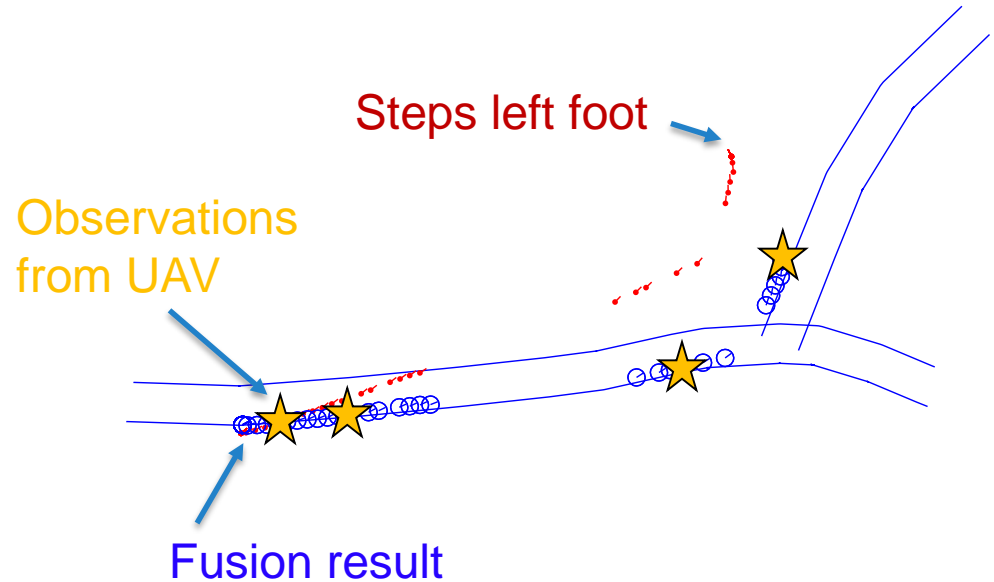


Fusion for Collaborative Navigation

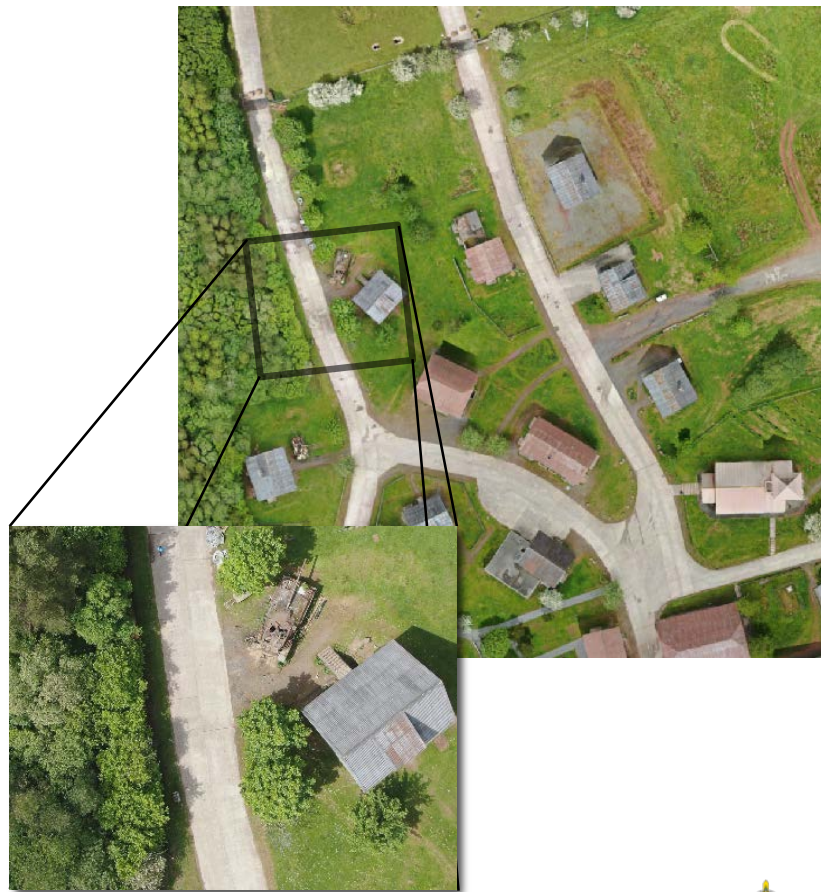
Introduction

- Ground units with foot-mounted IMUs
- UAV with camera-based navigation
- Ground units' position estimates updated when observed by UAV



UAV navigation

- Match image from onboard camera to georeferenced "map"
- Matching positions are reasonable position hypotheses
- Six degrees of freedom



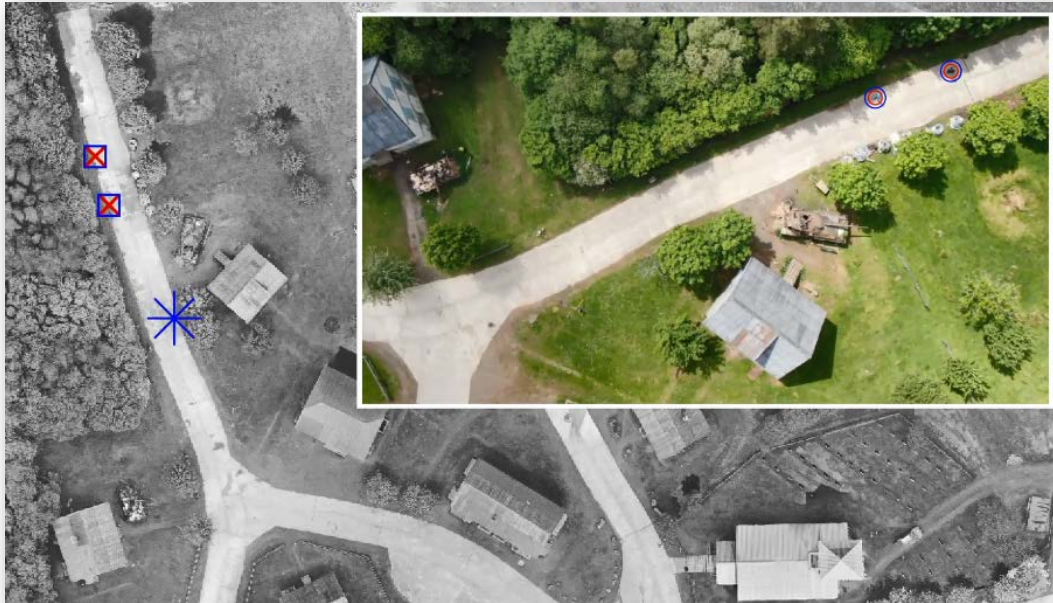
UAV navigation

- An easier problem
 - Altitude from barometer
 - Heading from magnetometer
 - Roll = pitch = 0
 - Horizontal positioning remains (2D)
- Position: image correlation
- Velocity: optical flow
- Fused in particle filter



Ground unit detection

- Moving objects detected in UAV camera images
 - Deviations in optical flow + tracking to confirm actual targets





So we have a 3D model...

- What else can we do?



So we have a 3D model...

- What else can we do?
- Estimate all 6 degrees of freedom by matching image to 3D model
- Relaxes requirement on additional sensors and camera gimbal



3D model matching

- Start at initial guess (pos+ori)
 - Find displacement field
 - Compute camera pose update
 - Iterate if needed

Camera image



Initial guess



Final estimate



Image from 3D model

Difference image

3D model matching

- Start at initial guess (pos+ori)
 - Find displacement field
 - Compute camera pose update
 - Iterate if needed
- MONST3R: miniature optical navigation system through 3D recognition – probably at SPIE Orlando 2022

Camera image



Initial guess



Final estimate

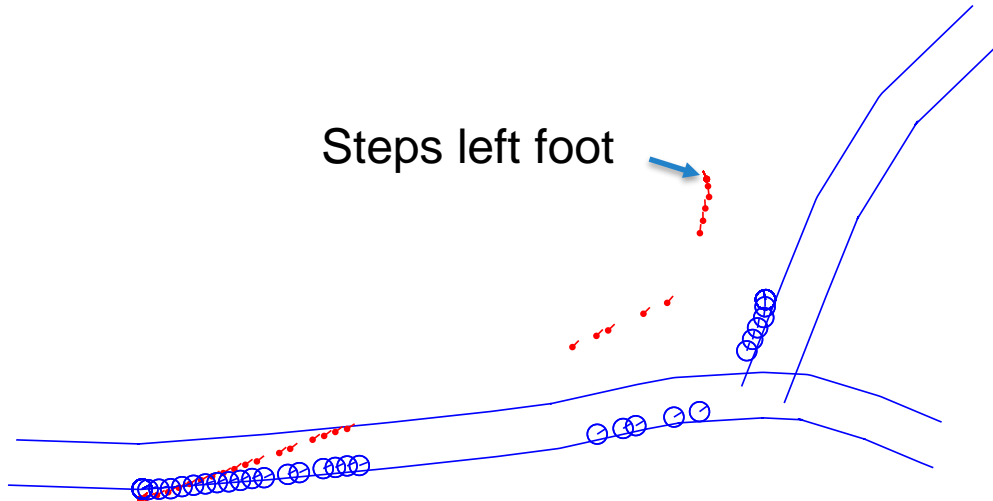


Image from 3D model

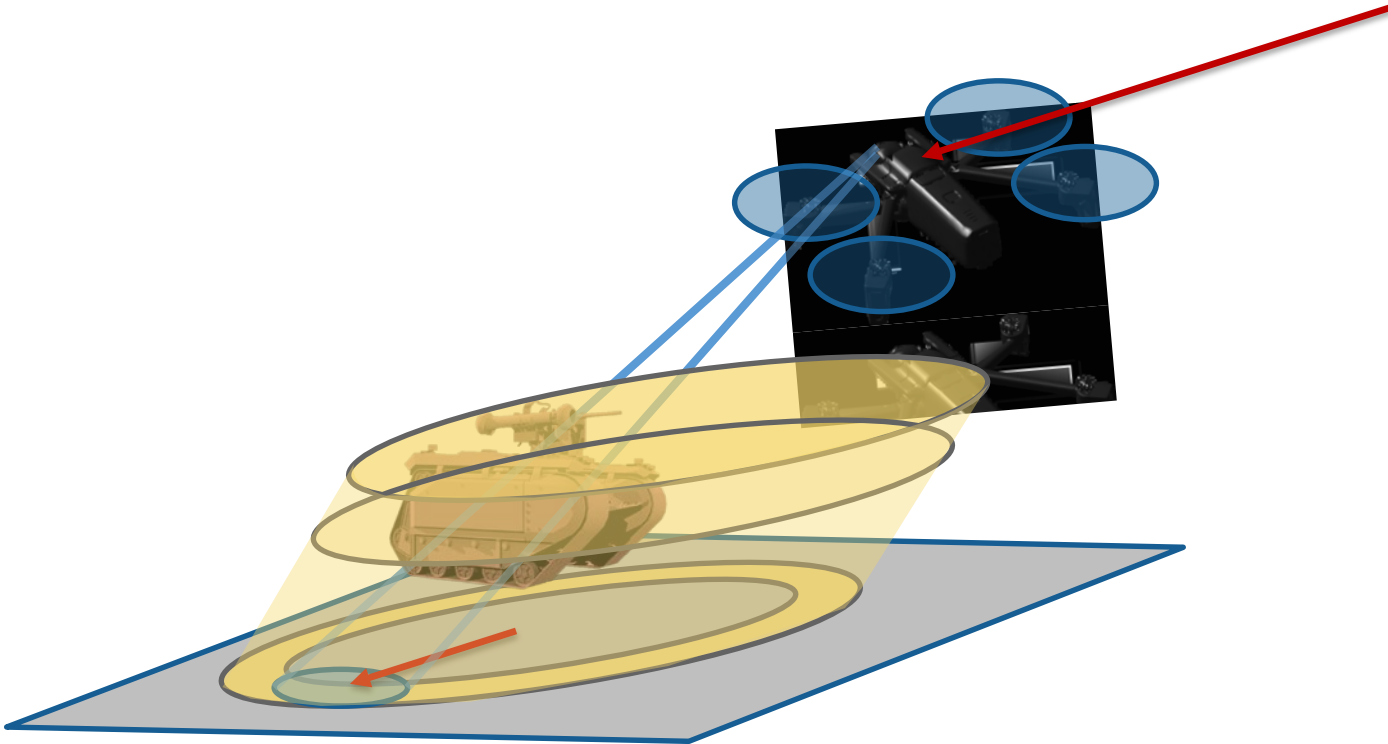
Difference image



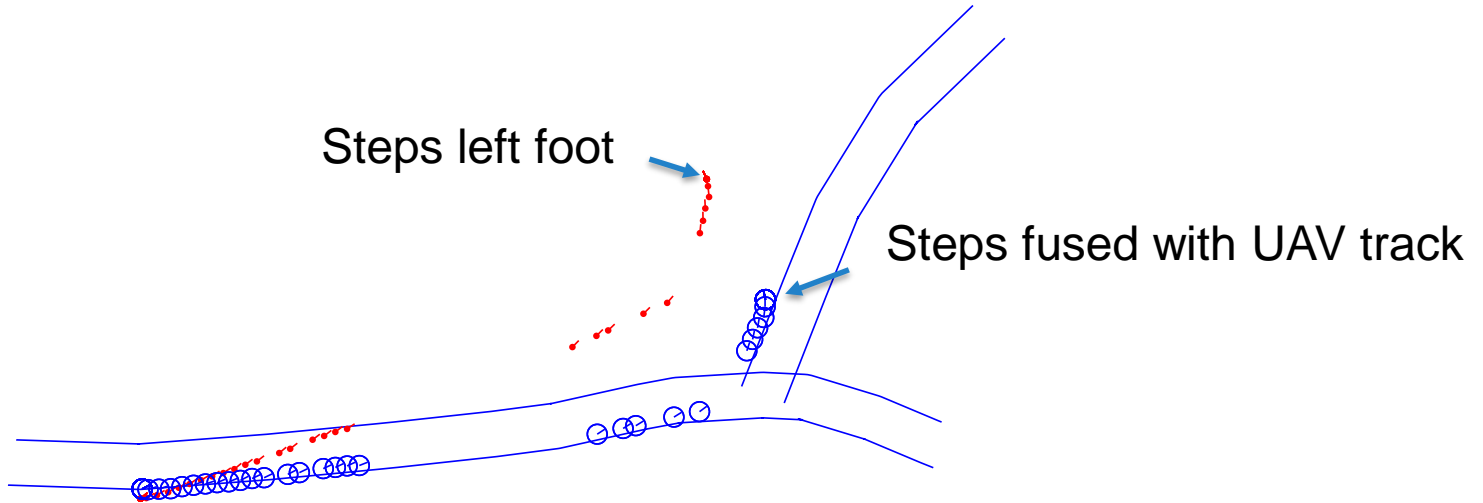
Footmounted sensor provides steps



UAV observation + navigation error



Footmounted sensor steps fused with UAS



Inverse Covariance Intersection(ICI)

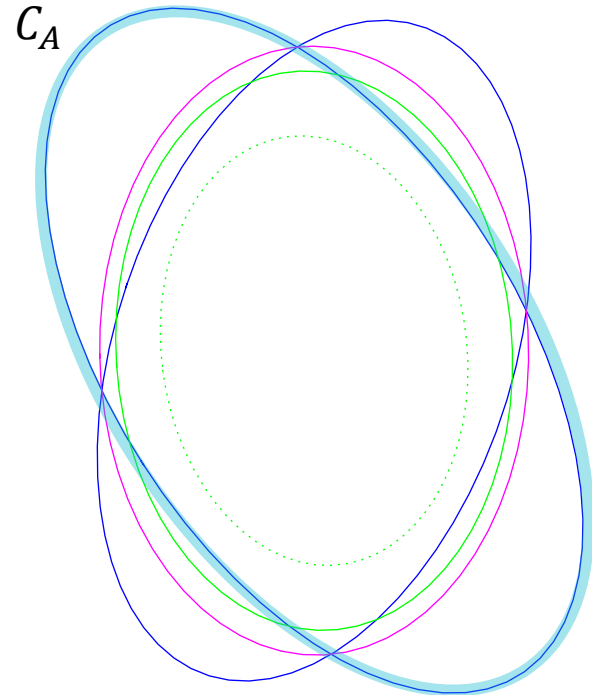
- background

- "Information" in Fisher-sense

$$I = C^{-1}$$

- Naive information fusion:

$$C^{-1} = C_A^{-1} + C_B^{-1}$$



Inverse Covariance Intersection(ICI)

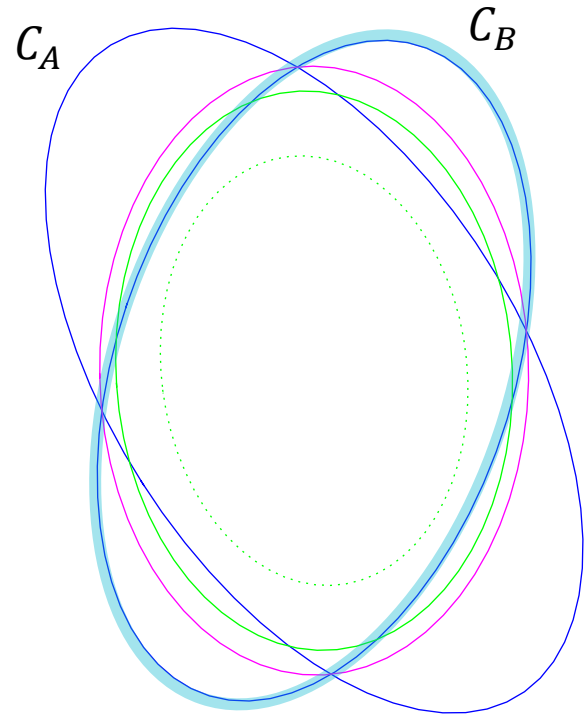
- background

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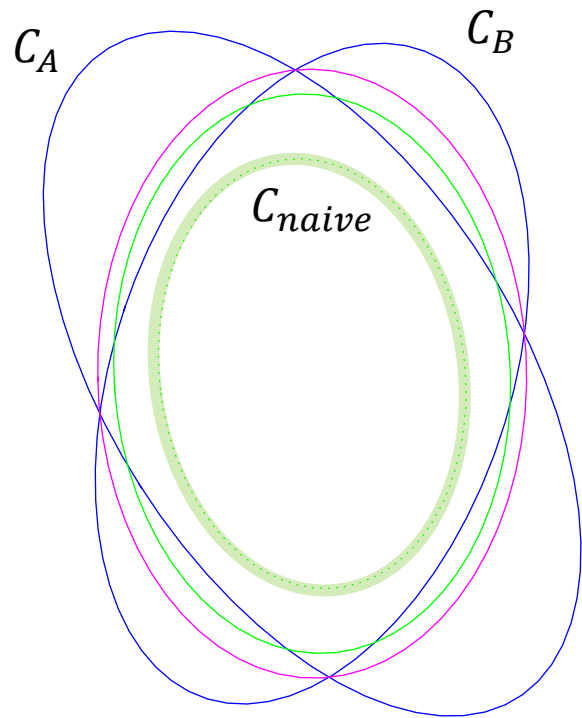
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Inverse Covariance Intersection(ICI)

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- "Information" in Fisher-sense

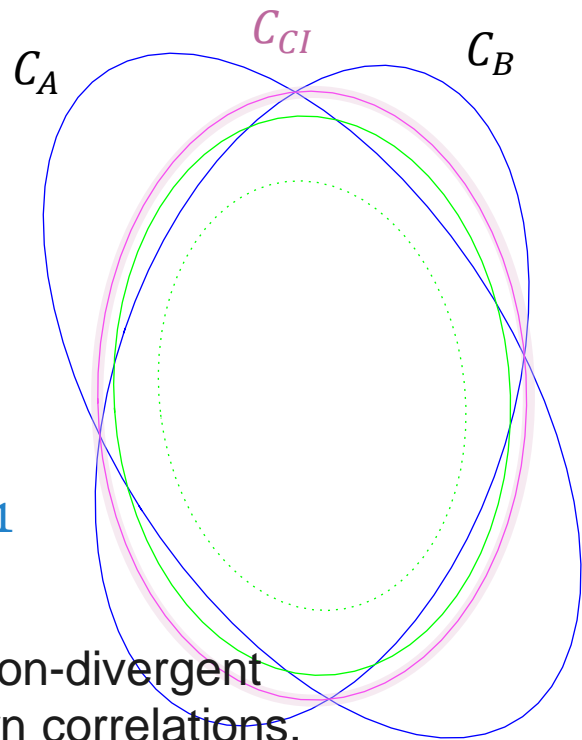
$$I = C^{-1}$$

- Naive information fusion:

$$C^{-1} = C_A^{-1} + C_B^{-1}$$

- Covariance Intersection:

$$C_{CI}^{-1} = \omega C_A^{-1} + (1 - \omega) C_B^{-1}$$



Julier, S. J., & Uhlmann, J. K. (1997, June). A non-divergent estimation algorithm in the presence of unknown correlations. In *Proceedings of the 1997 American Control Conference (Cat. No. 97CH36041)* (Vol. 4, pp. 2369-2373). IEEE.

Inverse Covariance Intersection(ICI)

- background

- "Information" in Fisher-sense

$$I = C^{-1}$$

- Naive information fusion:

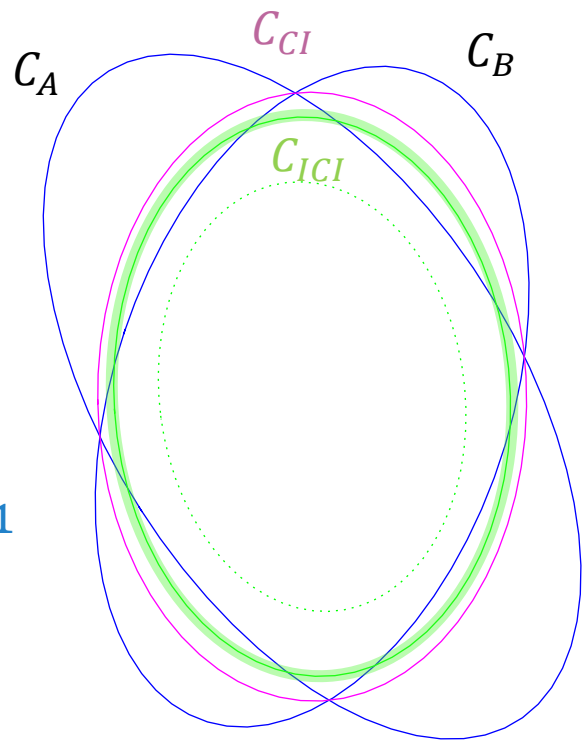
$$C^{-1} = C_A^{-1} + C_B^{-1}$$

- Covariance Intersection:

$$C_{CI}^{-1} = \omega C_A^{-1} + (1 - \omega) C_B^{-1}$$

- ICI :

$$C_{ICI}^{-1} = C_A^{-1} + C_B^{-1} - \Gamma^{-1}$$



Inverse Covariance Intersection(ICI)

- background

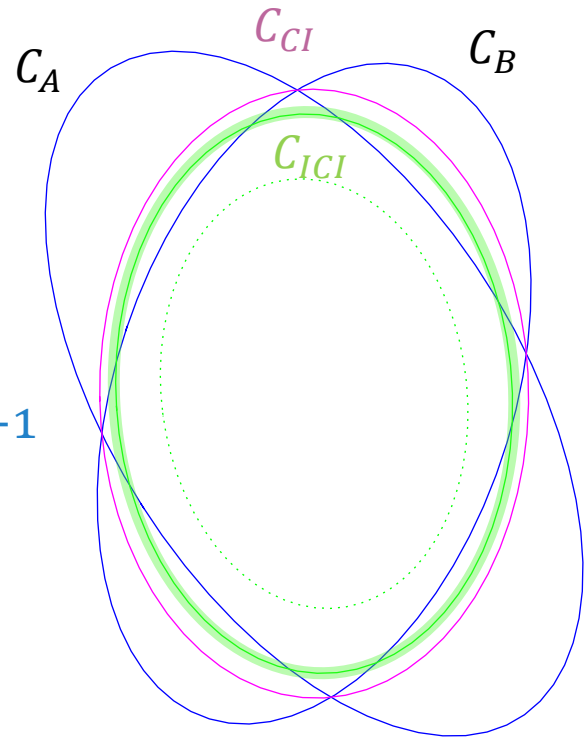
- "Information" in Fisher-sense

$$I = C^{-1}$$

- ICI :

$$C_{ICI}^{-1} = C_A^{-1} + C_B^{-1} - \Gamma^{-1}$$
$$\Gamma^{-1} \leq (\omega C_A + (1 - \omega)C_B)^{-1}$$

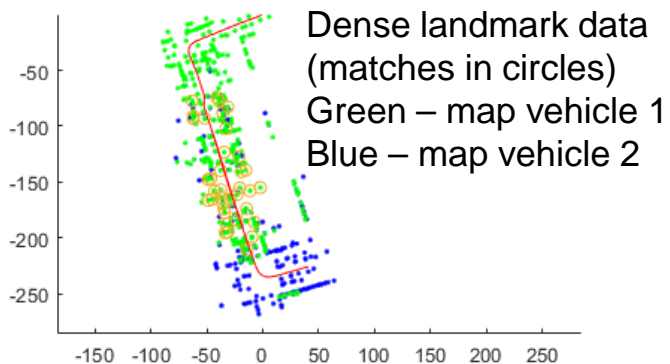
Noack, B., Sijs, J., Reinhardt, M., & Hanebeck, U. D. (2017). Decentralized data fusion with inverse covariance intersection. *Automatica*, 79, 35-41.



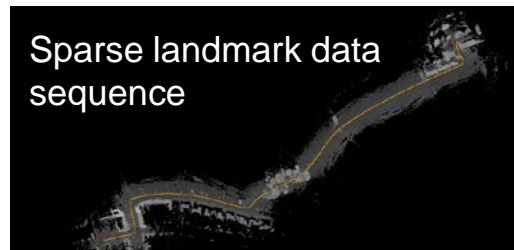
Landmark sharing

UGV launched from host vehicle
Live demo not possible in SET229

➤ Earlier collected data

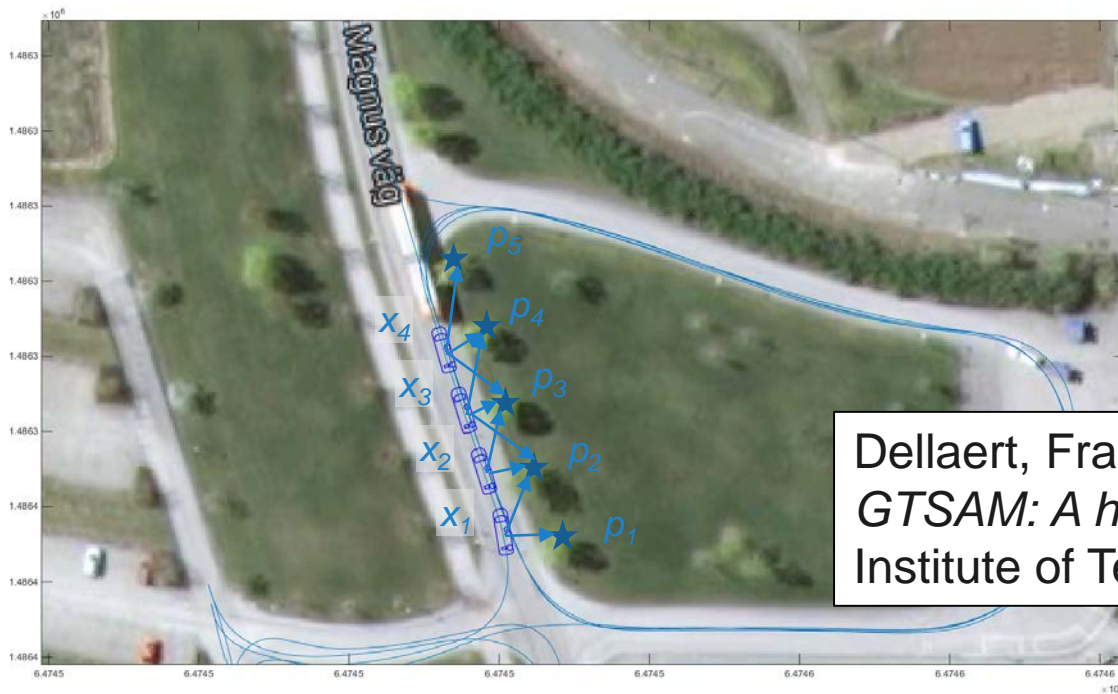


3D model ©FOI, with thanks to SENTA Range Commandant

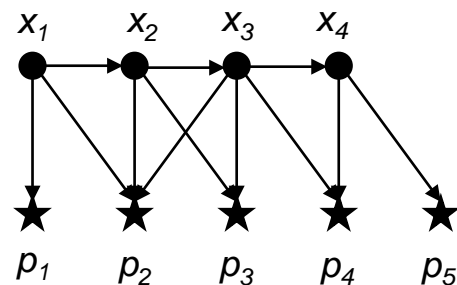


SAM smoothing and mapping

Vehicle pose & landmarks



Graph representation



Dellaert, Frank. *Factor graphs and GTSAM: A hands-on introduction*. Georgia Institute of Technology, 2012.

Collaborative navigation (IROS2008 + GTSAM 2012)

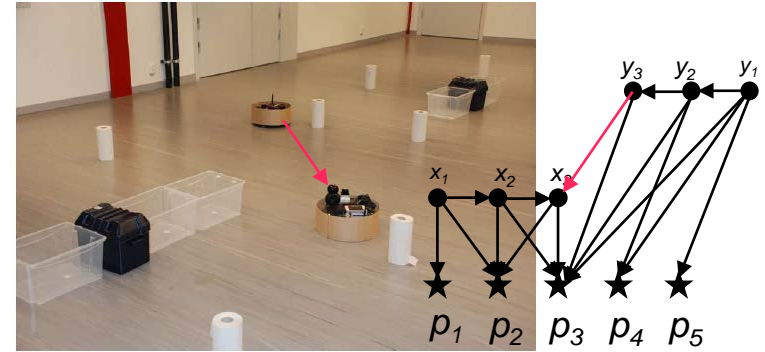
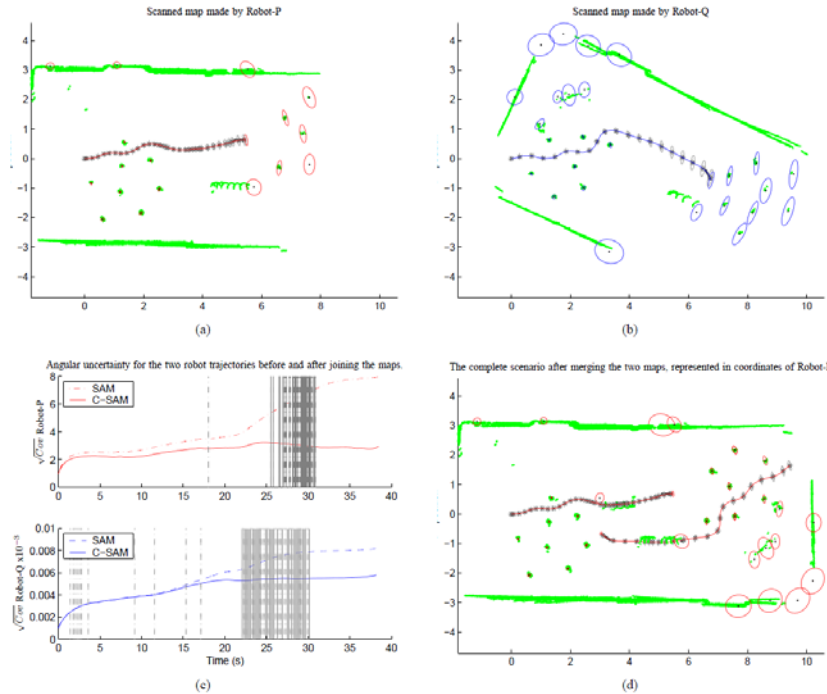


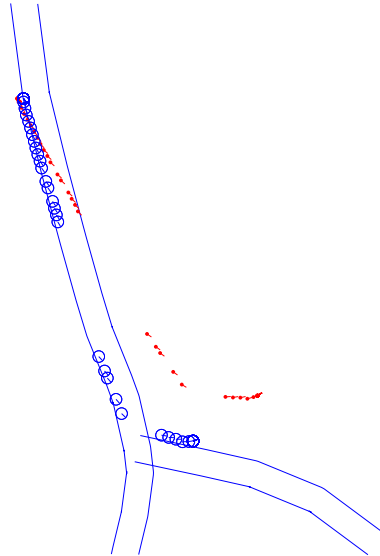
Fig. 1. Two robots meet after exploration. The individually created and linearized maps are shared and joined into one single map. The new map information is then used as a priori information as exploration continues.

“On Multi-robot Map Fusion by Inter-robot Observations”

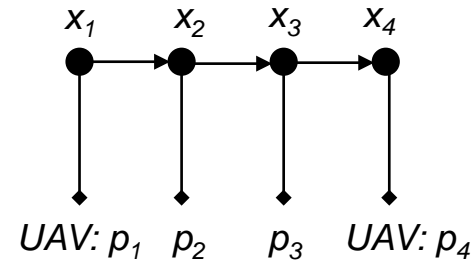
Lars A. A. Andersson & Jonas Nygård
International Conference on Intelligent
Robots and Systems (IROS) 2008

SAM smoothing and mapping

Foot pose

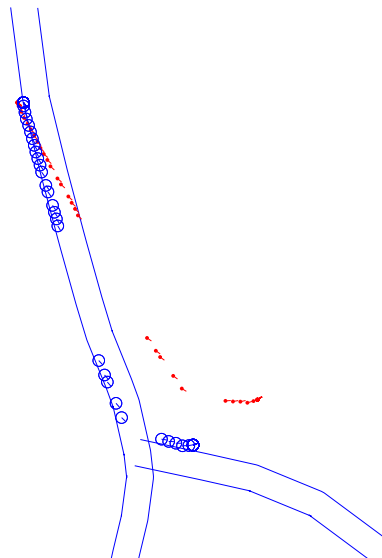


Graph representation

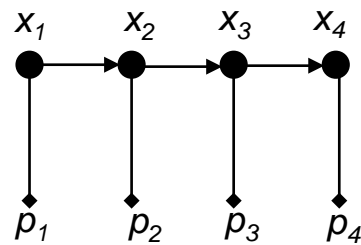


SAM smoothing and mapping & ICI update

Foot pose



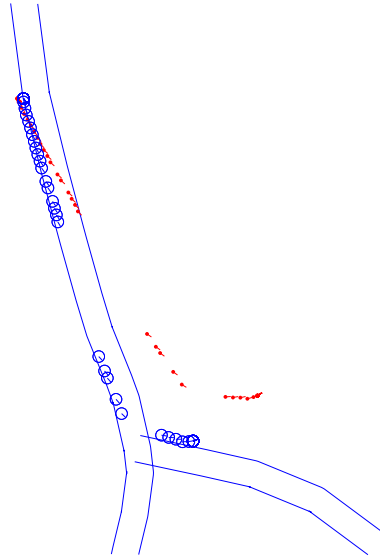
Graph representation



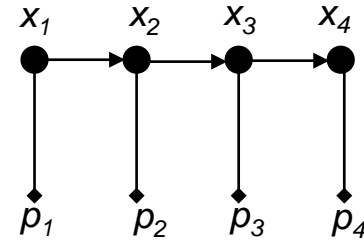
$$C_{ICI}^{-1} = C_A^{-1} + (C_B^{-1} - \Gamma^{-1})$$

SAM smoothing and mapping & ICI update

Foot pose



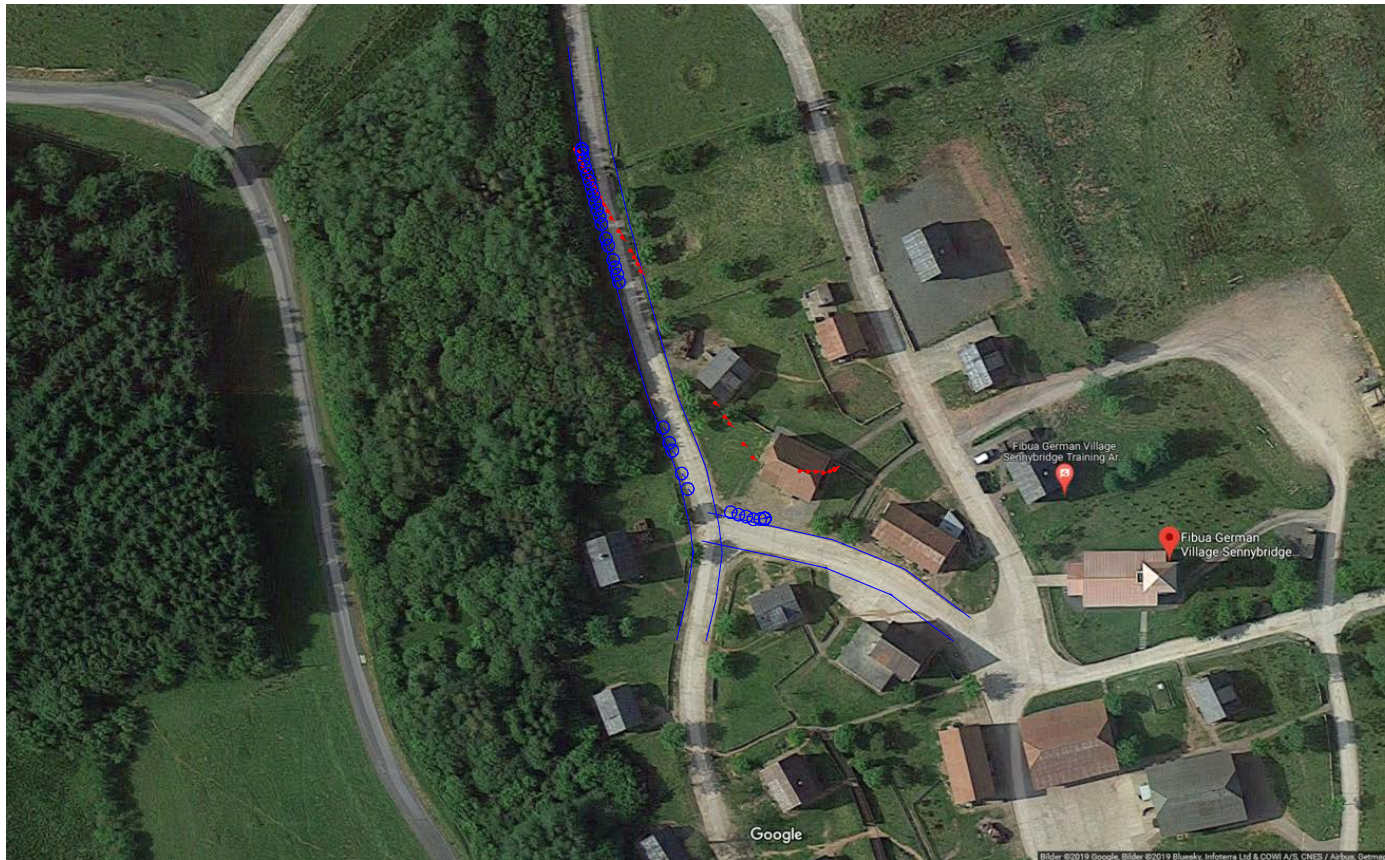
Graph representation



$$C_{ICI}^{-1} = C_A^{-1} + (C_B^{-1} - \Gamma^{-1})$$

May become negative

Results on orthophoto



Discussion & future work