Creating a student-friendly final week exam schedule

I wanted to reschedule our final exam (spring 2021) dates and hours in a student-friendly way. For this, I have set some constraints that may be in our favour, and I was wondering if I can still get a decent final exam schedule despite these restrictions. And I succeeded...

First of all, I want to mention how many variables we use and what they are. Since our aim is to assign the names of the courses in the empty slots of an exam calendar to be created, we need two variables for each course corresponding to the day and the staring time of the exam. Since this semester (Spring 2021) has 31 course exams, we need 62 variables in total.

e.g.
```
(declare-const BBM405-d Int)
(declare-const BBM405-h Int)
```

Constraints:

1. The exam week, which is close to the deadline for the final assignments and starts as soon as the classes are over, upsets the students. Therefore, if exams must be held within the first 2 weeks after the end of the semester, we can schedule the exams as late as possible and minimize the total exam day time. Thus, we will have more time to study as well. In our case, shifting all exams to the 2nd week of June (7th, 8th, 9th, 10th and 11th) will be our first restriction. But only when I limited it to these days I got "unsat" output from the z3-solver. So I had to take another day from the first week, which is the friday of the first week (4th)

   e.g.
   ```
   (or (= BBM405-d 4)(= BBM405-d 7)(= BBM405-d 8)(= BBM405-d 9)(= BBM405-d 10)(= BBM405-d 11))
   ```

2. Another constraint is that the date and time of the exams for non-departmental courses cannot be easily changed. That's why I randomly selected and fixed the date and time of these classes to be in the 2nd week.

   e.g.
   ```
   (= MAT124-d 10)
   (= MAT124-h 14)
   ```

3. **(Domain)** Examinations of department courses can be any of the days in the constraints specified in the first item (4th, 7th, 8th, 9th, 10th or 11th of June).

4. **(Domain)** The exam start time can vary between 09.00 and 18.00. An exam ends at 19.00 at the latest. Starting times should also be chosen considering how many hours the exam will take.

5. Except for the 4xx coded department courses, the courses must end at 17.00 at the latest.

6. BBM102, BBM202 and BBM405 exams take 3 hours. AIT204, MUH104, BEB650, TKD104, BBM428 exams take 1 hour. The exams for all the remaining courses take 2 hours.

   e.g. Below are examples of different situations according to the above constraints.

```
(or (= BBM102-h 9)(= BBM102-h 10)(= BBM102-h 11)(= BBM102-h 12)(= BBM102-h 13)(=
BBM102-h 14))

(or (= BBM342-h 9)(= BBM342-h 10)(= BBM342-h 11)(= BBM342-h 12)(= BBM342-h 13)(=
BBM342-h 14)(= BBM342-h 15))

(or (= BBM405-h 9)(= BBM405-h 10)(= BBM405-h 11)(= BBM405-h 12)(= BBM405-h 13)(=
BBM405-h 14)(= BBM405-h 15)(= BBM405-h 16))

(or (= BBM406-h 9)(= BBM406-h 10)(= BBM406-h 11)(= BBM406-h 12)(= BBM406-h 13)(=
BBM406-h 14)(= BBM406-h 15)(= BBM406-h 16)(= BBM406-h 17))

(or (= BBM428-h 9)(= BBM428-h 10)(= BBM428-h 11)(= BBM428-h 12)(= BBM428-h 13)(=
BBM428-h 14)(= BBM428-h 15)(= BBM428-h 16)(= BBM428-h 17)(= BBM428-h 18))

(or (= AIN200-h 9)(= AIN200-h 10)(= AIN200-h 11)(= AIN200-h 12)(= AIN200-h 13)(=
AIN200-h 14)(= AIN200-h 15))
```

7. In addition, it is an advantage for us that the exams of the compulsory courses for each class (1st year, 2nd year and 3rd year courses) are not held on the same day. That's why I put a constraint on it: Examinations of important courses of each class that require hard study cannot be held on the same day. Also, I haven't forgotten about artificial intelligence engineering students. Their compulsory courses in the same year cannot be done on the same day.

   e.g.

```
(distinct BBM102-d FIZ138-d FIZ117-d MAT124-d)
(distinct BBM202-d BBM234-d ELE296-d MAT254-d IST292-d)
(distinct BBM342-d BBM382-d)
(distinct BBM202-d BBM242-d AIN200-d AIN212-d)
```

8. There are many technical electives. That's why I couldn't put the constraint of each course exam is done in one day like I put it in other classes. However, there can be a maximum of 2 exams in a day for 4xx coded courses. Since the exam for the BBM428 seminar course is an easy course, the exam for this course can be taken on any day. (That is, there can be a maximum of 3 4xx coded courses on the day of the exam for this course). I used the following propositional formula to achieve this constraint:

If the exam for lesson A and the exam for lesson B are held on the same day, the exam for lesson C must be held on a different day than the exam for lesson A. (which means that it will be held on a different day than the B course exam.) Thus, a maximum of 2 exams can be given on the same day, excluding the BBM428 exam. In order to meet this constraint, all triple combinations of 4xx coded courses except BBM428 should be considered.

```
(=> (= courseA-d courseB-d) (distinct courseC-d courseA-d))
```

e.g.

```
(=> (= BBM405-d BBM406-d) (distinct BBM410-d BBM405-d))
```

9. Since there are 2 exams in the same day in 4xx coded courses, it can be challenging for a student who has to take these two exams on the same day, to take the other exams as soon as one is finished, without a break. Therefore, another constraint is that there must be at least 1 hour break between the exams of the 4xx coded courses that will be held on the same day.

   If the examination of lesson A and the examination of lesson B are to be held on the same day, the end time of the examination of lesson A and the start time of the examination of lesson B, and the end time of the examination of lesson B and the start time of the examination of lesson A must not be the same.

   ```
   (=> (= courseA-d courseB-d) (and (distinct (+ courseA-h exam-duration-courseA)
   courseB-h)(distinct (+ courseB-h exam-duration-courseB) courseA-h)))
   ```

   e.g.

   ```
   (=> (= BBM405-d BBM406-d) (and (distinct (+ BBM405-h 3) BBM406-h) (distinct (+
   BBM406-h 2) BBM405-h)))
   ```

10. And finally, the main constraint is that no exams of any course overlap each other.

    If the examination of lesson A and the examination of lesson B are to be held on the same day, the end time of the examination of lesson A must be less or equal to the start time of the examination of lesson B, or, the end time of the examination of lesson B must be less or equal to the start time of the examination of lesson A.

    ```
    (=> (= courseA-d courseB-d) (or (<= (+ courseA-h exam-duration-courseA) courseB-h)
    (<= (+ courseB-h exam-duration-courseB) courseA-h)))
    ```

    e.g.

    ```
    (=> (= BBM405-d MAT254-d) (or (<= (+ BBM405-h 3) MAT254-h) (<= (+ MAT254-h 2)
    BBM405-h)))
    ```

Note: Since there are many propositional formulas that will satisfy the above constraints (because there are too many possible combinations), I wrote a python code that you can find in the file I submitted, which is called `helper.py`, in order to obtain all possible combinations. This python code also converts the obtained output model in the format of text file from z3-solver to a schedule table in the format of pandas dataframe.

Final week exam schedule I obtained

	Jun 4	Jun 7	Jun 8	Jun 9	Jun 10	Jun 11
09.00	[BBM442]	[FIZ138]	[BBM406]	[IST292]	[ING112]	[BBM382]
10.00	NaN	NaN	NaN	NaN	NaN	NaN
11.00	[BBM342]	[ELE296]	[MAT254]	[BBM242]	[BBM405]	[BBM234]
12.00	NaN	NaN	NaN	NaN	NaN	NaN
13.00	[BBM202]	[BBM416]	[BBM102]	[BBM432]	NaN	[BBM467]
14.00	NaN	NaN	NaN	NaN	[MAT124]	NaN
15.00	NaN	[AIN200]	NaN	[BEB650]	NaN	[AIN212]
16.00	[BBM456]	NaN	[BBM486]	[MUH104]	[TKD104]	NaN
17.00	NaN	[BBM421]	NaN	[FIZ117]	[BBM461]	[BBM410]
18.00	[BBM428]	NaN	[AIT204]	NaN	NaN	NaN

And in the end, I got successful results in the problem of rescheduling the final exams, which I formulated as a CSP. In this constraint satisfaction problem, I used a total of 62 variables for 31 lessons, exam dates and times for each lesson. The domain for these variables is the appropriate hours mentioned above and the days I try to minimize the total interval where the exams will be held. Constraints, on the other hand, are new regulations that will benefit us, students.

Now we have 4 more days to study for the final exams, with the final exam program I got from this SAT problem that I solved using the smtlib syntax and with the help of z3-solver. Finals can start on Friday of the first week. The exams are spread out over these 6 exam days as conveniently as possible. In other words, I tried to distribute the exams that students had to take on different days within the constraints mentioned above, taking into account all students, and while doing this, I minimized the total exam week duration.