Navigation in straightline surveys

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The HUGIN AUV program

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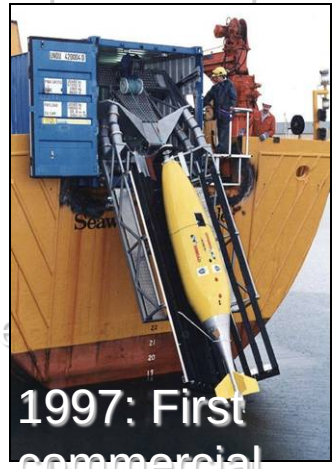
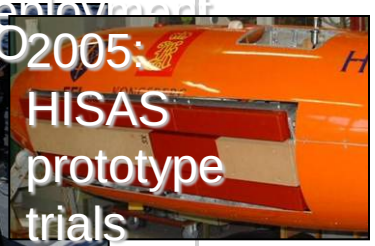
1992 1994 1996 1998 2000 2002 2004 2006 2008





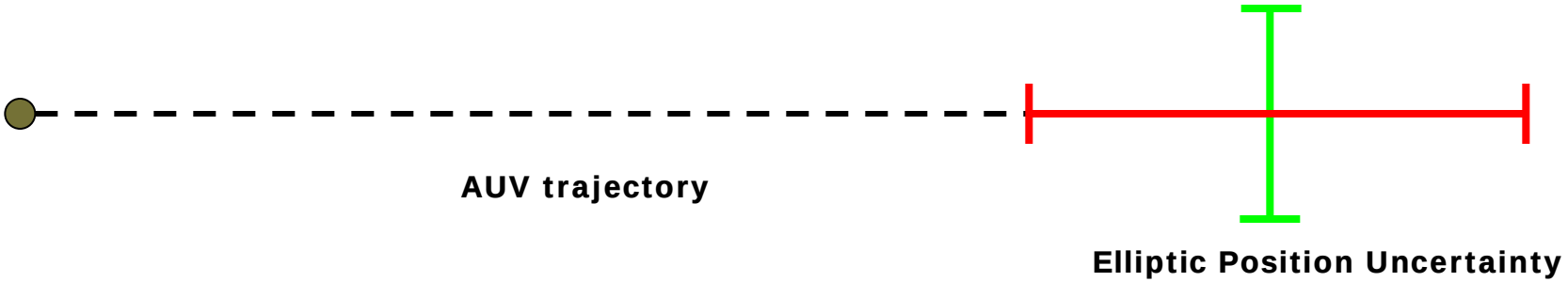
- **26 vehicles sold**
  - 18 to Navies & government agencies
  - 8 to commercial survey companies
- **10+ years of commercial operations** – Around 200,000 line km surveyed
- Participation in **30+ Navy operations** and exercises since 2001

HAIN

- Hydro acoustic Aided Inertial Navigation
- Same basic HW and SW as HUGIN's navigation system
- Used for surface and subsea vehicles
  - DP for surface vessels
  - ROVs
  - Tow fishes
- Logs all measurement for later post-processing in NavLab

The Straightline navigation problem

- Navigationally the toughest motion pattern.
  - AUV autonomous navigation is in theory a factor 10 better using lawn-mower pattern.
  - With position updates, the factor is 1-2, but still significant.

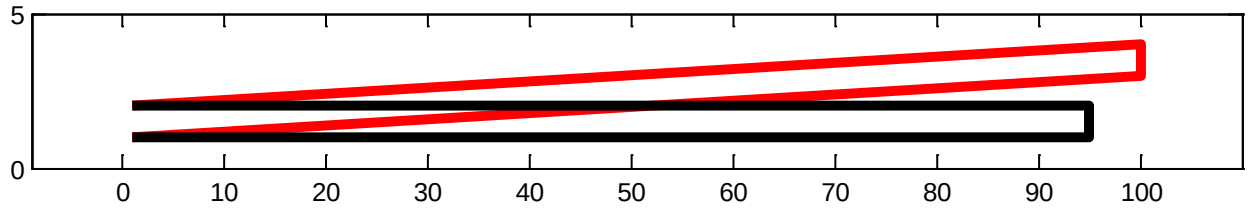


Across track position error drift: Mainly IMU induced

Along track position error drift: Mainly DVL induced

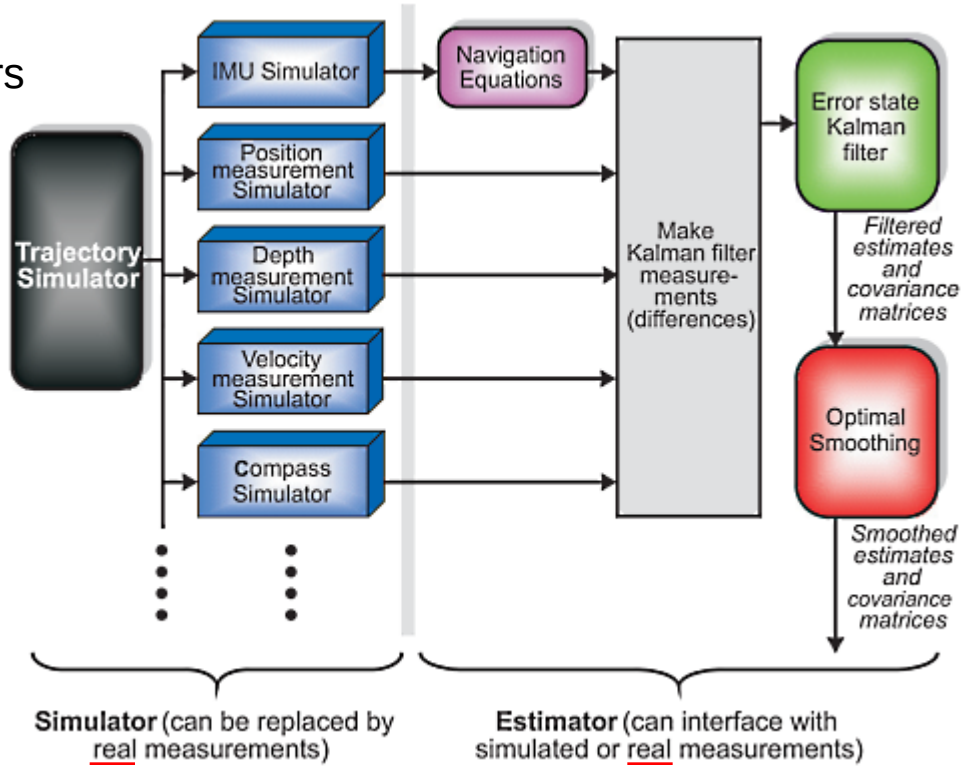
The straightline problems

- Correlations are fewer.
- Less cancelling effects.
  - Back and forth will remove a lot of errors.
- 1-way straightline is the benchmark of AUV autonomous navigation.
- Less QC
  - Less navigation sensor correlations
  - No overlapping MBE or sidescan
- BUT: Sensors tend to exhibit different behavior during turns.



Post-processing - NavLab

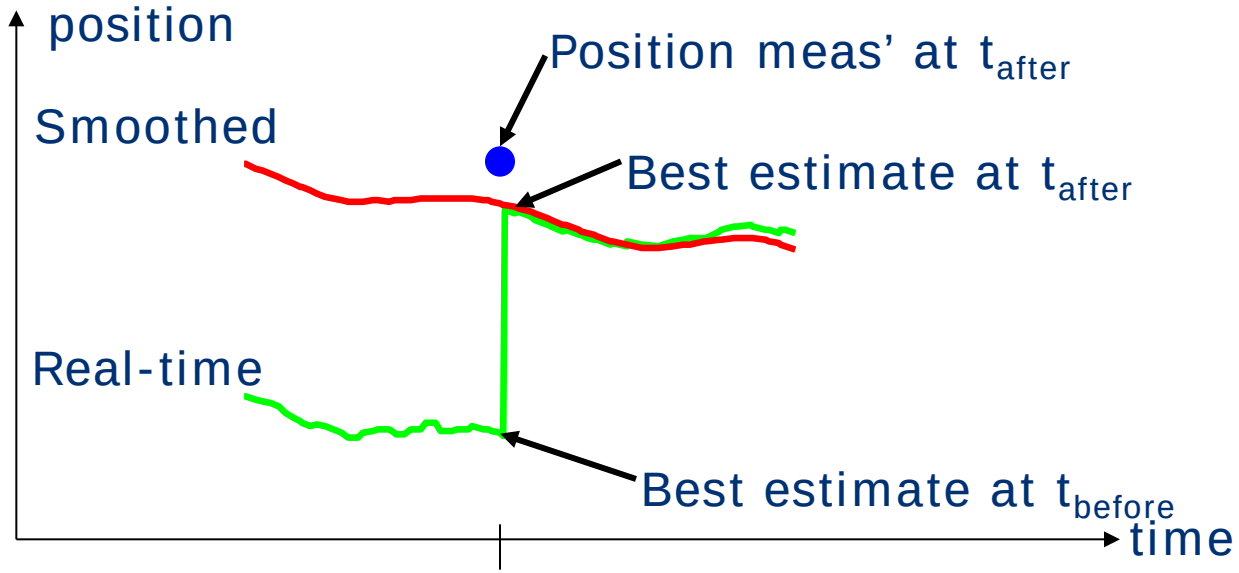
- Benefits
  - Adding additional data
  - Removing effects of faulty sensors
  - Smoother estimates
  - More accurate estimates
  - Option of manual QC
  - Improve settings
- Drawbacks
  - Not available in real-time
  - Additional man-power?



What is smoothing?

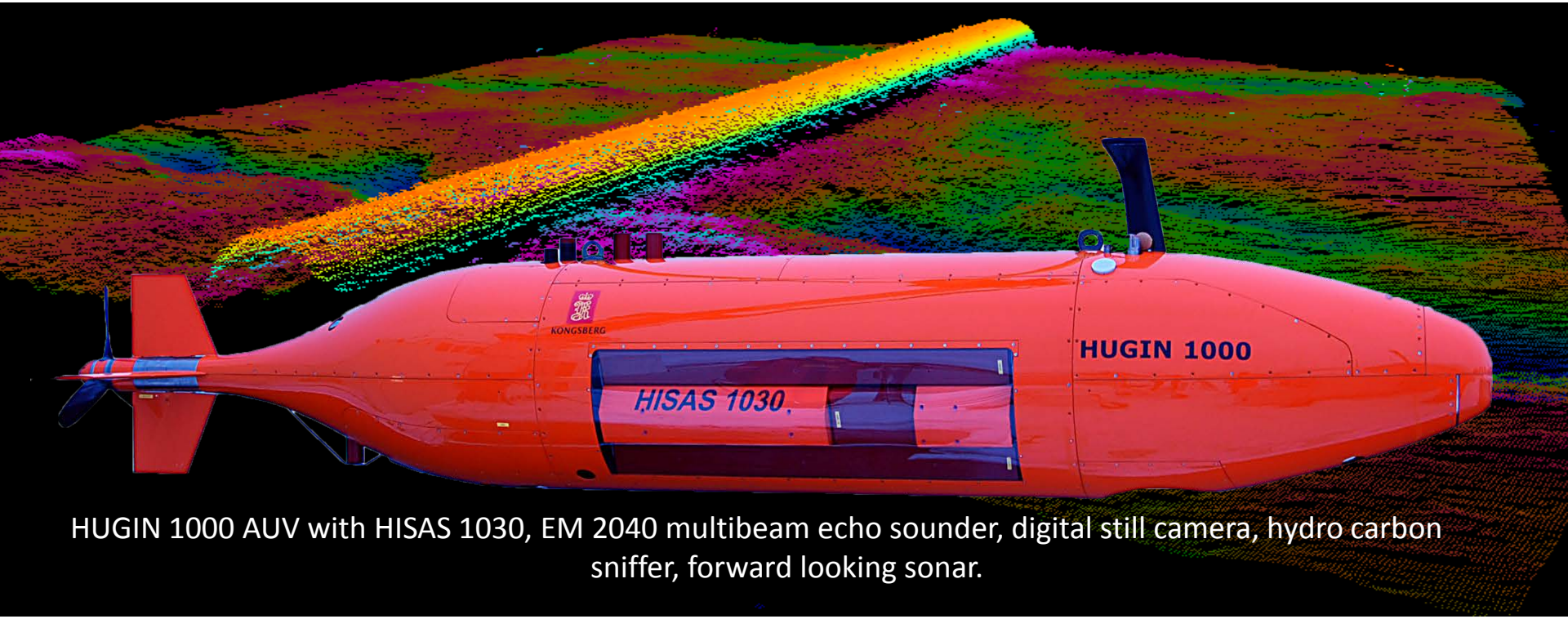
- ~~Manually create a smooth curve to fit noisy data~~ **No!**
- Post-processing
- Approach for obtaining optimal estimates of states, e.g. vehicle position, attitude, velocity, and sensor errors
- Utilizing **all** (past and future) measurements in the fusion

Example: estimating states at time t_a:



AUV pipeline inspection

- HISAS /SSS + digital still camera + multi-beam + sniffer
- One pass to the side of pipeline, one pass directly over
- Detect, track and map pipe with both HISAS/SSS and multi-beam
- Use sniffer to detect leakages
- Real time tracking: vehicle follows actual pipeline



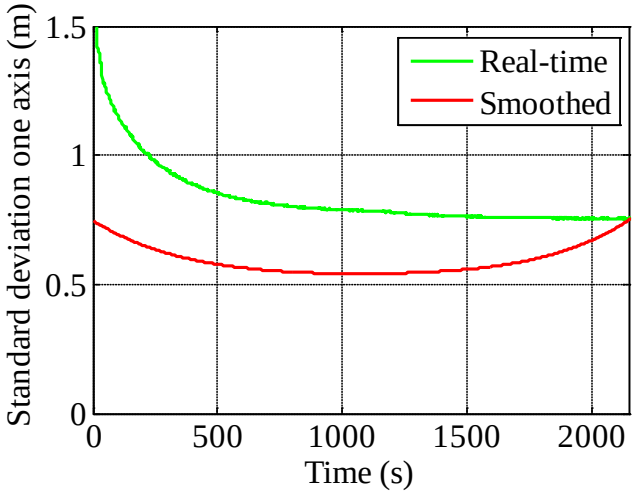
HUGIN 1000 AUV with HISAS 1030, EM 2040 multibeam echo sounder, digital still camera, hydro carbon sniffer, forward looking sonar.

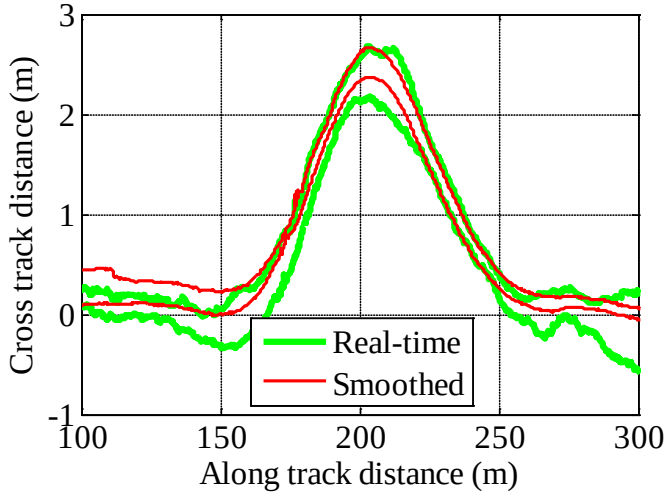
Examples HAIN

ROV validation run

- Physically following bottom mounted equipment

  $\Rightarrow$ identical route in two runs
- Depth about 1000 m
- Smoothed data show best performance
- Reported standard deviation is partially verified



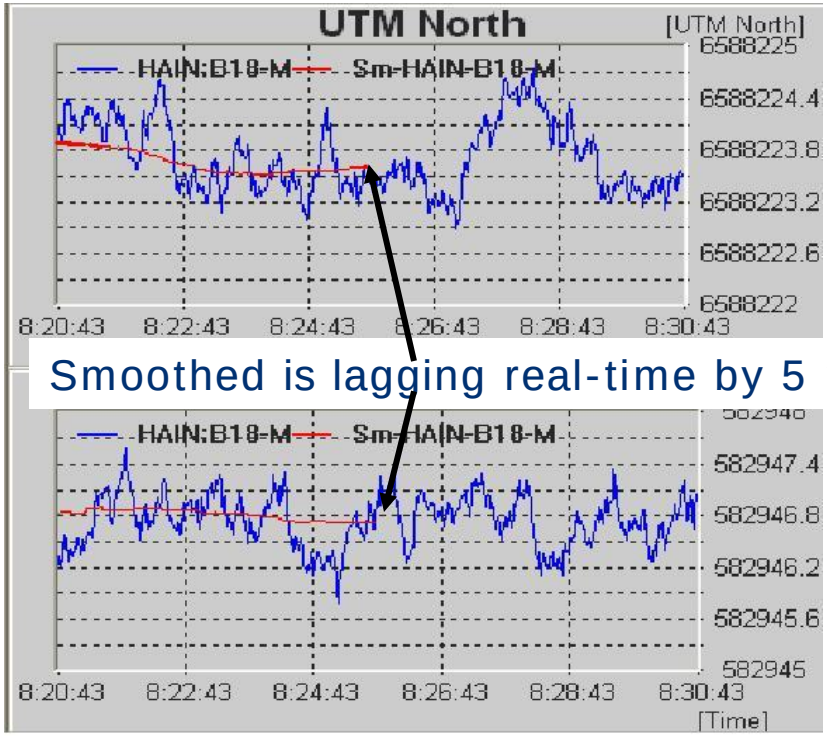


AUV vs ROV navigation

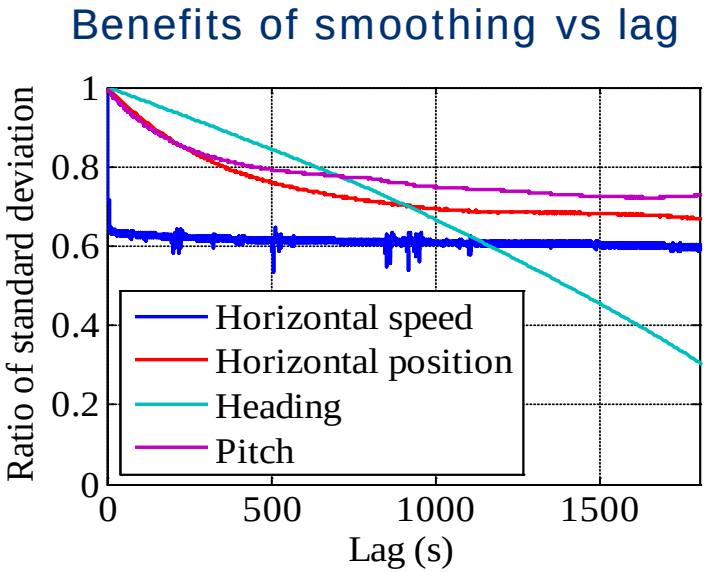
- AUVs benefits
  - Built for smooth motion and low acoustic noise resulting in better performance of acoustic sensors.
  - Sensors placed for optimal performance.
  - Navigation system factory tuned and setup is rarely changed.
- ROVs benefits
  - All navigational input available real-time
  - More variation in motion leads to observability of different errors.

- NOTE:
  Navigation system is the same
  - Sensor performance may differ cause of vehicle
  - Vehicle model may be used for added QC

Pseudo real-time smoothing in HAIN



Smoothed is lagging real-time by 5 mins



- HAIN produces smoothed values at a given lag of real time
- Little improvement when lag reaches 500-1000 s
- Heading takes a long time to settle completely

HAIN Demo

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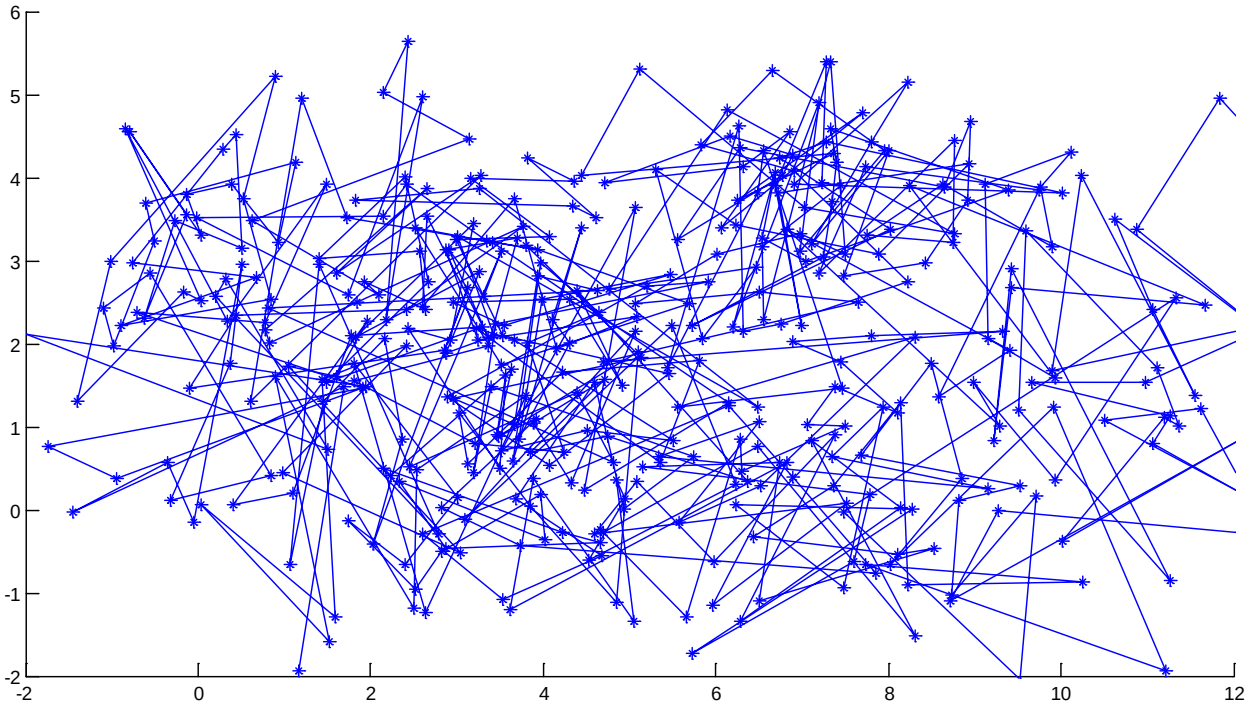

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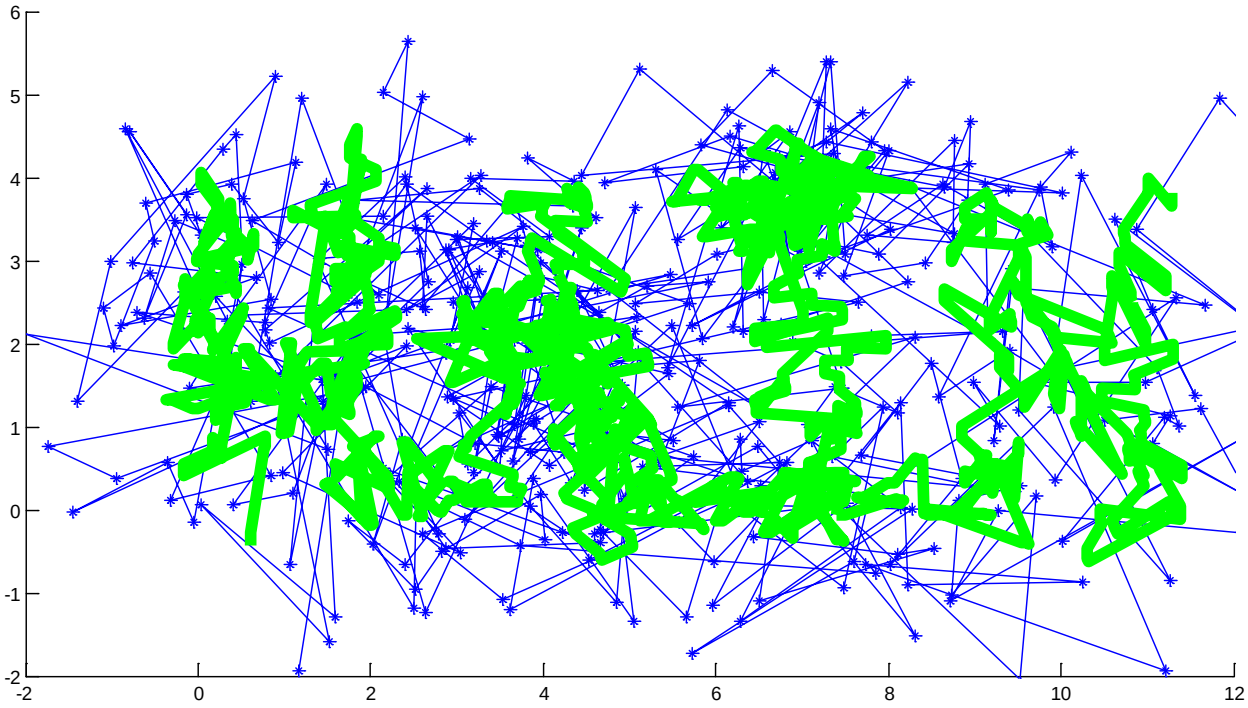

HAIN Demo

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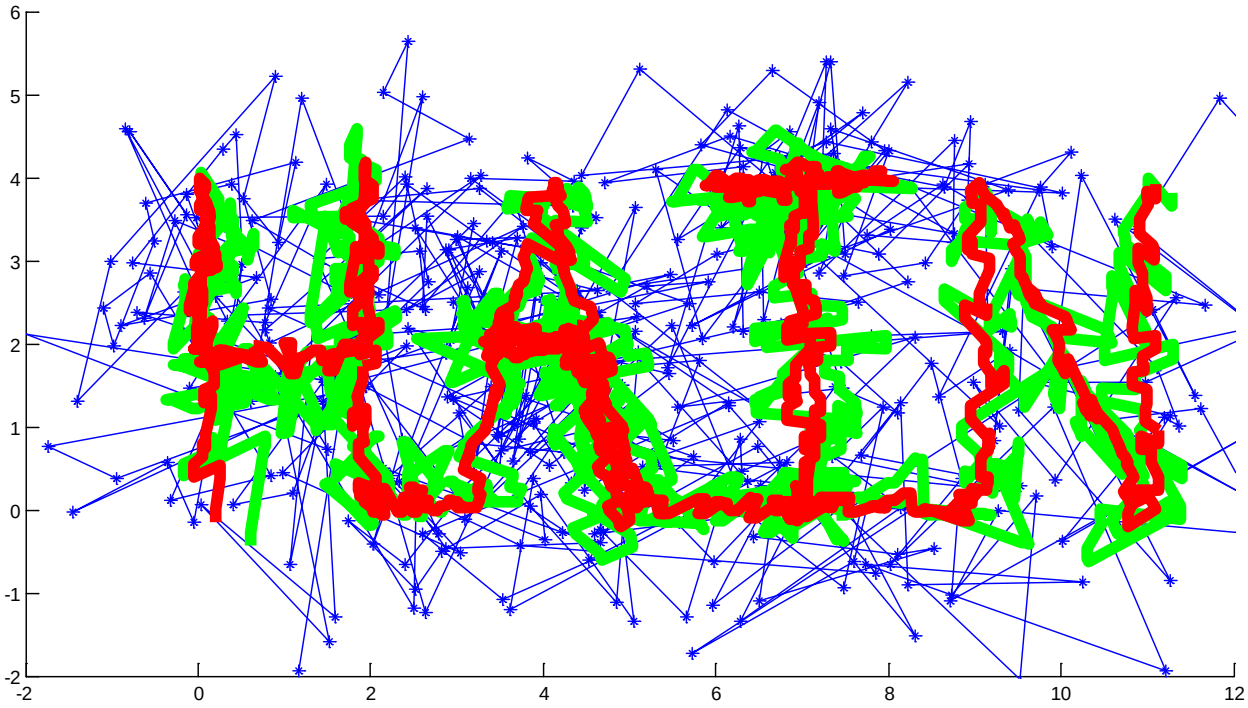

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