Analysis of the Changing Room Assignment Problem for Fet IL

Table of Contents

Introduction

Fet IL (Fet Idrettslag, literally «Fet Sports Club») is a Norwegian sports club located in Fet, in close proximity to Lillestrøm and Oslo. Until recently, they had one indoor arena, Fethallen, with a single field, which was primarily used for handball. Fethallen has four changing rooms and digital signs which display the day's handball matches as well as which changing rooms the teams are assigned. The algorithm used to assign changing rooms was very simple: The teams for the first match were assigned the two first changing rooms, the teams for the second match were assigned the two last changing rooms, the next match's teams were assigned the first two changing rooms, and so on; alternating between the two pairs of changing rooms. This worked reasonably well.

In November 2017, Fet IL opened their new indoor arena, EIKA Fet Arena. This arena houses two fields, allowing two matches to run in parallel (usually one handball and one floorball), and has eight changing rooms. However, some of them share showers, which means that we cannot assign teams to those changing rooms however we please. Thus, the simple algorithm for assigning changing rooms to teams used for Fethallen is not suitable for EIKA Fet Arena.

The goal of this project is to build a system which is able to assign changing rooms for the teams that play at EIKA Fet Arena, extending the existing digital signage system. This analysis is meant to help reason about the problem, and serve as an introduction for new people who wish to learn more about the project, whether for learning purposes or because they want to extend or maintain the system.

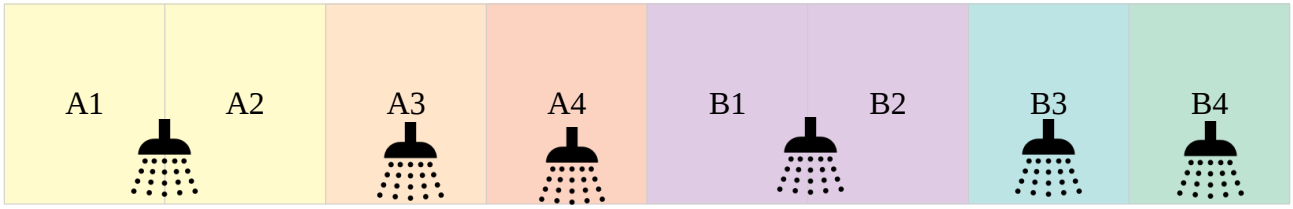
Dictionary

While the system is intended for Norwegian audiences, software systems are typically written in English, and English is therefore used for this document so the language stays the same in the project. This dictionary specifies which English word is used for the different Norwegian words, related to sports.

Norsk bokmål	English	Short description
Garderobe	Changing room	Room used to change to and from sports clothes, shower after matches and discuss tactics before, during and after matches.
Hall	Indoor arena	Building containing fields where matches are played.
Bane	Field	Place where one match is played.
Infoskjerm, informasjonsskjerm	Digital sign (specific) or digital signage (general)	Screens used to display informational content, such as the matches scheduled for that day.
Spiller	Player	Participant in a team.
Lag	Team	One of the sides of a match. We consider one team to be one collection of players from a sports club; thus, Fet boys 11 and Fet boys 12 are different teams.
Innebandy	Floorball	A sport.

Problem description

EIKA Fet Arena has, as previously mentioned, eight changing rooms. They are labelled A1, A2, A3, A4, B1, B2, B3 and B4 to coincide with the two fields, which are named A and B. Two pairs of changing rooms share shower, without any doors between the two changing rooms and the shower. This means they can see and hear each other. Specifically, A1 and A2 and B1 and B2 are the two pairs. A3, A4, B3 and B4 are normal changing rooms where each room has its own shower. This is illustrated in the following figure.



The following restrictions apply to the teams that are assigned changing rooms which share shower:

- C1: They must be of the same gender.
- C2: Preferably, they are not opponents.
- C3: Preferably, the age difference is not too high.

For all changing rooms, these restrictions apply:

- C4: Each changing room is assigned to one team at a time.
- C5: Each team is assigned a changing room which they are free to use a certain number of minutes before their match, until a certain number of minutes after their match.
- C6: Preferably, the lowest number of changing rooms are used throughout a day.
- C7: Some changing rooms are preferred more than others.

The rationale for these restrictions follow.

Restrictions for teams sharing shower

These restrictions apply pairwise to the teams that are assigned A1 and A2, and B1 and B2. That is, if team X is assigned A1 and team Y is assigned A2, these restrictions apply between X and Y.

C1: Same gender

Obvious.

C2: Preferably not opponents

The changing room is often used to discuss tactics. This is done before the match to prepare, during breaks in the match to adapt and after the match to reflect. It is natural for the team leaders to discuss their opponent, especially during the match, and the element of surprise is often used so the opposing players must react and adapt on the fly, without the chance to discuss with their team

leaders (except for timeouts). If the teams can hear each other because they share showers, they cannot really discuss their strategy.

Another reason is that players may get bad feelings towards their opponents as a part of the excitement and engagement in their match, especially as the stakes get higher. The underlying conflict might escalate if they were to shout at each other and share space. Additionally, the winning team will usually continue their celebrations in the changing room, which could hurt players of the losing team.

This is an optional requirement (hence “preferably”) because one of the teams may choose to discuss their tactics outside of their changing room, working around the first problem. The second problem is not so easy to work around, so this requirement should only be violated if the alternative is to not give a team a changing room at all.

C3: Preferably not too high age difference

Even if the two teams are of the same gender, they may have reservations against changing clothes and showering together if one is fairly old and the other fairly young. That said, public changing rooms like those found in connection with swimming pools are only split based on gender, not age, so we can assume it’s not too much of a problem. It’s still kept as a “would be nice”-requirement.

Restrictions for all changing rooms

These restrictions are general in nature, and apply to all changing rooms.

C4: Each changing room is assigned to one team at a time

This essentially means that a team won’t need to share their changing room with another team. This is a basic expectation teams have to changing rooms; the rooms are usually not suitable for more than one team at a time.

C5: Each team is assigned a changing room which they are free to use a certain number of minutes before their match, until a certain number of minutes after their match

Each team needs to use their changing room for a few different purposes:

- Before the match
  - Change into sport gear
  - Do simple warm-up
  - Fill water bottles
  - Discuss tactics for the match ahead
- During the match, in a break
  - Relax and discuss tactics for the next round
  - Refill water bottles

- After the match
  - Relax and reflect on the match that was played
  - Shower
  - Change back to normal clothes

Additionally, the changing room is used to store the team's belongings while they are at the arena.

From these purposes, you can see that the changing room is essentially used by the team from the moment they arrive until the moment they leave. Typically, teams arrive 45-60 minutes before their match starts, and the individual players leave as soon as the discussion is over and they have showered and changed back; assume this takes 30 minutes. This means that teams should be allocated a changing room at least 45 minutes before their match starts, until at least 30 minutes after the match is finished. Note that these times may be different for different sports and different age groups, and for home teams and visiting teams.

C6: Preferably, use the lowest amount of changing rooms

Both fields of EIKA Fet Arena are not necessarily used every day. When only one field is used, the number of changing rooms needed goes down. By not using all changing rooms, you save yourself from washing them unnecessarily. This is not so important.

C7: Some changing rooms are preferred more than others

Some changing rooms may be more inaccessible or less favorable than others. This is not important at all, but rather just a preference.

Problem in AI terms

This problem falls into the Artificial Intelligence part of computer science. You can imagine that we are creating a system which replaces a human assigning changing rooms to teams on a whiteboard.

Specifically, this problem is a part of the Weighted Constraint Satisfaction Problems (WCSP), which are problems where you have variables, each of which needs to be assigned a value from a list of possible values, and constraints which define some combinations of assignments which are not allowed, and combinations of assignments that are not preferred and incur a cost. Please see the Wikipedia articles on Weighted constraint satisfaction problem and the more simple Constraint satisfaction problem for more details.

The following discussion assumes some knowledge of AI concepts, though the section on Performance Measure may be interesting for all audiences.

Sensors

The actor has access to the following information:

- Matches
  - Start time

    - End time
    - Gender
    - Age
    - Teams
- Changing rooms
    - Knows which changing rooms share showers

Actuators

The actor may do the following:

- Return assignment of which team should use which changing room, and which constraints had to be violated.
- Declare the problem to be unsolvable.

Environment

The actor's environment has the following properties:

- Fully observable: All information can be accessed at all times.
- Deterministic: Teams can be assumed to use the changing room they are assigned.
- Discrete: The actor need only assign rooms at the beginning of the day, in one big swoop.
- Periodic: Yesterday's assignments and matches have nothing to do with how today's teams should be assigned. However, inside one day, the assignments are all related to each other.
- Only one actor

Performance measure

The performance measure is a measurement of how well the actor does its job. 0 means perfect, higher numbers mean a worse performance. The following table shows the "cost" of violating each constraint mentioned above, and is based on the discussion of how important they are in relation to each other.

ID	Constraint violation	Cost of violating
C1	Two teams of different genders share shower	∞
C2	Opponents share shower	10000
C3	Two teams with high age difference share shower	100
C4	Two teams share changing room	∞
C5	A team is not assigned a changing room	∞
C6	One more changing room is used during the day	10
C7	A not-preferred changing room is used during the day	1

Note how the costs are assigned so that the violations are ordered. Since there are 8 changing rooms, the max cost of violating C7 is 8, while the cost of violating C6 once is 10. Thus, given the choice of using one more changing room and using not-preferred changing rooms, the system will always prefer to use not-preferred changing rooms. The same approach is used for the other constraints. We therefore have this order of importance:

$$C7 < C6 < C3 < C2 < C1 = C4 = C5$$

Less important constraints are always violated before more important constraints. The point is to avoid a situation where the system violates a more important constraint once instead of making a less important violation many times. If the system did that, it could decide that two opponents should share shower to avoid five cases of teams with high age difference sharing showers.

C1, C4 and C5 are assigned a cost of ∞ (infinity), meaning that they are hard requirements (cannot be violated).

You may have noticed that a perfect score of zero is impossible, unless there are no matches that day, since simply using a changing room comes with a cost. This is fine because the performance measure is used to compare different solutions to each other, so we can know which solution is better.

Existing solutions

While there are some solutions for assigning school subjects to rooms, they are focused on higher education and would not be suited for representing constraints related to the shared showers. There are also many solutions for reserving meeting rooms, but they do not handle the task of automatically assigning teams to rooms. An extensive search on Google and Github did not reveal any existing solution to this problem, though that may be due to unfamiliar terminology on the author’s part.

There exist generic solutions for representing and solving Constraint satisfaction problems and Weighted constraint satisfaction problems, such as toulbar2.

Sketch of new solution

The problem needs to be formulated as a weighted constraint satisfaction problem, which can then be put into an existing solver for this kind of problem. In addition, the system must be fitted into a bigger picture, where scheduled matches are fetched, parsed, given to the changing room assignment system and finally given to the digital signage system.

Formulation as weighted constraint satisfaction problem

Each team is one variable, whose domain is the list of changing rooms. The constraints defined earlier will then constrain the assignments of changing rooms to teams. For example, two teams whose allocated changing room time overlaps, cannot be assigned the same changing room, because then they would share it for some time.

Let’s say the following teams are scheduled to play (based on the actual schedule):

Date	Time	Field	Gender	Age	Home team	Visiting team
07.01.2018	14:00	B	Boys	12	Fet/Lillestrøm	Asker 4
07.01.2018	15:00	B	Girls	15	Fet 3	Lillestrøm HK 3
07.01.2018	16:15	B	Girls	15	Fet 2	Skedsmo

Our variables would then be:

- Fet/Lillestrøm Boys 12 14:00 B
- Asker 4 Boys 12 14:00 B
- Fet 3 Girls 15 15:00 B
- Lillestrøm HK 3 Girls 15 15:00 B
- Fet 2 Girls 15 16:15 B
- Skedsmo Girls 15 16:15 B

The initial domain (possible values) for each of these variables would be the changing rooms:

- A1
- A2
- A3
- A4
- B1
- B2
- B3
- B4

Each of the constraints would limit which of the variables may have the same value. For example, “Fet/Lillestrøm Boys 12 14:00 B” cannot have the same value as “Lillestrøm HK 3 Girls 15 15:00 B”, because then they would have to share changing room, violating C4 (each changing room cannot be assigned to two teams at the same time). Yet we must still assign a value to those variables, or else we would be violating C5 (each team must have a changing room).

Similarly, we must handle the problem of the shared showers. If “Fet/Lillestrøm Boys 12 14:00 B” is assigned the value A1, then “Lillestrøm HK 3 Girls 15 15:00 B” cannot be assigned the value A2, since that would violate C1 (may share showers only if they share gender).

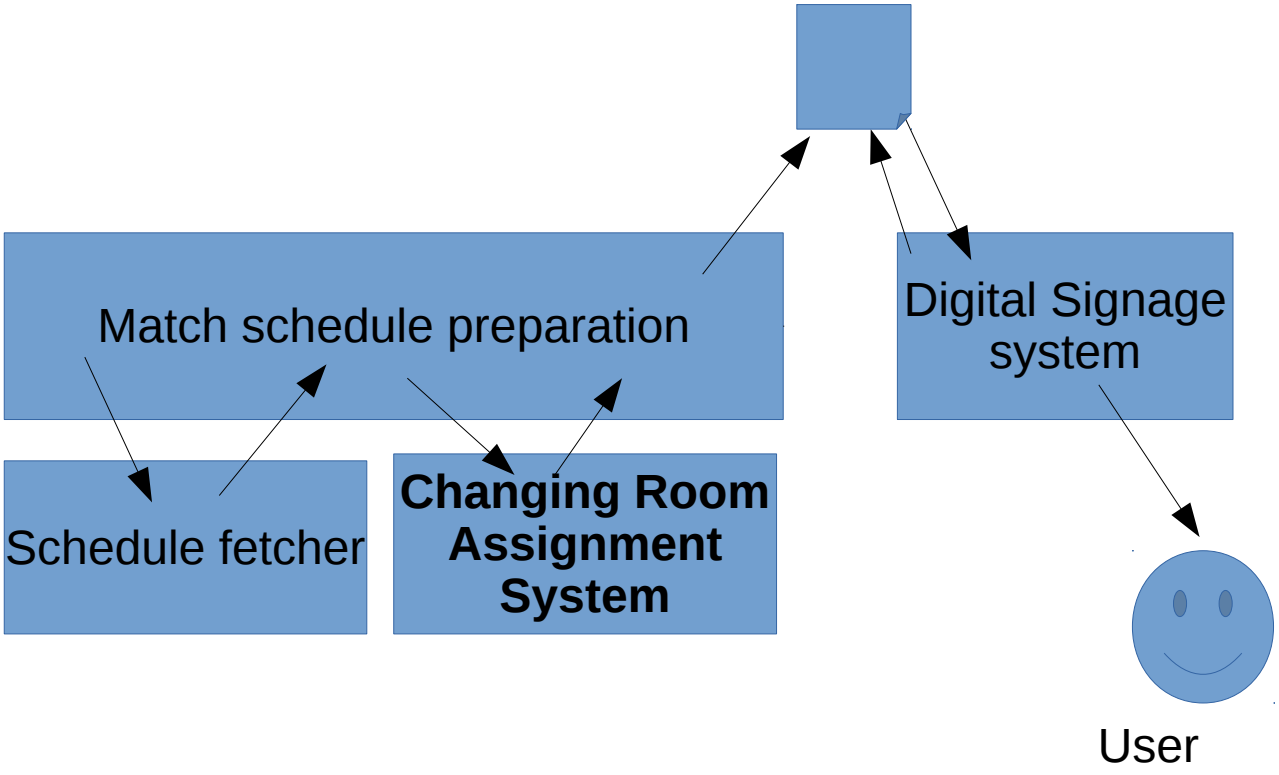
One possible assignment of values to variables would be as follows:

Variable	Value
Fet/Lillestrøm Boys 12 14:00 B	A3
Asker 4 Boys 12 14:00 B	A4
Fet 3 Girls 15 15:00 B	B3
Lillestrøm HK 3 Girls 15 15:00 B	B4
Fet 2 Girls 15 16:15 B	A3
Skedsmo Girls 15 16:15 B	A4

Architecture

The software architecture is sketched out in the following sections.

The big picture



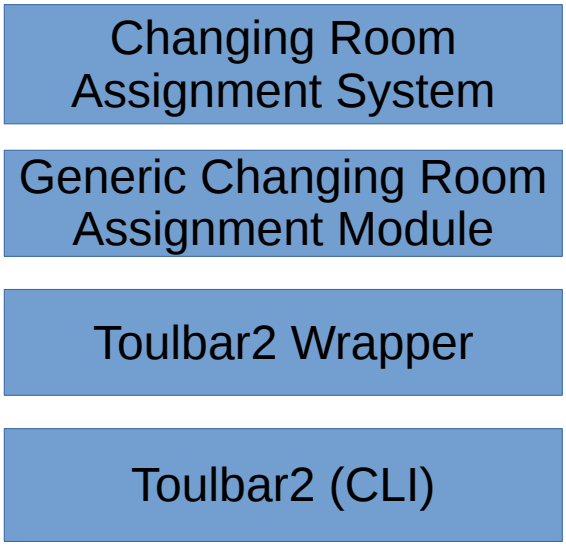
The system as a whole could be split into two parts: one is run once per day, preparing the schedule and assigning changing rooms. The result is then made available for the digital signage system. The job of the digital signage system is to parse the results and simply display them.

The reason for separating the two is because the digital signage system is written in PHP, and is deployed using a typical LAMP hosting service. This environment is not suitable for running the

changing room assignment system for two reasons: The process of assigning changing rooms may take more time than web servers are typically given, and you usually do not have enough rights to install separate programs such as Toulbar2 to help solve the weighted constraint satisfaction problem.

By separating them, the digital signage may keep its current environment, while the match schedule preparations are done regularly somewhere else. Additionally, the two systems need not use the same technologies, giving us some freedom.

Module view of the Changing Room Assignment System



A layered architecture is shown. The top layer handles the information specific about EIKA Fet Arena, telling the layer below about what teams need changing rooms, which changing rooms there are, which changing rooms share shower, which teams are opponents, which teams need changing rooms at the same time and so on. This is basically the environment the artificial intelligence works inside, providing the actor the sensors and actuators described earlier.

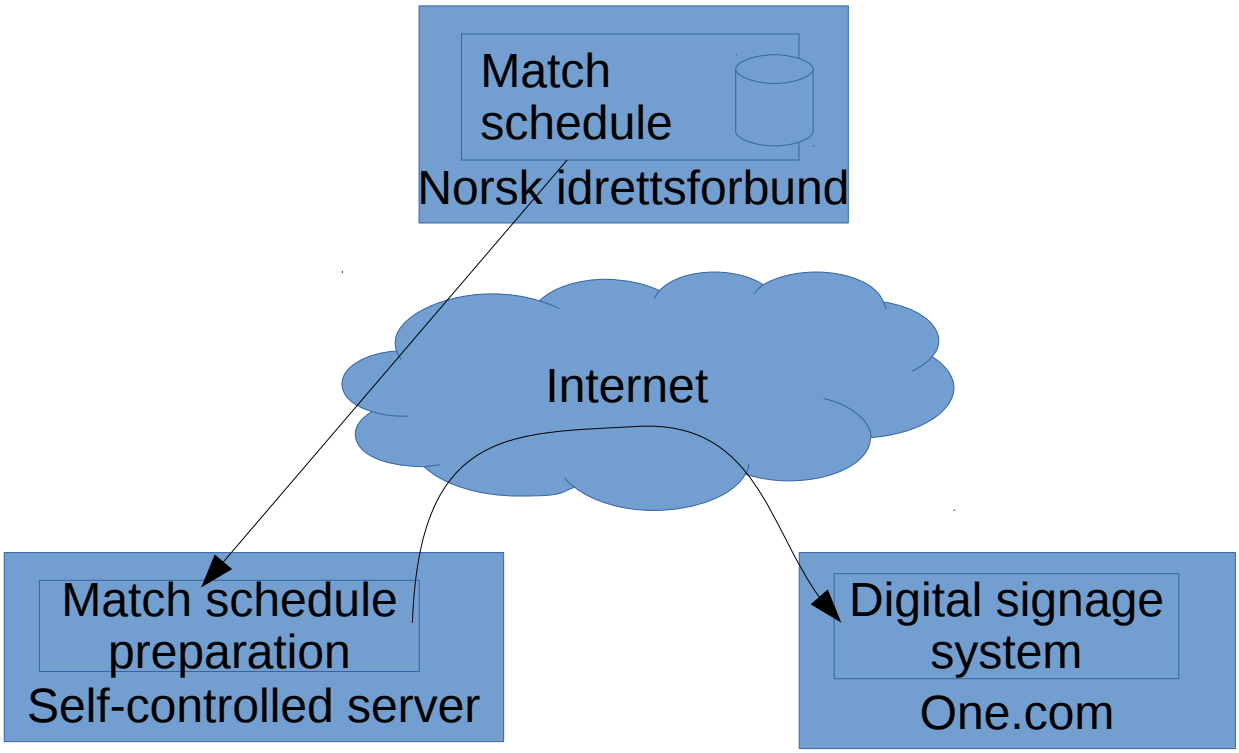
The second layer from the top is more generic, and can potentially be used by other sport clubs that wish to assign teams to changing rooms. It is responsible for mapping between the high-level concepts of the changing room assignment problem and their equivalent in the world of weighted constraint satisfaction problems.

The Toulbar2 Wrapper provides an abstraction over the Toulbar2 interface, letting you specify the different parts of the weighted constraint satisfaction problem in a natural way. It then translates this into a format understood by Toulbar2, specifically the “Weighted Constraint Satisfaction Problem” file format described on Toulbar2’s website. The wrapper also handles running the Toulbar2 program, receiving the solution and mapping it back to the abstraction the layer above expects.

The Toulbar2 program is assumed to be installed on the computer, and is run by the Toulbar2 wrapper. This is an already existing program, see http://www7.inra.fr/mia/T/toulbar2/documentation.html for details. The NumberJack Python module was considered, but its mental model is not a natural fit for the problem.

The layered architecture is used to make the program readable and promote modifiability, by ensuring the right level of abstraction is used for the different parts and separating concerns. It also promotes reusability, since the Toulbar2 Wrapper and the Generic Changing Room Assignment Module can be made into separate packages which other developers may use however they like, for instance through pip.

Physical view



The arrows indicate the flow of data. The match schedule is fetched from Norsk idrettsforbund, which has collected match schedules for several sports into one table. The changing room assignment is added, and the schedule together with changing room assignments is made available for the digital signage system. This may be done by making the result available through a webserver, transferring files or by some other means. The digital signage system then displays the data made available to it.

Possible problems

There are some problems which need special care going forward:

- There may be schedules which are impossible to satisfy
  - Especially floorball consists of matches with duration as low as 45 minutes, which means teams may not finish showering before the next team needs the changing room (assuming the teams don’t arrive closer to the match time)
  - What do we want to do when there is no possible assignment?

        - Decrease how long teams have access to their changing room (mainly by decreasing how long before the match they get access) and try again
        - Don’t assign changing rooms, and let the teams find one themselves
        - Notify volunteers, so they may try to allocate changing rooms manually
        - Cover the entrances to the shared showers, and relax the requirements related to shared showers (though this means the teams there won’t be able to shower)
- A self-controlled server may be hard to maintain
    - It requires that someone with the right computer experience is always available to volunteer for the sports club
- Weighted constraint satisfaction problems is an advanced topic
    - Even experienced programmers might not understand how it all works, as it depends on insights into this field of AI specifically
- We need more accurate times of when teams expect to have a changing room
    - While the ballpark figure of 45 minutes before match start was used above, this might be different between handball and floorball, and also between different age groups and home and visiting teams. More accurate estimates could be the difference between a possible and an impossible schedule
- Users of the arena may find the changing room assignments to be odd, since they don’t see the complexity involved. “I could do a better job myself”
    - There may also be problems with the schedule which are obvious to humans, but are not encoded in this solution
    - The system needs to reach a certain quality so it does not get a bad reputation among volunteers and players

Summary

Due to the shared showers at the new arena, a new system for assigning changing rooms to teams must be made. It must take into consideration the age, gender and relation between teams that will share showers, and should do its best to fulfill other preferences as well.

The problem of assigning a changing room to each team is identified as a Weighted constraint satisfaction problem. There exists solutions for solving such problems, but they are either not good enough or they are low-level, requiring a few levels of abstraction.

The issue of what to do with “impossible” schedules needs to be discussed inside the sports club, and the performance measure and the requirements should be assessed to verify that they match the expectations of volunteers and teams. It would also be great if the time of arrival of teams could be better predicted. For example, the author has no experience with floorball and does not know if the teams arrive as early as handball teams.