Vilnius Gediminas Technical University

Title: Monitoring of on Earth Vegetation by Means of Spectral Analysis
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Need

In cultivating of agricultural goods forest engineering and others branches of human activities related to plants there is a need of determining the exact area of vegetating plants and their types, this is especially important in case some of the plants cultivation is being subsidized or controlled by governmental organizations. Areas and types of such vegetation could be most easily determined implementing airborne equipment for spectral analysis of visible range (since each type of plant emits its very specific spectrum of visible colors), such monitoring systems are presently implemented using low to middle earth orbit satellites or aircrafts. In case of satellites implementation the resolution of imaging is quite limited same as the flexibility of the system, in case of aircraft based systems – it is practically impossible to obtain regular results.

Mission Objectives

1. Be able during the short mission time perform the areal spectral imaging of the area to be examined. This would provide valuable data for control of vegetation types etc.
2. Perform the ongoing spectral analysis of vegetation for constant control during the entire mission time.
3. Allow installing new software intended for particular tasks of images processing. This operation can be done both on orbit and on earth before the launch.

Concept of Operations

The space segment of the mission should consist of up to 10-20 nano-satellites equipped with the narrow area coverage high resolution spectral analysis cameras and reliable attitude determination and control systems. The very basic idea of the mission(s) is implementation of a large number of nano-satellites equipped with high resolution narrow angle spectral cameras for obtaining small images of the surface of the earth (at area under interest) and composing a mosaic of those images. The mosaic image should be composed of images obtained from different satellites of the swarm therefore fast imaging with high enough resolution could be provided. The data (images) obtained by the satellites could be processed directly at the satellite to determine areas of interest and small packages of processed data sent to ground stations. Or raw data could be sent to ground stations and later processed on ground.

In case of data processing on board of the satellite, the only limitation for the operation could be power budget and on board processor capabilities, therefore such method should be implemented in case of normal operation of satellite (fully charged batteries, fully deployed sun panels, enough of sun energy etc.). Data processing software could be uploaded to the satellites while being on orbit. This could allow flexible data processing.

In case of impossibility of onboard data processing (problems with the power budget, new tasks for data processing etc.) the raw images from satellites should be sent to the ground stations. To maintain appropriate large data packages transmission (raster images) a constellation of satellites should be used – the data should be transmitted from one satellite to another (being close to the ground station at that certain period of time) and then down to the ground station. It should be considered that all of the satellites should perform the tasks of imaging over a certain area of earth surface (under interest) and during all the left time of flying data processing and transmitting tasks could be performed (Fig. 1).

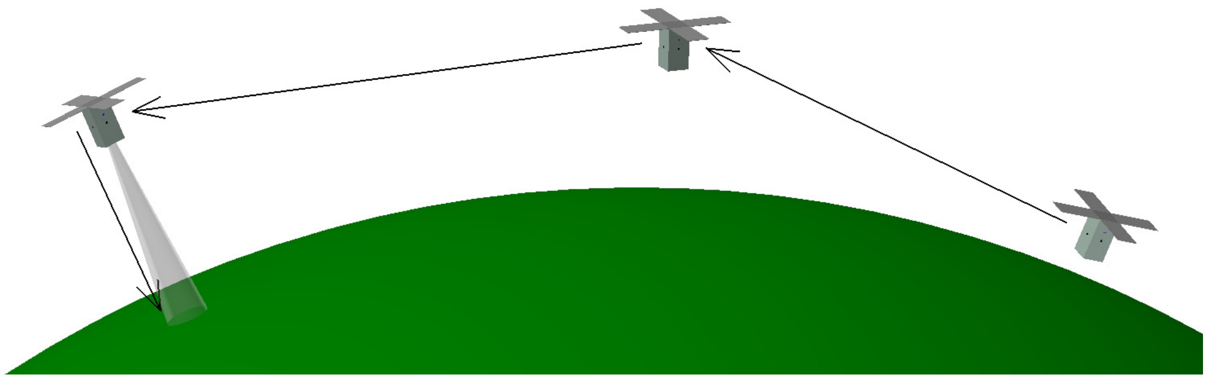

Fig. 1 Several satellites transmitting signal via another satellite to the ground station

An implementation of additional single geo-stationary satellite for data transmission could be also considered. In this case (geo-stationary transmission satellite available) the data form nano-satellites (visible by geo-stationary satellite) could be transmitted via mentioned satellite directly to the ground station.

For obtaining the data of biomass of measured areas an additional LIDAR type sensors could be implemented. In this case the data of biomass upper surface above the ground could be measured by means of laser scanning (the scanning could be performed implementing non-moving laser scanner just to obtain the height at several points). That way both type and area of plants could be determined using spectral camera thus the height of plants by means of laser scanning. The upper surface of vegetation should be determined in two measurements: non-vegetation time measurements and vegetation time measurements. Non-vegetation time measurements are needed due the low accuracy of present geoid model at some areas. By comparing the non-vegetation distance measurements with the vegetation time ones the height of the plants at measured area could be determined. Similar plants height measurements could be performed implementing the photogrammetric methods (triangulation of raster images), nonetheless accuracy of measurements would be lower than in case laser scanning. Photogrammetric measurements could be implemented in case of impossibility of implementation of laser scanning and be considered as the reserve vegetation height measurement system.

Ground segment should consist of at least one ground control system (preferably there should be several ground control systems positioned worldwide for better data acquisition) working in an S-band (2.4 GHz) frequency.

Launch of the satellites could be performed both by a single carrier bringing all of the nano-satellites to orbit at once and deploying them at certain intervals so that they obtain same (or slightly different) orbits but with a certain time shift. Or there could be several carriers bringing satellites to orbit one by one (or in groups) and deploying them at similar orbits.

Key Performance Parameters

1. Determination of area, position and type of vegetation is extremely important at nowadays. This could be said considering some plants areas under protection, illegal plants growing determination, determination of plants which are being supported by the governmental or others organizations etc. Such control can be performed implementing visible range interferometry (since each plant emits very special spectrum).
2. Determination of volume of vegetation (biomass) could be performed by combining laser scanner (vegetation height) measurements with the area measuremnts.
3. A constellation of nano-satellites equipped with the narrow angle high resolution spectral cameras could perform imaging of small areas of earth surface under interest and then a general mosaic of images can be composed.

4. Nano-satellites flying at low earth orbits could reach better resolution comparing to the large satellites performing similar tasks but flying at higher orbits.
5. Implementation of large number of relatively small could give flexibility of to the system which is lacking in case of large high cost satellites.
6. Nano-satellites could be implemented over any part of earth surface (even over territory of foreign states) which cannot be done by means of aircraft based imaging system.
7. Relatively low cost of the satellites would allow their quick modernizations and launching therefore quickly adopting them to the particular tasks to be done.

Space Segment Description

It is considered that the space element of the system should consist of up to 10-20 nano-satellites flying on similar orbits but with a certain time shift.

The total mass of singe satellite should not exceed 10 kg, which is quite possible implementing modern technologies.

The satellite itself should consist of:

1. Spectral imaging camera (of visual specter) of high resolution but narrow view angle. Camera should allow resolution better the approx. 10-20 m, which is achievable at low earth orbits (500 – 700 km).
2. Laser scanner (an implementation of scanner relying on different measurement principles is possible), for vegetation height determination. A singe coordinate (1D) laser or distance-meter could be implemented (to measure only several points on surface of vegetation to determine its height) with other points obtaining due to the flying speed of satellite or attitude control (pointing by changing of angle) of the satellite.
3. Images processing hardware and software. To decrease the amount of data to be transmitted to ground stations largest part of the image processing should be performed directly at the satellite (in case it is possible), some powerful and low energy consuming processors are essential for these tasks. The software intended for special tasks of image processing could be updated and installed both on orbit or before launch (due to low cost of satellites).
4. Power supply unit. To provide power for satellite work and especially image data processing some sun batteries of sufficient area should be implemented (further calculations should be done in this area). Most of the power consuming operations (precise attitude determination, and control, image making etc.) should be performed while flying on sunny side of the earth, therefore onboard batteries could be implemented only for image processing, data transmission and rough attitude determination and control tasks.
5. Attitude determination and control system should consist of several parts:
    a. Orbital GPS receiver for position determination of satellite and image orientation.
    b. Magnetometers for rough attitude determination,
    c. Star sensors for precise attitude determination. Star sensor should be considered as the main means of absolute attitude determination.
    d. Magneto torques for rough attitude control.
    e. Reaction wheels for precise attitude control during fine attitude determination and image taking procedures

    Therefore the attitude of the satellite should be roughly determined by means of magnetometers and roughly controlled by magneto torques. The accurate absolute attitude on the night (dark) side of the earth should be determined by the star sensors. The precise attitude control should be performed by means of reaction wheels (during imaging process).
6. Data transmission and communication system. The system should allow both data transmission in S-band to the ground station and to the other satellite (for further transmission to the ground).

Orbit/Constellation Description

The constellation of nano-satellites should consist of up to 10 – 20 of satellites flying on the low earth orbit (500 – 700 km). Such low earth orbit would ensure high resolution of imaging though mission time could be limited.

The constellation of satellites could allow mosaicking of small high resolution spectral images taken from different satellites.

Constellation of satellites would also allow data transmission not directly to the ground station (which is difficult due to the short time over ground station) but via several other satellites of the constellation to the ground station. This could ensure constant data transmission from the satellites to the ground.

Implementation Plan

It is considered that the idea could not be fully materialize in Lithuanian institutions due to lack of experience in the field. Therefore some of work could be done locally in Lithuania and some should be done at institutions abroad or implementing foreign researchers, engineers and their knowledge.

The total price of the design and construction of single satellite could be estimated (in local prices) as being in range of 300 000 – 400 000 euros, at very rough pricing.

The entire project (except the launch) could take some 2-5 years to develop (depending on the sponsorship available).

The project should be organized mostly implementing the work of the university students (which is very possible), that way the entire price can be reduces thus the time schedule of the project extended.

Some most notable risks of the project can be highlighted:

1. Lack of the spectral imaging camera of needed resolution and mass capable working in space (tests need to be accomplished).
2. Difficulties in power budged (high power consumptions of instrumentation).
3. Insufficient data transmission capacities.
4. Lack of the carriers for nano-satellites, especially at needed orbits.
5. Lack of experience of local Lithuanian team.

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