Tutorial XI - Arena Seat Planning under Distancing Rules

Applied Optimization with Julia

Introduction

Solutions

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Imagine you're tasked with optimizing seating arrangements for a major event venue during a pandemic. You need to balance safety with efficiency, ensuring groups can enjoy the event while maintaining proper distancing.

Your challenge is to:

1. Place different-sized groups strategically
2. Maintain safe distances between all attendees
3. Maximize either revenue or total attendance
4. Work around venue constraints and blocked seats

The Venue Layout

Here's our event venue's seating arrangement, as we have used in the lecture:

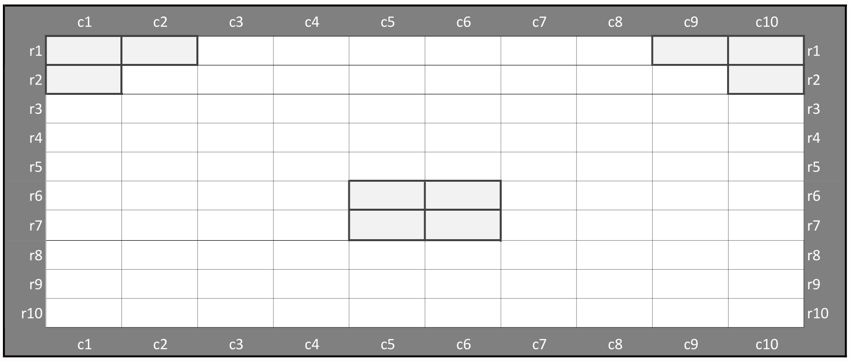

Figure 1: Each white square represents an available seat, while grey squares are blocked

Group Types and Their Characteristics

We have different types of groups wanting to attend the event:

- Singles (Type ‘a’): Solo attendees
- Couples (Types ‘b’ and ‘c’): Two people travelling together
- Small families (Types ‘d’ and ‘e’): Groups of four
- Large families (Types ‘f’ and ‘g’): Groups of six

Each group type has:

- A different ticket value (score)
- Limited availability (how many such groups want tickets)
- Space requirements (how many consecutive seats they need)

As we approach the end of the course, we’ll remove some previous “guardrails” to give you more freedom in solving the problem.

> **Tip**
>
> Don’t worry, if you cannot solve everything by yourself. Try your best and ask for help if you need it!

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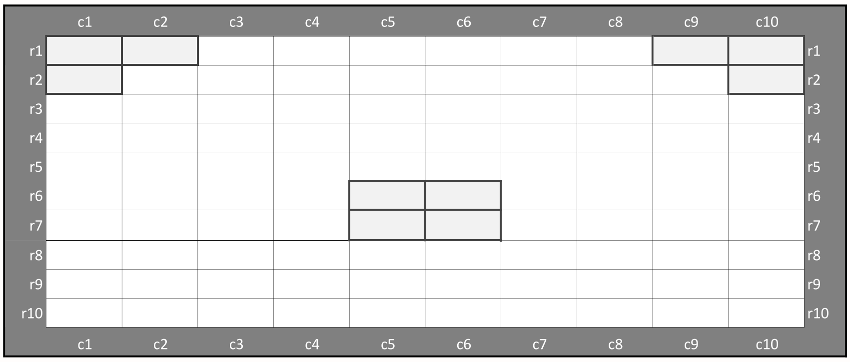
1. Implement the Model

First, define all necessary sets, parameters, and variables to model the problem in Julia. The seating area layout is shown below:



Distance Requirements

The following distancing rules must be maintained:

- Minimum one empty seat between groups
- One empty seat between rows
- One empty seat diagonally
- Maximum two groups per row
- Grey seats are obstacles and cannot be used

> **! Common Pitfalls**
>
> Watch out for the edge cases when implementing distancing constraints - especially around blocked seats!

Define the Model

> **i Note**
>
> The groups are given differently than in the lecture! Either adjust the data or the model, depending on what you think is easier.

```julia
using JuMP
using HiGHS

# Model
arena_model = Model(HiGHS.Optimizer)

# Sets
row_set = 1:10
col_set = 1:10

# Group data
groups = [
    "a",
    "b",
```

```
    "c",
    "d",
    "e",
    "f",
    "g"]
req_seats = Dict(
    "a" => 1,
    "b" => 2,
    "c" => 2,
    "d" => 4,
    "e" => 4,
    "f" => 6,
    "g" => 6)
scores = Dict(
    "a" => 1,
    "b" => 2,
    "c" => 4,
    "d" => 4,
    "e" => 5,
    "f" => 6,
    "g" => 12)
availability = Dict(
    "a" => 3,
    "b" => 2,
    "c" => 3,
    "d" => 5,
    "e" => 2,
    "f" => 1,
    "g" => 1)

# Blocked seats (coordinates [row, column])
blocked_seats = [
    (1, 1),(1, 2),(1,9),(1,10),
    (2, 1),(2, 10),
    (6, 5),(6,6),
    (7, 5),(7,6),
]

# Variables
@variable(arena_model, x[groups, row_set, col_set], Bin)

# YOUR CODE BELOW

# Suggested structure:
# 1. Create parameters
# 2. Set objective function
# 3. Add constraints
# 4. Solve the model
```

Visualization

To test your solution, visualize it with a plot in Julia. The visualization is a great tool to check if your solution is correct. We figure it is likely, that you won't have an applicable solution after the first round, even if your model is working correctly. If everything works from the start, great!

```
using Plots

# Create visualization of the solution
function visualize_seating(model)
    # Get solution values
    solution_matrix = fill("", 10, 10)

    # Fill matrix with group assignments
    for r in 1:10, c in 1:10
        for g in groups
            if value(model[:x][g,r,c]) > 0.5  # Using 0.5 to handle
floating point
                solution_matrix[r,c] = g
            end
        end
    end

    # Create color mapping for groups
    color_map = Dict(
        "" => :white,  # Empty seats
        "a" => :blue,
        "b" => :green,
        "c" => :red,
        "d" => :purple,
        "e" => :orange,
        "f" => :yellow,
        "g" => :pink
    )

    # Mark blocked seats
    for (r,c) in blocked_seats
        solution_matrix[r,c] = ""  # Empty string for blocked seats
    end

    # Create plot
    p = plot(
        aspect_ratio=:equal,
        xlims=(0.5,10.5),
        ylims=(0.5,10.5),
        yflip=true,  # Flip y-axis to match traditional seating layout
        legend=:outerright
    )

    # Plot seats
    for r in 1:10, c in 1:10
        group = solution_matrix[r,c]
        if group != ""
            group_length = req_seats[group]
            for i in 1:group_length
                if c+i-1 <= 10
                    println("Group $group in $r,$(c+i-1)")
```

```
                        scatter!([c+i-1], [r],
                                color=color_map[group],
                                label=nothing,
                                markersize=10,
                                markershape=:square)
                    end
                end
            else
                # Plot empty or blocked seats
                is_blocked = (r,c) in blocked_seats
                if is_blocked
                    println("Blocked seat in $r,$c")
                    scatter!([c], [r],
                            color=is_blocked ? :gray : :white,
                            markersize=10,
                            markershape=:square,
                            label= nothing)
                end
            end
        end

    title!("Arena Seating Layout")
    xlabel!("Column")
    ylabel!("Row")

    return p
end

# Display the visualization
p = visualize_seating(arena_model)
display(p)
```

If you encounter any difficulties ad cannot solve the problem, please document your issues here:

```
#=


=#
```

---

2. Maximize the number of seats in use

Now let's explore a different optimization objective! Instead of focusing on revenue, imagine you're trying to accommodate as many people as possible at your venue - perhaps for a community event where maximizing attendance is more important than maximizing profit.

> 💡 Tip
>
> Think about how this changes your objective function. What matters now is not the score per group, but how many seats each group occupies!

Try implementing this new objective while keeping all the safety constraints in place.

```
# YOUR CODE BELOW
```

Check if your solution is correct by visualizing it with the `visualize_seating` function below.

How many seats more are in use when compared to the previous solution? Write a short code that calculates and prints the difference.

```
# YOUR CODE BELOW
```

Solutions

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Bibliography