AstroFingertip

Real-time Conjunction Assessment with Collision Probability and Miss Distance in SPACEMAP

2023 KSAS Spring Conference (Ramada Plaza Hotel in Jeju)

2023. 4. 20

Peter Ryu[13], Shawn Choi[123], C. Song[23], H. Kim[23], J. Jang[23], M. Ji[23],
John Kim[1], Lowell Kim[1], Douglas Deok-Soo Kim[123*]

SpaceMap INC. [1], Hanyang University[2] ,
Voronoi Diagram Research Center[3]

Safety & Efficiency in Space

1. Always important (since 1957)

2. Situation changes
   I. Big data → Bigger data
      ✓ Catalogue size : $O(10^4)$ → $O(10^6)$
         - #Satellites & #Launches ↑
         - Sensor capability (i.e., Sensing granularity)
         - Sensing medium: Optical, Radar, Laser, & Passive EM
         - Sensor location: Ground-based → (Ground + Space)-based

   II. Hard problems → Harder problems
      ✓ CA/COLA → Optimization problems + Intelligence problems

Mission of SpaceMap

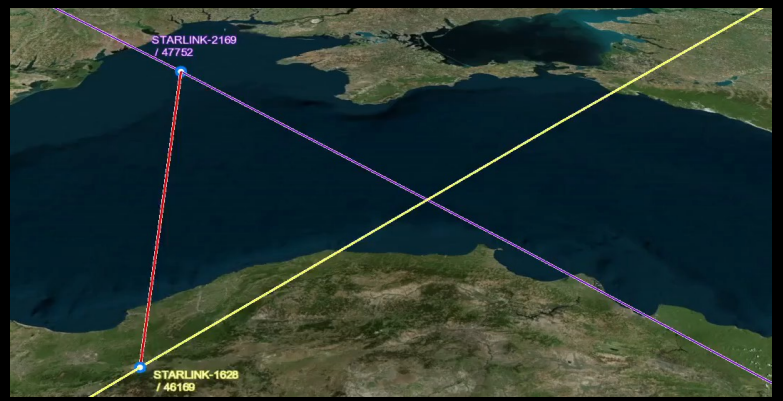
We aim to provide a real-time decision-making platform
of the best-possible solutions
for safe and efficient use of space assets.

Conjunction Assessment

‘Safety’ : Real-time CA/COLA (Conj. Assess./Coll. Avoid.)

- (Example) Find the closest two LEO RSOs tomorrow (24h)

Company	Response Time	Cost	비고
SPACEMAP	< 1 sec	Low/Free	Easy to use
Competition	Minutes to hours	Expensive	Hard to use



Red: Approachig; Green: Going away

STK : >3hours, >$300K/copy
Leo Labs : O($5K) / (sat * month)
Spire : More expensive

Launch CA & Launch Optimization

Will anyone hit my launch vehicle tomorrow?
Find the safest ToL in the 9:00 - 12:00 window tomorrow morning.

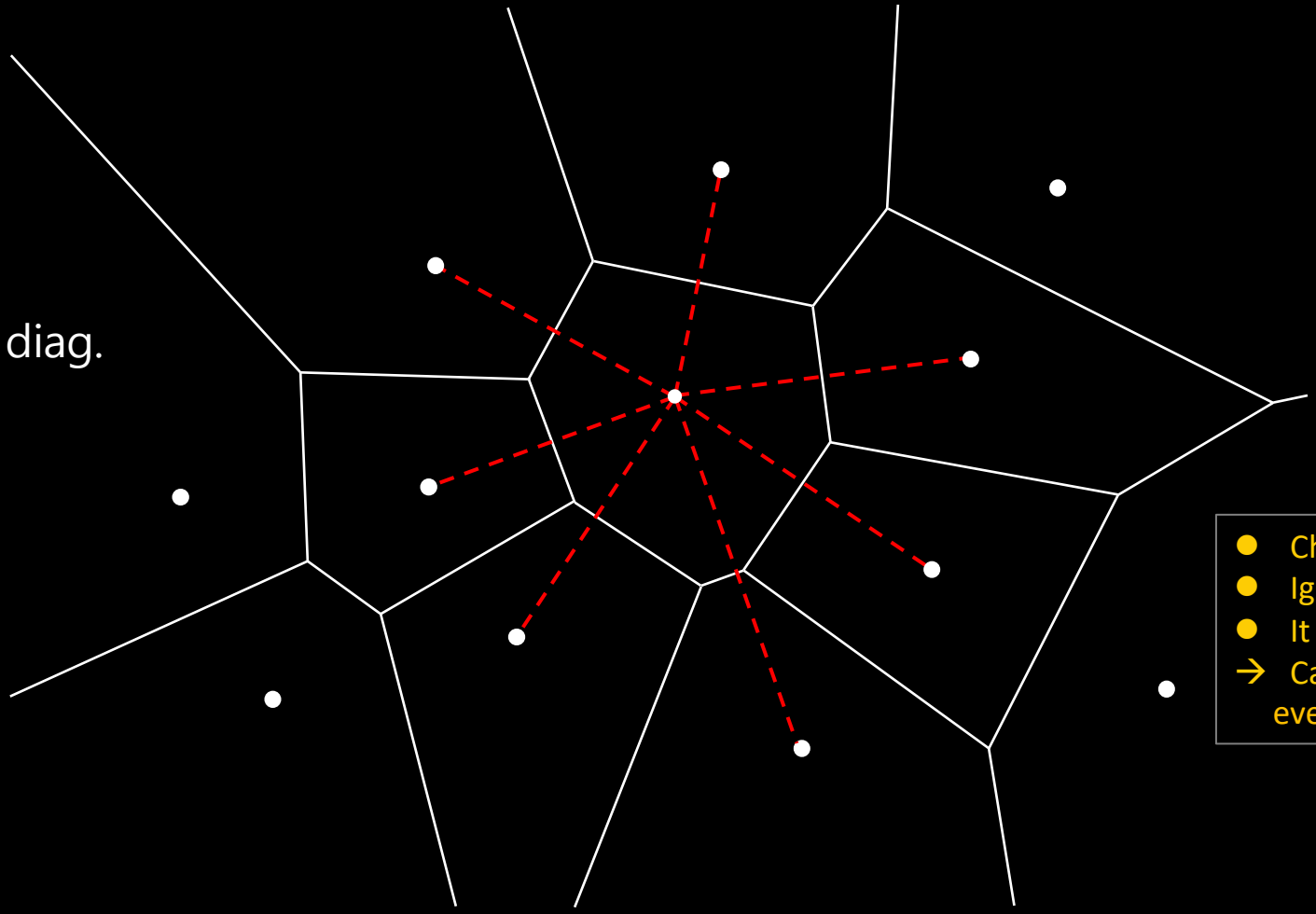
Yellow curves: Launch trajectory
Red line: Approaching
Green line: Going away
ToL: Time of Launch
Screen capture from SPACEMAP

Near Real-time & Very Fast

Voronoi Diagram

Voronoi is a powerful tool for spatial reasoning!

- Input : points
- Output : Voronoi diag.



- Check only Voronoi neighbors.
- Ignore farther neighbors.
- It takes O(N) time.

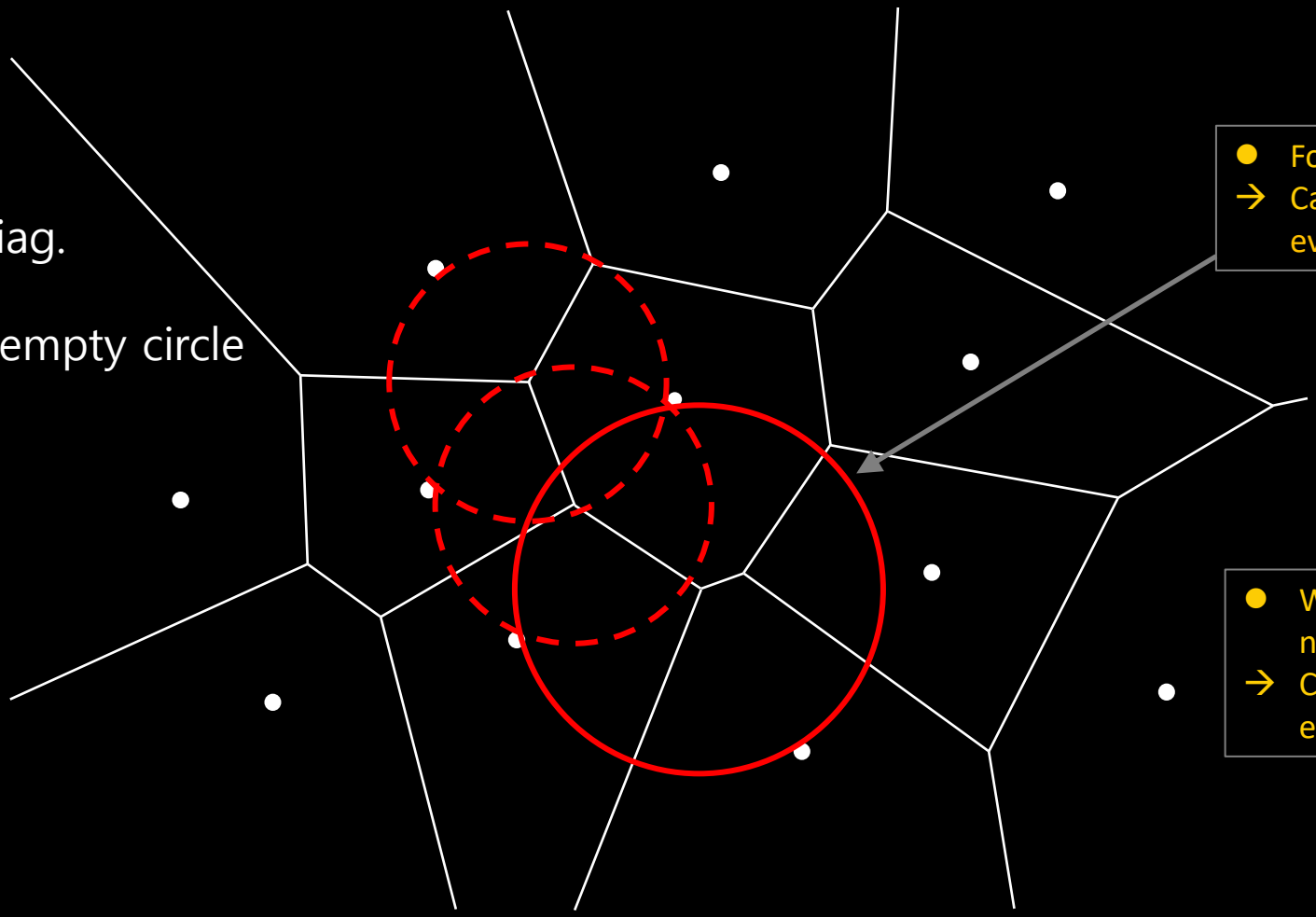
→ Can be computed in real time even for a large N (N: # points).

(Nearest Neighbor)

Voronoi Diagram

Visit N neighbors in real time.

- Input : Voronoi diag.
- Output : biggest empty circle



- Found in O(N) time.
→ Can be computed in real time even for a large N (N: # points).

- Without Voronoi, $O(N^4)$ time necessary.
→ Cannot be computed in real time even for a moderate-sized N.

(Biggest Empty Circle)

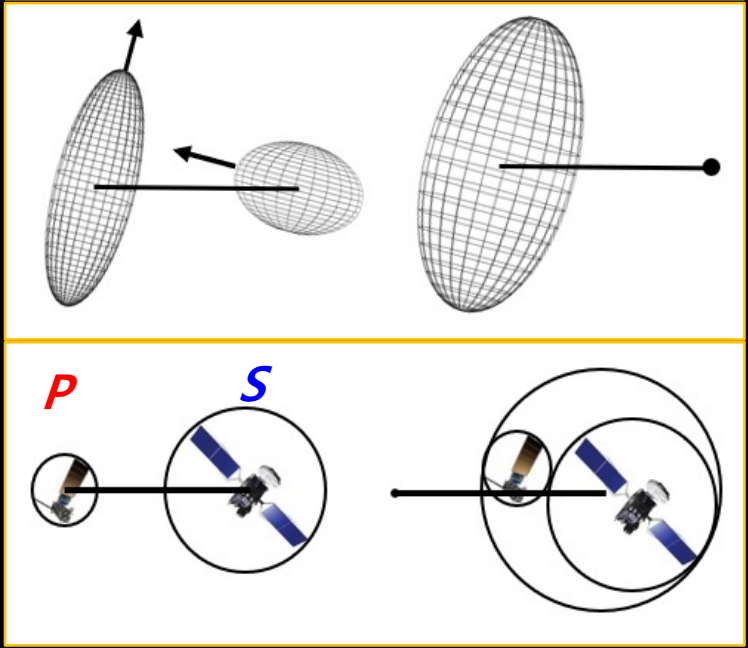
Collision Probability (Pc)

1. Modeling approaches
   - ✓ Kinetic theory of gases
   - ✓ Relative position of two objects (F. K. Chan, 2008)
   - ✓ Monte Carlo simulation

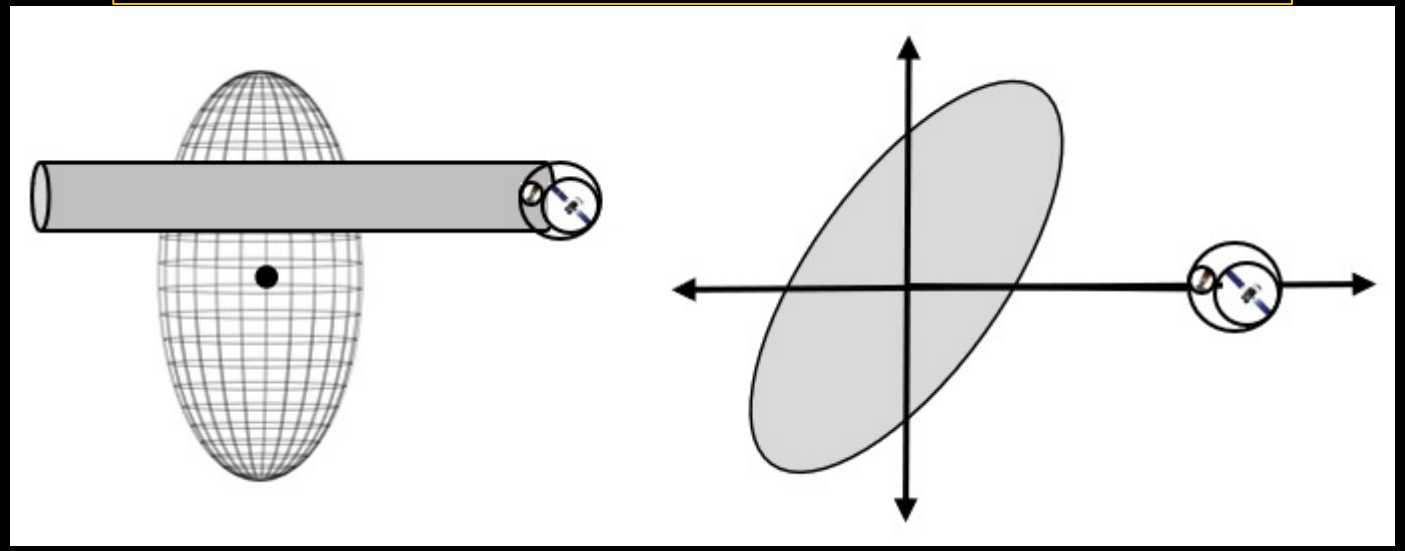
2. Relative position approach
   - ✓ Short-term encounter (2D Pc, Foster & Estes, 1992)
   - ✓ Long-term encounter (3D Pc, Hall 2021)

Collision Probability

(Primary, Secondary) at TCA
- Positional Covariance
- Object Size



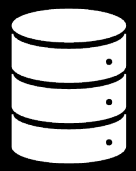
$$P_C = \frac{1}{\sqrt{(2\pi)^2|C^*|}} \iint_A \exp\left(-\frac{1}{2}\vec{r}^T C^{*-1}\vec{r}\right) dXdZ$$



NASA/CNES Short Course Note (2022)

CARA (Conjunction Assessment Risk Analysis)

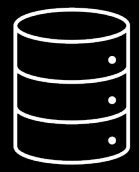
1. Software tools developed by NASA
2. Collision probability (e.g. Foster & Estes, 1992)
3. MATLAB code available @
   - ✓ github.com/nasa/CARA_Analysis_Tools.git



TLE (space-track)

Positional Covariance

github.com/AleksanderLidtke/ConjunctionDetection.git



DISCOS (ESA)
NASA ???

Object Size

https://discosweb.esoc.esa.int/

CARA

Osweiler (2006)

Example1:
Search Conjunctions


```
{
    "total_count": 75,
    "current_count": 75,
    "conjunctions": [
        {
            "created_at": "2023-04-19T12:00:00.000Z",
            "primary_id": 39227,
            "primary_name": "KOMPSAT 5",
            "secondary_id": 47358,
            "secondary_name": "STARLINK-2055",
            "dca": 7.266,
            "tca": "2023-04-18T09:51:42.271Z",
            "probability": "N/A"
        },
        {
            "created_at": "2023-04-19T12:00:00.000Z",
            "primary_id": 39227,
            "primary_name": "KOMPSAT 5",
            "secondary_id": 47358,
            "secondary_name": "STARLINK-2055",
            "dca": 7.692,
            "tca": "2023-04-18T11:27:23.672Z",
            "probability": "1.876e-13"
        },
```

Example1: Search Conjunctions

```python
import astrolibrary
from astrolibrary.data.constellation import Constellation

if __name__ == "__main__":
    # create an astrolibrary client named ROK_airforce
    ROK_airforce = astrolibrary.Client('input your accees token!')

    # call api with default parameters
    result = ROK_airforce.conjunction_API.search_conjunctions()
    print(result)

    # <class 'astrolibrary.data.conjunction.Conjunction'>
    print(type(result.conjunctions[0]))

    # An error occurs because conjunction result is not a dictionary type
    # print(result['conjunctions'][0]['p_id'])    # error code
    print(result.conjunctions[0].primary_id)  # success code

    # How to call an API with differenet parameters
    result2 = ROK_airforce.conjunction_API.search_conjunctions(
        limit=5, page=10, sort="dca"
    )
    print(result2)

    # How to search for a specific space object you want
    result3 = ROK_airforce.conjunction_API.search_conjunctions(
        limit=10, sort="tca", norad_id_or_name="starlink"
    )
    print(result3)

    # API to find a conjunction between a specific satellite and satellite constellation
    result4 = ROK_airforce.conjunction_API.search_conjunctions_by_target_object(
        target_norad_id=39227, constellation=Constellation.STARLINK
    )
    print(result4)
```

① ②

1. Create client class instance

- Copy your access token from the platform website
- Use the copied token to create a client. In the example on the right, a client named ROK_airforce is created.

2. Call get conjunctions API

- Call search conjunctions API with default parameters.
- As shown in the previous slide, the output is in JSON format but the actual data type is a conjunction class.
- You can use the API in various ways, such as specifying the limit and page, selecting a sorting method, and designating the target space object.

AstroFingertip – Why?

CA @ your fingertip!

Information at your fingertip (COMDEX, 1994)

Try us @ spacemap42.com

Thank You!

peter.ryu@spacemap42.com
douglas.kim@spacemap42.com