HTL Leonding
next level

HÖHERE TECHNISCHE
BUNDESLEHRANSTALT
LEONDING

SeatGen - The Seating Plan Generation Tool For Stadiums

DIPLOMA THESIS

submitted for the

Reife- und Diplomprüfung

at the

Department of IT-Medientechnik

Submitted by:

Michael Ruep
Michael Stenz

Supervisor:

Prof. Mag. Martin Huemer

Project Partner:

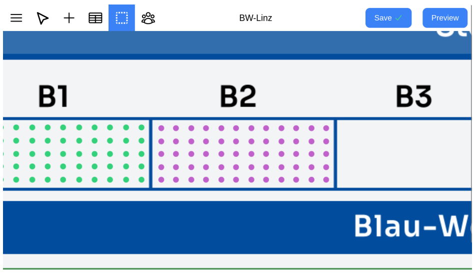
Solvistas GmbH

Leonding, April 4, 2025

I hereby declare that I have composed the presented paper independently and on my own, without any other resources than the ones indicated. All thoughts taken directly or indirectly from external sources are properly denoted as such. This paper has neither been previously submitted to another authority nor has it been published yet. The presented paper is identical to the electronically transmitted document.

Leonding, April 4, 2025 Michael Ruep & Michael Stenz

Abstract



Seatgen is a internal tool for the company Solvistas. We cooperated with Solvistas to help them with their organization and management of their product, which sells tickets for sport-events which take place in stadiums. Seatgen allows the members of Solvistas to create and edit stadium plans in a fraction of the time that it used to take. With a selection of our handy tools, the workflow to create an entire seating plan gets very efficient and allows the people to create, move and edit seats, areas and more. The tool is designed to be user-friendly and intuitive so that the people at Solvistas don't have to spend a lot of time learning new software.

Inhaltsverzeichnis

1 Introduction **1**

1.1 Initial Situation 1

1.2 Problem Statement 1

1.3 Goal 2

2 Context / Environment Analysis **3**

2.1 Overview 3

2.2 Stakeholder Analysis 3

2.3 Technical Environment and Constraints 4

2.4 Relevance of Direct Manipulation 5

2.5 Summary 5

3 Technologies **6**

3.1 React 6

3.2 Spring Boot and Kotlin 6

3.3 Database 7

3.4 AWS - S3 10

3.5 Leaflet 10

4 Implementation **11**

4.1 Frontend Architecture 12

4.2 Leaflet Integration 12

4.3 Map Generation 12

4.4 Add-Tool 12

4.5 Multiselect-Tool 12

4.6 Grid-Tool 12

4.7 Standing-Area-Tool 12

4.8 Optimizations 12

4.9 Design-Patterns 12

5 Summary **13**

Literaturverzeichnis **VI**

Abbildungsverzeichnis **VII**

Tabellenverzeichnis **VIII**

List of Listings **IX**

Appendix **X**

1 Introduction

1.1 Initial Situation

The company Solvistas GmbH is a software development company, and one of their main products is the Ticketing project. Ticketing is a software solution that enables customers to purchase tickets for seats or sections in stadiums and other venues hosting events. The software is used by various sports clubs and event organizers to manage ticket sales for their events.

1.2 Problem Statement

The as just mentioned stadiums and venues have a lot of seats and different areas, and therefore the Ticketing software needs to know the layout of the seats. These layouts can have lots of complex shapes like curves and other irregular shapes. The current process of creating these so-called seat plans is done manually by editing text files. There are many problems, and it's a very tedious process when editing seat plans within a text editor. To name a few: When changing the layout of a stadium, all the text files have to be reworked by a schooled developer. This costs the customer a lot of money, and the developer a lot of time. Also, it's very hard to imagine how the rendered plan looks, when staring at text files.

Uploading the plan image is another tedious task when creating new plans. To convert the given SVG file into a functional map compatible with their system, the developer must manually upscale and slice the SVG into tiles, repeating this process for each zoom level—typically 5 to 7 times. Additionally, since each tile is divided into four smaller tiles at every zoom level, the number of tiles increases exponentially. As a result, a massive number of files must be uploaded to an AWS S3 bucket, making the process even more time-consuming.

1.3 Goal

The goal of the diploma thesis was to develop a custom solution for the company Solvistas and solve all these aforementioned problems with a tool that's intuitive to use and easy to learn, saving time and costs. We wanted to create a visual editor to create and manage seat plans for events in a stadium. This editor allows customers to create and edit new seating plans themselves, making the process so accessible and easy to use that no more schooled developers are required to make changes in a seating plan.

@Huemer Milestomes ????

2 Context / Environment Analysis

2.1 Overview

Stadiums are typically operated by sports clubs, concert organizers, or third-party management companies. These actors want to sell their tickets efficiently and accurately for a large amout of offers. The environment is therefore characterized by:

- **Varied Layouts:** Modern stadiums feature a curved layout, irregular seat patterns, and different pricing tiers. Managing the seat data in plain text is error-prone and time-intensive.
- **Frequent Configuration Changes:** Depending on ongoing events and seasons, stadium layouts are frequently restructured, requiring updated seat plans.
- **Limited Technical Staff:** The event organizers often rely on external developers to alter seat plan definitions, creating additional costs.

From a user-experience standpoint, these challenges make it clear that an intuitive, graphical editing interface is needed to replace the text-based seat data manipulation. This concept aligns with the principles of *direct manipulation interfaces*, as described by Hutchins, Hollan, and Norman, which emphasize reducing the cognitive distance between user intent and system actions by allowing direct interaction with visual representations [1]. In the context of SeatGen, users can place, move, and edit seats through an intuitive graphical interface rather than modifying abstract raw text data. Similar to how direct manipulation in statistical tools allows users to interact with data graphs instead of numbers, SeatGen provides a **spatially direct approach** to stadium seat planning.

2.2 Stakeholder Analysis

Several parties interact with the SeatGen tool:

- **Developers:** Historically, Solvistas' developers modified the seat layout text files. Our new approach aims to minimize their involvement in the long term, except for initial and advanced configurations.
- **Event Organizers and Stadium Managers:** These stakeholders need the intuitive tools to make update to the seat maps without dealing with complex raw data formats.
- **Ticketing Platform Users:** The final seat layouts are used in Solvistas' ticketing service. Although these end-users do not edit the data themselves, the accuracy and clarity of seat layouts crucially impact their experience at the stadium.

By identifying these actors and their needs, we put the main focus on a graphical, user-friendly solution for seat map creation and maintenance.

3 Technologies

3.1 React

3.2 Spring Boot and Kotlin

For the backend logic, we chose Spring Boot as it is a core technology in Solvistas' tech stack. This decision ensures that the project remains maintainable by Solvistas developers in the long run. Our backend had several key responsibilities, including:

- Handling the storage of the seatplan metadata
- Converting SVGs into image tiles
- Uploading the converted tiles to an S3 bucket
- Serving all of this data to the frontend via REST

For image processing tasks such as resizing and slicing SVGs and PNGs, we initially considered Python due to its well-documented and easy-to-use image manipulation libraries like CairoSVG and OpenCV. However, we ultimately decided to keep the processing within the Java/Kotlin ecosystem, using libraries like Batik and ImageIO. While Java/Kotlin image processing is not as straightforward as Python due to less extensive documentation and fewer community resources, it allowed us to keep our backend technology stack consistent. Additionally, using Java/Kotlin ensured we did not need to manage separate runtime environments. One challenge with Java-based image processing is memory management—heap size and garbage collection must always be considered, especially when processing large images.

For file uploads, Amazon S3 provides excellent support for Java and Kotlin through the AWS SDK, with extensive documentation and examples. This made it easy to integrate S3 into our backend for storing and retrieving image tiles efficiently.

As for the language, we used Kotlin in Spring Boot even though it's not used in many of Solvistas' projects. We still decided that Kotlin was the better option because it is a modern language that is fully interoperable with Java and has many features that make it easier to write clean and concise code, thus reducing errors, improving readability, and maintainability. It eliminates much of the boilerplate code required in Java and provides a rich standard library with many built-in utility functions, significantly reducing development time. Kotlin has no essential functionalities that Java couldn't provide, but it is more modern and has a more concise syntax.

Additionally, Kotlin introduces powerful features such as null safety, which helps create more robust applications with fewer runtime errors. Furthermore, Kotlin provides strong support for functional programming, including higher-order functions, lambda expressions, and extension functions, making it easier to write expressive and reusable code.

Another key advantage is Kotlin's coroutines, which allow for highly efficient asynchronous programming without the complexity of Java's traditional thread management. This makes Kotlin particularly well-suited for handling concurrent tasks, such as processing multiple image transformations simultaneously which reduces our image processing time by a factor a lot.

Kotlin's seamless integration with Spring Boot also allows for idiomatic DSLs (Domain-Specific Languages), which can simplify configuration and reduce verbosity in code. The language's structured concurrency and intuitive syntax contribute to cleaner, more maintainable backend services, ensuring long-term scalability.

Finally, Kotlin's growing adoption within the Spring ecosystem, along with first-class support from JetBrains and the Spring team, makes it a viable choice for modern backend development. Its developer-friendly nature, combined with reduced verbosity and enhanced safety features, makes it a forward-thinking investment despite its lower adoption within Solvistas' existing projects.

In the end, we chose Spring Boot with Kotlin because of our team's expertise with the language and the fact that all other components of the Ticketing software were already written in Spring Boot.

3.3 Database

We chose PostgreSQL as our database for several key reasons. First, we required a relational database since our data follows a structured design that is best represented through classical relational models. Additionally, using a relational database simplifies the process of exporting generated data into the Ticketing database, which also adheres to a relational structure.

Our system is designed to be compatible with multiple relational databases, not just PostgreSQL, as we utilize Java Persistence API (JPA) as our Object-Relational Mapping (ORM) framework. To maintain database flexibility, we deliberately avoided PostgreSQL-specific commands. While leveraging PL/pgSQL for business logic could have provided benefits such as enhanced security, improved performance, and greater data consistency, we prioritized keeping our database implementation interchangeable.

For database connectivity in our Spring Boot application, we utilized the Spring Data JPA library. This library streamlines the process of connecting to a database and executing queries while implementing the repository pattern. Through this pattern, we define custom queries in an interface, which Spring Boot automatically implements at runtime. This approach simplifies query management, making it easier to maintain and use repository methods directly within our codebase.

To manage database migrations efficiently, we adopted the Flyway library. Flyway enables us to define database changes through SQL scripts that execute automatically when the application starts. This ensures our database schema remains consistent with the latest changes, significantly simplifying deployment and mitigating potential conflicts across different environments. Managing migrations this way also helps prevent issues arising from different database versions among team members. Additionally, since Flyway migrations consist of entire SQL scripts, we can execute both Data Definition Language (DDL) and Data Manipulation Language (DML) commands. This capability is particularly beneficial for tasks such as migrating data between tables, altering column data types, and implementing other business logic-related transformations.

When selecting a migration tool, we evaluated both Liquibase and Flyway. While both are open-source and provide seamless integration with Spring Boot and other Java frameworks, we ultimately opted for Flyway due to its simplicity and our specific use case. Since we are a small team with infrequent parallel database changes, Flyway's linear migration approach suits our workflow without introducing complications. Although this approach might present challenges in larger teams with concurrent database modifications, it remains a practical choice for our current needs.

Flyway also offers a cleaner versioning system by requiring migration filenames to follow a structured naming convention: `VX.X.X__migration_name.sql` (where X.X.X is the version of the migration). In contrast, Liquibase utilizes changelog files, which provide additional features but introduce unnecessary complexity for our use case. These changelog files can be written in SQL, XML, YAML, or JSON, but they require extensive Liquibase-specific formatting. The following example illustrates a Liquibase-formatted SQL changelog file 1. Flyway's approach, which relies on plain SQL migration files, makes it more readable and easier to maintain.

Listing 1: Liquibase example changelog

```sql
--liquibase formatted sql

--changeset nvoxland:1
create table test1 (
    id int primary key,
    name varchar(255)
);
--rollback drop table test1;

--changeset nvoxland:2
insert into test1 (id, name) values (1, 'name 1');
insert into test1 (id,  name) values (2, 'name 2');

--changeset nvoxland:3 dbms:oracle
create sequence seq_test;
```

To ensure database consistency, Flyway generates a flyway_schema_history table that tracks all executed migrations. This table stores metadata for each migration, including the version, description, execution timestamp, and a checksum. The checksum prevents modifications to previously applied migrations, ensuring consistency but potentially causing unexpected errors during local development. In such cases, manual intervention in the flyway_schema_history table may be required, but except for these rare cases the flyway_schema_history table should not be manipulated manually.

By maintaining this history, Flyway can determine which migrations have been applied and which are still pending. Each migration also has a state, which can be pending, applied, failed, undone, and more—detailed in the Flyway documentation. These states allow system administrators to quickly identify and resolve migration and deployment issues.

When considering how to store our image data, we evaluated PostgreSQL's built-in options, including BLOBs (Binary Large Objects) and TOAST (The Oversized-Attribute Storage Technique). While these mechanisms allow PostgreSQL to handle large binary files, we ultimately decided against using them due to performance concerns, maintenance overhead, scalability limitations and company reasons. Even though, TOAST is very performant and automatically compresses and stores large column values outside the main table structure, making it a more attractive option than traditional BLOBs, accessing and manipulating the stored images via SQL queries can become a bottleneck.

ORMs like Hibernate tend to retrieve large column values by default unless explicitly configured otherwise, potentially leading to performance degradation when dealing with frequent queries. This means extra effort would be required to optimize database queries to avoid unnecessary data retrieval, increasing development complexity.

3.4 AWS - S3

Amazon S3 (Simple Storage Service) is a scalable object storage service provided by Amazon Web Services (AWS). It allows users to store and retrieve large amounts of data in the cloud, with a focus on high availability, durability, and security. S3 is widely used for storing static assets such as images, videos, documents, and backups, and it is designed to provide low-latency access to data from anywhere in the world and in our case the image tiles of the seatplan. With features such as data encryption, versioning, and lifecycle policies, S3 offers a flexible and cost-effective solution for managing large datasets. S3 also provides an extensive API that allows developers to interact with their storage buckets programmatically. In this application we access the API via the AWS SDK for Java which is provided and maintained by Amazon.

In the Ticketing project, all image tiles are stored in an AWS S3 bucket. S3 was required due to its robust performance, reliability, and seamless integration with the AWS ecosystem, which is already in use at Solvistas. By utilizing the Amazon S3 SDK, the file upload process is automated, reducing manual effort and minimizing the risk of errors.

Using S3 also improves frontend performance by ensuring that image retrieval does not depend on the backend server's speed. Instead of acting as a middleware for serving images, the backend delegates this task directly to S3, reducing its workload and enhancing response times.

AWS S3 was the only option considered, as it is the cloud platform used by Solvistas, and the infrastructure costs are funded by the company.

3.5 Leaflet

4 Implementation

4.1 Frontend Architecture

4.1.1 React Components and Hooks

4.1.2 MapContext and Global State

4.1.3 Tool System and Event Handling

4.2 Leaflet Integration

4.2.1 Writing Extensions

4.3 Map Generation

4.3.1 AWS

4.3.2 Image Processing

4.4 Add-Tool

4.5 Multiselect-Tool

4.6 Grid-Tool

4.7 Standing-Area-Tool

4.7.1 Frontend

4.7.2 Backend

4.8 Optimizations

4.9 Design-Patterns

5 Summary

Literaturverzeichnis

[1] J. D. H. Edwin L. Hutchins und D. A. Norman, „Direct Manipulation Interfaces," *Human–Computer Interaction*, Vol. 1, Nr. 4, S. 311–338, 1985. Online verfügbar: https://doi.org/10.1207/s15327051hci0104_2

Abbildungsverzeichnis

Tabellenverzeichnis

List of Listings

1 Liquibase example changelog 9

Appendix