Session Architectures for Collaborative Orbit Determination using Ground Station Networks

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May 2, 2018
Initial acquisition with cluster launches is difficult

- There is increased access to space - cluster launches and TLE Lottery
- We can construct Autonomous Ground Station Networks (AGSNs).
- Initial acquisition through Doppler based OD.
- Deep space orbit determination
An ML Algorithm to do OD

- Orbital parameters $\Gamma$
- Uncertainty distribution $P_\Gamma$
- Observation interval $\mathcal{T}$
- Observed by ground station network
- Machine Learning Algorithm to estimate orbits $^1$

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$^1$Sharma et. al IPNPR 2015
Can a practical GSN satisfy Algorithmic Conditions?

The machine learning algorithm requires some conditions to be met

- Guaranteed observation of samples of any orbit from uncertainty distribution
- Observability
- Continuity of map
Spectrum analysis in a GS

Autonomous Software Ground Station

(Sharma, Cutler, 2018)
The global network has a learning cluster
We can integrate OD into GSN Sessions

- GSNs work by reserving nodes (ground stations) through sessions.

- Orbit determination will be done inside of an “ODTrack Session”.

- The ODTrack Session is a group of GS Sessions.
The learning cluster determines the OD session

• Learning Cluster samples the uncertainty distribution.
• Selects ground stations based on visibility.
• Coordinated antenna pointing.
Best explained by an example scenario

A simple model of random deployment

Samples of initial state deployment

(Sharma, Cutler, 2018)
Intervals of uncertain passes

- Break down OD into intervals of observation
- One pointing direction per interval

Wellington Doppler distribution has pass intervals

Wellington azimuth elevation distribution has bands
Point at the expected zero Doppler point

Collect zero Doppler time points

- Antenna is approximated as a cone (cone angle: 3dB beamwidth)
- Antenna will point to the expected value of the azimuth elevation distribution

(Azim., elev.) probability of zero Doppler

Antenna cone points along expected AzEl

(Sharma, Cutler, 2018)
A Pointing Profile

- Training Data is limited to learning with the profile information
- Profile + Interval information is sent to ASGS
- ODTrack Session is reserved for interval periods
- ASGS points antennas and examines spectrum during ODTrack intervals

Azimuth and elevation of pruned training data

(Sharma, Cutler, 2018)
Simulated Scenario

- Total Uncertainty in initial position of satellites: 863 km
- Observation Interval: 6 hours
- Deployment Interval: 200s
- Average Separation at initial state: 36km
- Noise in Doppler shift estimation: $2.5\% \Delta f_{maxDoppler}$
- Synchronization error between Ground stations: $\leq 1ms$
- Probability of transmission = 0.08 (1 in 10 seconds)
Results

Average error in initial position estimation: 21.44km

Histogram of position error

Histogram of velocity error
Conclusion and Future Work

- ODTrack Session Architecture for GSNs
- Algorithms for session instantiation for OD
- Coordinated Pointing Profiles for GSNs

Future Work

- Multiple antenna ground station nodes
- Integrating Learning with independent RADAR and Ground station based Doppler observations
Thanks
References