Development of Optimal Mission Scheduling Algorithm for Spotlight Mode based on Mechanical Beam Steering

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Introduction

- Beam pointing of passive SAR satellites is done through mechanical beam steering, as compared to electric beam steering of active SAR satellites
- Accordingly, spotlight mode requires passive SAR satellites to be agile
- Previous researches about optimal scheduling of electro-optical satellite isn't applicable to SAR satellite because additional maneuver for synthetizing a image is needed for SAR satellite
- A direct application of the well-established EO observation algorithm to SAR satellites is difficult
- In this research, an optimal mission scheduling algorithm is proposed based on various constraints of a typical SAR satellite
- Results from attitude control modeling of SAR satellites are presented, and an optimal mission scheduling algorithm is explained where the dynamic programming is applied to a representative SAR satellite with mechanical beam steering capability
- The proposed algorithm can derive the design solution in accordance with user's requirement (number of images in one path).
- Developed optimal scheduling algorithm considers attitude maneuver of Broadside Collection spotlight mode and Squint Collection spotlight mode (Fig. 1)

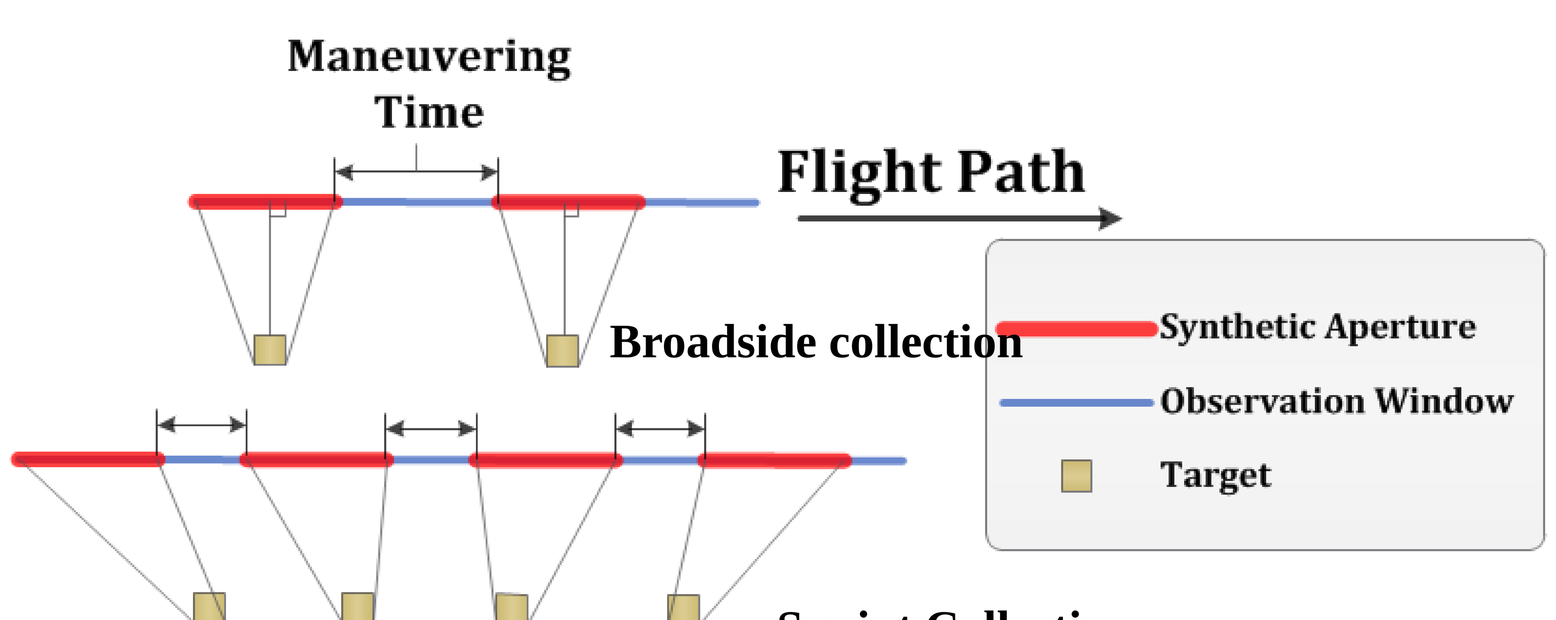

Fig. 1. Conceptual comparison of broad collection and squint collection spotlight mode

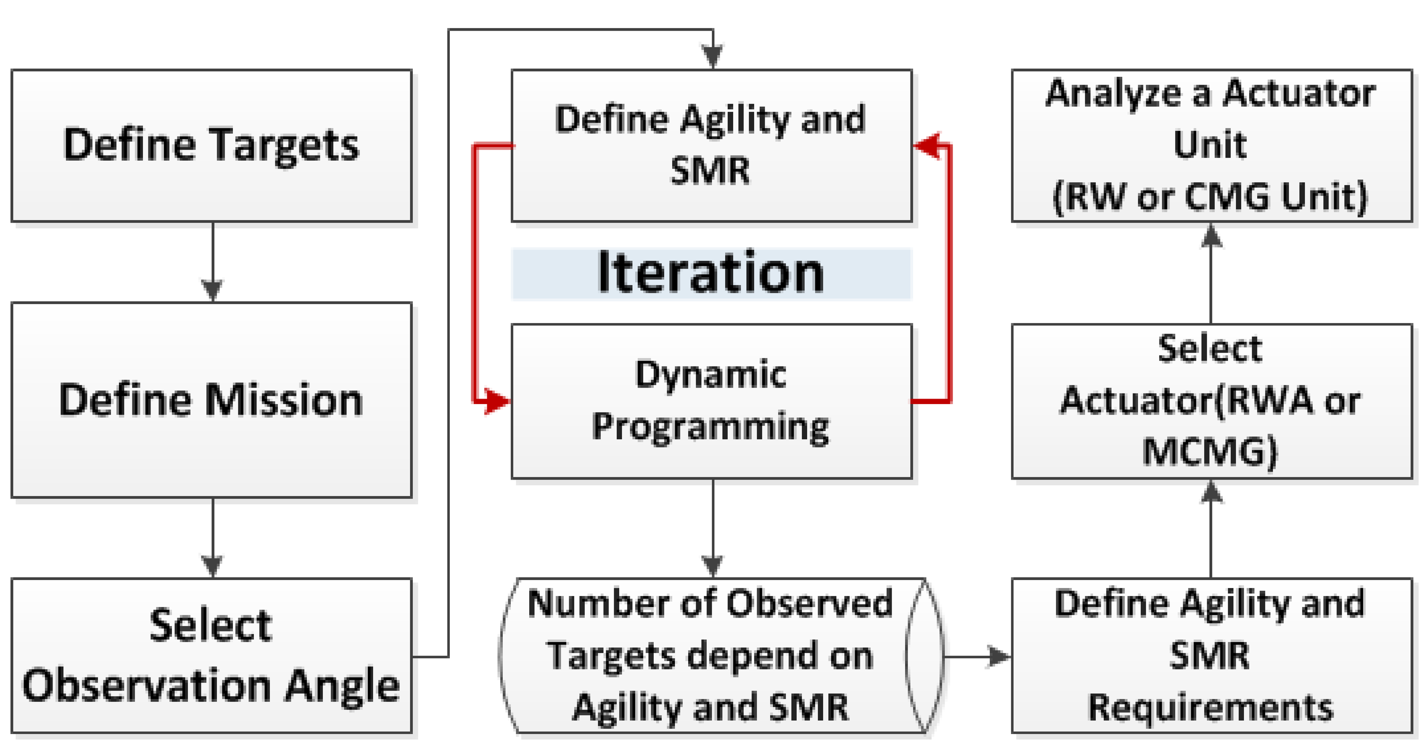

Fig. 2. Mission analysis procedure for derivation of agility and SMR

Mechanical Beam Steering SAR Scheduling Methodology

Program Statement;

Find $(t, \mathbf{x}, \phi, \theta, \psi)$ Maximize $J = \sum_{i=1}^{N} c_i$

State = $(target, time) = (i, t_k)$

Subject to $\frac{f_1(\beta_m) + f_1(\beta_k)}{2} + f_2(\beta_m, \beta_k) < t_m - t_k$

$incidence(min) < \boldsymbol{\beta} < incidence(max)$

where t is the time, $\mathbf{x}$ is a vector of satellite position, c_i is the priority of target i, i is target's number, t_k is the meantime to observe k[th] target, t_m is the meantime to observe m[th] target. $f_1(\beta)$ is a function of incidence angle and the time required for synthesizing the image at the position of incidence angle(β).

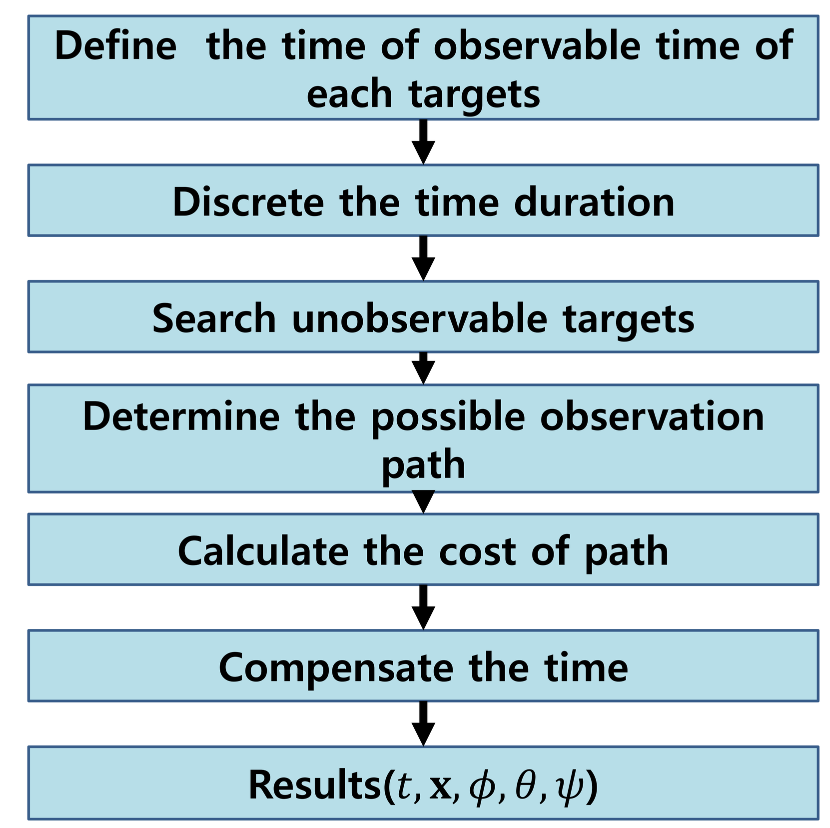

Fig. 3. Dynamic programming algorithm procedure

- Input variables(target's position, importance of target, satellite orbit, time information(duration , time step))
- Suggesting mission analysis procedure for design of attitude control system(Fig. 2)
- Using 'Dynamic Programming' for optimal scheduling(Fig. 3 and 4)
- Considering attitude maneuver concepts for mechanical beam steering SAR satellite(Fig. 5)
- Using the simplified attitude maneuver profile(Fig. 6)

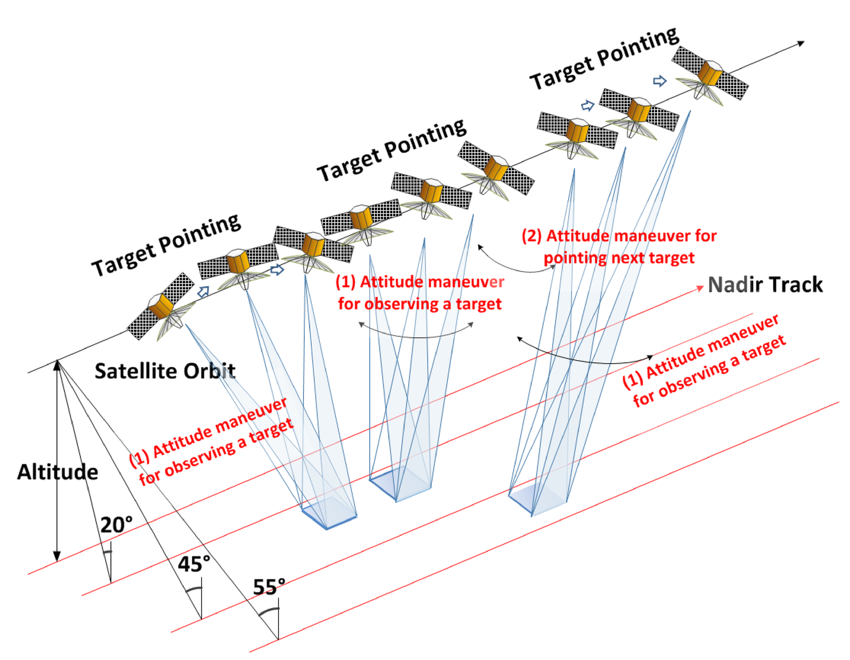

Fig. 5. Attitude maneuver concept for mechanical beam steering

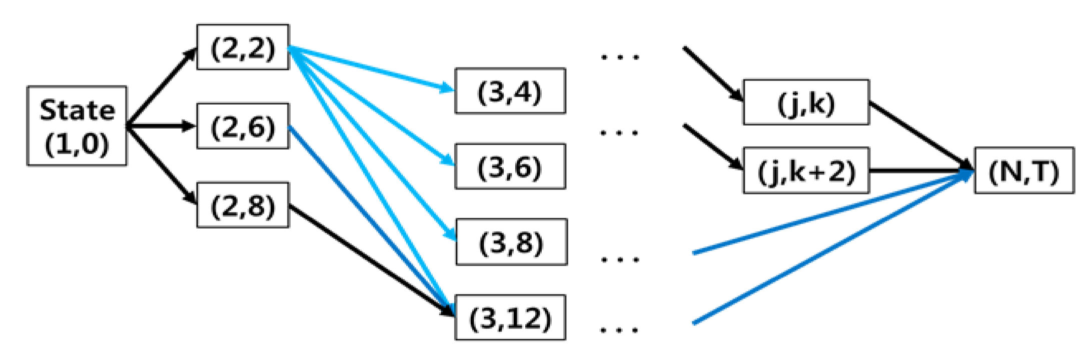

Fig. 4. Dynamic programming concept

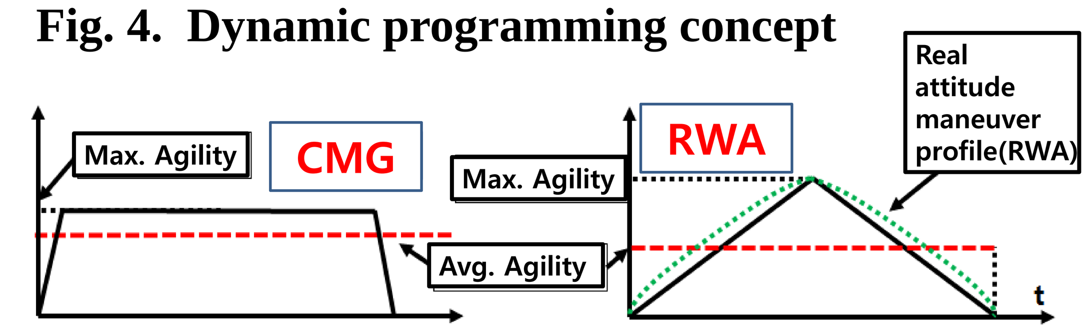

Fig. 6. Simplified attitude maneuver profile

Simulation Results

- Performing optimal scheduling for specific area.
- Comparing the broad collection spotlight mode squint collection spotlight mode in optimal scheduling results
- Analyzing the number of images taken on one ground path according to SMR(Slew Maneuver Response)
- Selecting SMR between 0.2 ~1.2 deg./sec.^{2}
- Obit for simulation has an inclination of 47 deg and 550km altitude. Incidence angle is between 25 and 55 deg.

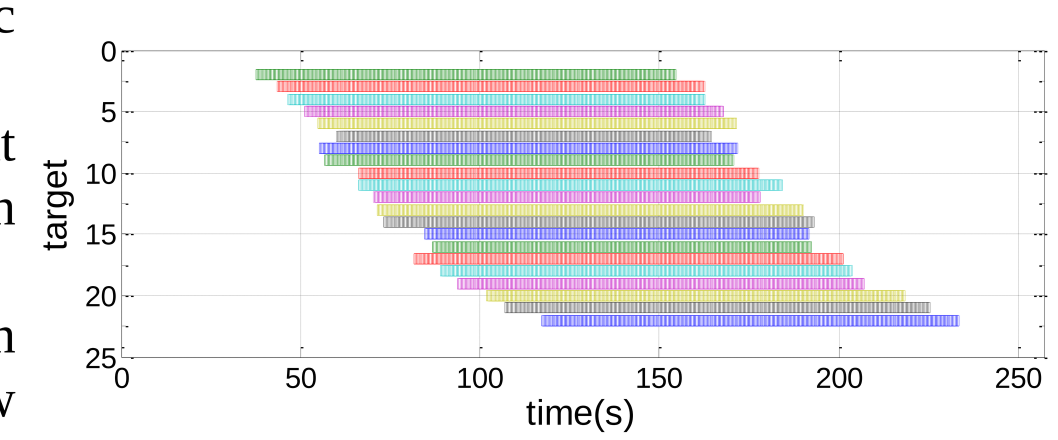

Fig. 7. Time line analysis results of broadside collection for optimal scheduling

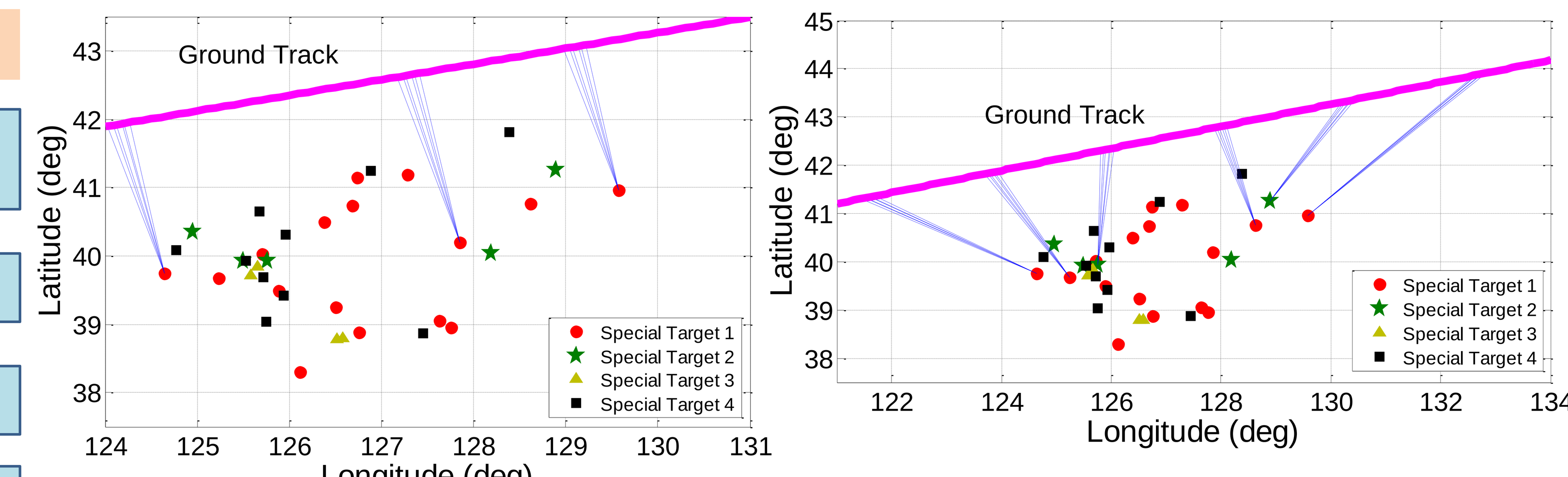

Fig.8. Scenario analysis results(left; broadside collection, right; squint collection)

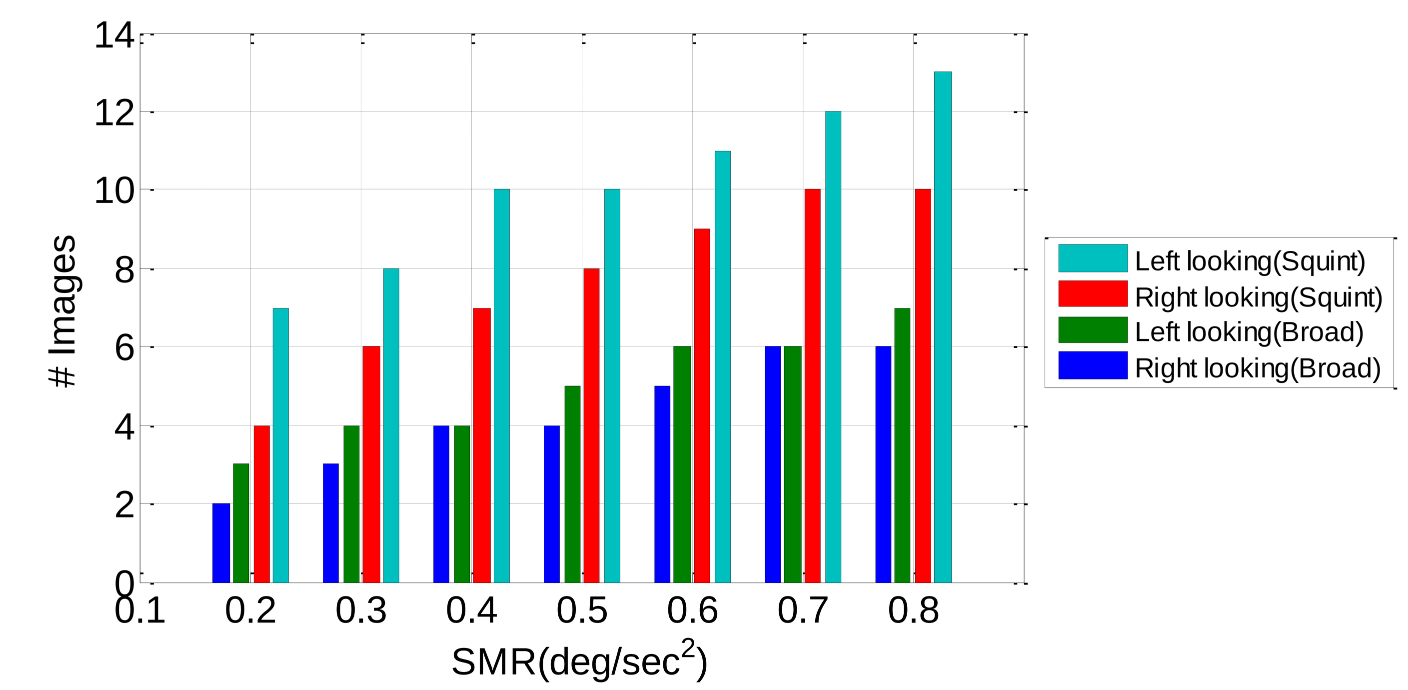

Fig.9. Simulation results according to SMRs

Conclusion & Discussion

- A simulation model about two-type spotlight modes of SAR satellite with mechanical beam steering has been developed
- According to this model, optimal scheduling algorithm is developed by using dynamic programming
- A model for performing mechanical beam steering using simplified attitude maneuver profiles has been established.
- It has been made possible to estimate the performance of attitude control system for meeting user's mission requirement such as the number of image on one ground path.
- The measure of effectiveness(the number of images on one path) according to SMR, based on the proposed algorithm has been performed

Future Work

- In this research, Dynamic programming is used for optimizing the schedule. But in the future, GA and PSO will be applied to the problem and the results will be compared

Reference

- Frank, Jeremy, et al. "Planning and scheduling for fleets of earth observing satellites." (2001).
- Lemaître, Michel, et al. "Selecting and scheduling observations of agile satellites." Aerospace Science and Technology 6.5 (2002): 367-381.