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# 1. Description of the models, discussing the decisions carried out.

## Model 1: Assignment of transmission antennae to satellites

We are given the following data:

Tabla

Descripción generada automáticamente

The following constraints are given

1. All satellites must have a transmission antenna assigned to it in all its time slots.

2. Since SAT1 and SAT2 have similar orbits, it is required to assign them the same antenna

3. Satellites SAT2, SAT4 and SAT5 should have assigned different antennae.

4. In case SAT5 communicates with ANT12, then SAT4 can not communicate with ANT11.

5. If, in any solution, ANT7 and ANT12 are used, then both must be assigned to time slots beginning before 12:00 or after

First, we define our variables (SAT1, SAT2, SAT3\_1, SAT3\_2, SAT4, SAT5, SAT6\_1, SAT6\_2) where:

Each satellite will have as the Domain all the possible antennas available at the timeslot, as shown in the table.

Noe we will analyze to determine possible constraints:

**Constraint 2**= SAT1SAT1, SAT2 = (ANT1, ANT1) (ANT2, ANT2) (ANT3, ANT3)

**Constraint 3** = SAT2SAT2, SAT4, SAT5 =

(ANT1, ANT8, ANT7) (ANT1, ANT11, ANT7) (ANT1, ANT12, ANT7)

(ANT1, ANT11, ANT12) (ANT1, ANT8, ANT12)

(ANT2, ANT8, ANT7) (ANT2, ANT11, ANT7) (ANT2, ANT12, ANT7)

(ANT2, ANT11, ANT12) (ANT2, ANT8, ANT12)

(ANT2, ANT11, ANT1) (ANT2, ANT8, ANT1) (ANT2, ANT12, ANT1)

(ANT3, ANT8, ANT7) (ANT3, ANT11, ANT7) (ANT3, ANT12, ANT7)

(ANT3, ANT11, ANT12) (ANT3, ANT8, ANT12)

(ANT3, ANT11, ANT1) (ANT3, ANT8, ANT1) (ANT3, ANT12, ANT1)

**Constraint 4** = SAT5SAT5, SAT4 = All combinations with sat5=ant8 + all combinations with sat5=ant11 + (ANT12, SAT8) (SAT12, SAT12)

For constraints 1, and 5, we wont use domain limitations, and we will use logical statements to limit the action paths:

Constraint 5: If SATi =ANT7 where i goes from (1, 12) AND SATj=ANT12 where j goes from (1,12):

If SAT(i) before 12 (equals SAT1, SA2, SAT3\_1, SAT5, SAT 6) :

SAT(j) also before 12 ((equals SAT1, SA2, SAT3\_1, SAT5, SAT 6) – SAT(i))

If SAT(i) after 12 (equals SAT3\_2, SA4, SAT6):

SAT(j) also after 12 ((equals SAT3\_2, SA4, SAT6) – SAT(i))

We want to gather all possible solutions that solve the problem.

## Model 2: Heuristic Search

In part 2, we are given the following data:

Gráfico

Descripción generada automáticamente con confianza media

We are given the following data:

SATx(i,j) where i = vision band and j= time and x {1,2}

#### Initial values:

SAT1 (pair(0,1), 0)

SAT2 (pair(2,3), 0)

And now we will set the actions, and the constraints for each of them

#### Constraints:

IDLE (i) = Preconditions -> Only done if there **is no** observation to be done in both bands (pair)

MEASURE (i) = Preconditions -> Only done if there **is** observation to be done in any of the bands (pair) and charge left

TURN (i) = Precondition -> charge left, plus heuristics should be in charge of handling when to turn (only if necessary)

DOWNLINK (i) = Preconditions -> Only done if there **is** observation memory to be send and charge left

CHARGE (i) = No conditions

General constraints:

* Only one action each time.
* Time can only go forward.

We are also given an input that will establish the location of the observation points and the costs of each action to be done

#### Branching factor calculation:

Firstly, we calculate the maximum theoretical value:

We have 5 different actions. If we power this value to the maximum depth of our tree, which is 12 (max hours), we obtain the maximum theoretical value:

We counted the nodes done by our implementation on the calculation of the solutions, and we got 700k nodes. With this value, we can now obtain our branching factor:

#### Heuristics:

We want our satellites path to be efficient, and not to miss any observation point. In order to do so, we have 2 main values to take into account for the heuristic:

The cost

The observations left

The energy left

The observation memory

The best heuristic possible will be given by minimal cost, 0 observations left and 0 energy left and 0 observations in memory.

Minimal cost will translate into minimal amount of operation performed. 0 observations left will mean that all the observation points have been measured and 0 observations in memory means that all info has been sent to the earth control point.

**Graph generation:**

We generate a queue of nodes where we are going to store all the nodes so we can calculate the remaining ones.

**A\* algorithm:**

We haven’t had enough time to properly implement the algorithm, even though the rough outline is there. Somewhere in the graph generation, our code can’t link successfully the nodes to its adjacents, so that the priority queue orders the lowest cost.

# 

# 2. Analysis of results

## Part 1: Assignment of transmission antennae to satellites analysis

When we execute our implementation with all the data given in the problem statement, we get 468 possible solutions.

To check our solutions in a fair way, we generate 5 random solutions from all of them to check the values and consistency. Here we can see an example:

{'SAT2': 'ANT3', 'SAT4': 'ANT11', 'SAT5': 'ANT1', 'SAT1': 'ANT3', 'SAT3\_1': 'ANT4', 'SAT6\_1': 'ANT7', 'SAT3\_2': 'ANT10', 'SAT6\_2': 'ANT4'}

{'SAT2': 'ANT2', 'SAT4': 'ANT12', 'SAT5': 'ANT1', 'SAT1': 'ANT2', 'SAT3\_1': 'ANT4', 'SAT6\_1': 'ANT9', 'SAT3\_2': 'ANT7', 'SAT6\_2': 'ANT4'}

{'SAT2': 'ANT2', 'SAT4': 'ANT8', 'SAT5': 'ANT12', 'SAT1': 'ANT2', 'SAT3\_1': 'ANT4', 'SAT6\_1': 'ANT9', 'SAT3\_2': 'ANT10', 'SAT6\_2': 'ANT4'}

{'SAT2': 'ANT2', 'SAT4': 'ANT8', 'SAT5': 'ANT1', 'SAT1': 'ANT2', 'SAT3\_1': 'ANT6', 'SAT6\_1': 'ANT9', 'SAT3\_2': 'ANT10', 'SAT6\_2': 'ANT3'}

{'SAT2': 'ANT1', 'SAT4': 'ANT8', 'SAT5': 'ANT12', 'SAT1': 'ANT1', 'SAT3\_1': 'ANT6', 'SAT6\_1': 'ANT9', 'SAT3\_2': 'ANT9', 'SAT6\_2': 'ANT4'}

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 0-3 | 3-6 | 6-9 | 9-13 | 13-16 | 16-19 | 19-21 | 21-24 |
| SAT1 | ANT3 | ANT3 | ANT3 | ANT3 | |  |  |  |  |
| SAT2 | ANT3 | ANT3 | ANT3 | ANT3 | |  |  |  |  |
| SAT3 |  |  | ANT4 | ANT4 | | ANT10 |  |  |  |
| SAT4 |  |  |  |  |  | ANT11 | ANT11 | ANT11 |
| SAT5 |  |  | ANT1 | ANT1 |  |  |  |  |
| SAT6 |  |  |  | ANT9 | ANT4 | ANT4 |  |  |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 0-3 | 3-6 | 6-9 | 9-13 | 13-16 | 16-19 | 19-21 | 21-24 |
| SAT1 | ANT2 | ANT2 | ANT2 | ANT2 | |  |  |  |  |
| SAT2 | ANT2 | ANT2 | ANT2 | ANT2 | |  |  |  |  |
| SAT3 |  |  | ANT4 | ANT4 | | ANT7 |  |  |  |
| SAT4 |  |  |  |  |  | ANT12 | ANT12 | ANT12 |
| SAT5 |  |  | ANT1 | ANT1 |  |  |  |  |
| SAT6 |  |  |  | ANT9 | ANT4 | ANT4 |  |  |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 0-3 | 3-6 | 6-9 | 9-13 | 13-16 | 16-19 | 19-21 | 21-24 |
| SAT1 | ANT2 | ANT2 | ANT2 | ANT2 | |  |  |  |  |
| SAT2 | ANT2 | ANT2 | ANT2 | ANT2 | |  |  |  |  |
| SAT3 |  |  | ANT4 | ANT4 | | ANT10 |  |  |  |
| SAT4 |  |  |  |  |  | ANT8 | ANT8 | ANT8 |
| SAT5 |  |  | ANT12 | ANT12 |  |  |  |  |
| SAT6 |  |  |  | ANT9 | ANT4 | ANT4 |  |  |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 0-3 | 3-6 | 6-9 | 9-13 | 13-16 | 16-19 | 19-21 | 21-24 |
| SAT1 | ANT2 | ANT2 | ANT2 | ANT2 | |  |  |  |  |
| SAT2 | ANT2 | ANT2 | ANT2 | ANT2 | |  |  |  |  |
| SAT3 |  |  | ANT6 | ANT6 | | ANT10 |  |  |  |
| SAT4 |  |  |  |  |  | ANT8 | ANT8 | ANT8 |
| SAT5 |  |  | ANT1 | ANT1 |  |  |  |  |
| SAT6 |  |  |  | ANT9 | ANT3 | ANT3 |  |  |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 0-3 | 3-6 | 6-9 | 9-13 | 13-16 | 16-19 | 19-21 | 21-24 |
| SAT1 | ANT1 | ANT1 | ANT1 | ANT1 | |  |  |  |  |
| SAT2 | ANT1 | ANT1 | ANT1 | ANT1 | |  |  |  |  |
| SAT3 |  |  | ANT6 | ANT6 | | ANT9 |  |  |  |
| SAT4 |  |  |  |  |  | ANT8 | ANT8 | ANT8 |
| SAT5 |  |  | ANT12 | ANT12 |  |  |  |  |
| SAT6 |  |  |  | ANT9 | ANT4 | ANT4 |  |  |

As we can see, we obtained all the possible solutions, and they fulfill all the constraints as expected

## 

## Test cases

### CASE 1: RELAXING CONSTRAINTS

We relaxed some constraints, as the same orbit ones and the constraint 4 (Satellites 4 & 5 limitations)

This will obviously lead to an increase in the solutions obtained. Now we get up to 2160 solutions. Here we can observe a couple of them.

{'SAT2': 'ANT3', 'SAT4': 'ANT12', 'SAT5': 'ANT1', 'SAT3\_1': 'ANT6', 'SAT6\_1': 'ANT9', 'SAT3\_2': 'ANT7', 'SAT6\_2': 'ANT3', 'SAT1': 'ANT1'}

{'SAT2': 'ANT1', 'SAT4': 'ANT11', 'SAT5': 'ANT12', 'SAT3\_1': 'ANT4', 'SAT6\_1': 'ANT7', 'SAT3\_2': 'ANT9', 'SAT6\_2': 'ANT3', 'SAT1': 'ANT3'}

### CASE 2: ADDING SATELLITES

We added up to 10 satellites, with their corresponding antennas.

This will obviously lead to an increase in the solutions obtained. Now we get up to 3744 solutions. Here we can observe a couple of them.

{'SAT2': 'ANT3', 'SAT4': 'ANT12', 'SAT5': 'ANT1', 'SAT1': 'ANT3', 'SAT9': 'ANT2', 'SAT8': 'ANT2', 'SAT10': 'ANT10', 'SAT3\_1': 'ANT6', 'SAT6\_1': 'ANT9', 'SAT3\_2': 'ANT10', 'SAT6\_2': 'ANT5', 'SAT7': 'ANT8'}

{'SAT2': 'ANT1', 'SAT4': 'ANT11', 'SAT5': 'ANT7', 'SAT1': 'ANT1', 'SAT9': 'ANT2', 'SAT8': 'ANT2', 'SAT10': 'ANT10', 'SAT3\_1': 'ANT6', 'SAT6\_1': 'ANT9', 'SAT3\_2': 'ANT7', 'SAT6\_2': 'ANT4', 'SAT7': 'ANT3'}

### CASE 3: DELETING SATELLITES

We deleted some satellites, with their corresponding antennas. The remaining satellites are SAT1, SAT2, SAT3, SAT4, SAT5

This will obviously lead to an decrease in the solutions obtained. Now we get up to 84 solutions. Here we can observe a couple of them.

{'SAT2': 'ANT3', 'SAT4': 'ANT8', 'SAT5': 'ANT7', 'SAT1': 'ANT3', 'SAT3\_1': 'ANT4', 'SAT3\_2': 'ANT9'}

{'SAT2': 'ANT1', 'SAT4': 'ANT11', 'SAT5': 'ANT7', 'SAT1': 'ANT1', 'SAT3\_1': 'ANT4', 'SAT3\_2': 'ANT9'}

## Part 2: Heuristic Search We haven’t been able to achieve the A\* algorithm, so unfortunately there are no test cases.

# 3. Final Remarks

We found this second lab assignment much more challenging and interesting, as it was as close as possible to a real case scenario.

During the development of the first part, we practiced over modeling CSP tasks, and learned how to use the constraint library of python, a tool that personally we found really useful. We achieved realistic and accurate results.

When we got to face the second part, we ran through several challenges, since even trying to follow the guidelines and stipulated time plans given, the last 2 weeks of the course result in the accumulation of many projects and exams, resulting in less time to focus on this part.

Also we felt that even if all the concepts were clearly explained in class, we had problems grounding the real implementation of the heuristics. We encountered new challenges, and we tried to solve them on our own making use of all the tools provided.

Finally, we are proud to say that all the contents developed for these subjects were done using OS tools such as LibreOffice and VIM