

Rent It

Software Development in Large Teams with International Collaboration,

*Second-Year Project,
Bachelor in Software Development,
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Group 12

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1 Preface

This report is the result of a project on the bachelor in Software Development at the IT-University of Copenhagen spanning from the 2nd of February 2012 to the 23rd of May 2012.

The project was given on the fourth semester of the bachelor and corresponds to 15 ECTS-credits.

The project ("Software Development in Large Teams with International Collaboration") is described as centered on developing and implementing a rental service for digital media. The goal is to develop a client-server solution backed by a relational database system.

Students work in the teams of four to six people and collaborate and negotiate with students from Singapore Management University (SMU) in English.

This specific project was done by five ITU students who collaborated with three SMU students.

The challenges of this projects were:

- Dealing with cultural gaps and time differences in communication with team members from Singapore.
- Sharing a balanced amount of information to have successful collaboration.
- Reaching agreements that both ITU and SMU students found satisfactory.
- Conducting constructive feedback on fellow students work.
- Constructing a client/server solution in C#.

Whenever we reference the Bibliography (found on page 29), we use the signature [1] to indicate such. [1] refers to the link to a blog describing "The Way of Testivus".

1.1 Scrum tracker, version control and service info

We use Git (at GitHub) as our version control system.

In addition, we use a free tool called Pivotal Tracker to track our user stories for the Scrum¹ development model we have chosen to use.

We have set up a server for publish a test copy of our service (and database). We use this service to automate tests of the client and the service interface.

git <https://github.com/itu-bswu/RentIt>

PivotalTracker pivotaltracker.com/projects/492063

Service address <http://rentit.itu.dk/RentIt12/Services/Service.svc>

Test Service address <http://rentit.dk:9000/Services/Service.svc>

Release database <http://rentit.itu.dk> (username: RentIt12Db — password: Zaq12wsx)

Test database rentit.dk (username: RentIT.dk — password: Vand22kanon)

¹Further detailed in our ?? chapter on ??.

2 Project overview

In this chapter we discuss our take on the project "Software Development in Large Teams with International Collaboration", what we feel are the important parts of the project, the must-haves of the final product and the assumptions we make going into our requirement specification.

2.1 Problem analysis

Not too many years ago, media rental of physical media was a lucrative business to be in¹. The last couple of years have been hard on companies making their business in physical media rental[3]. This is, at least partially, due to the increasing popularity of companies like Netflix[4] making it easier to rent media digitally, thus enabling users to do it from home and not spend time going to the actual shops.

To create a media rental service that would be seen as interesting (if not competitive), it has to be:

- Easy to use²
- Price competitive³
- (Optionally) Offer an expanded array of services compared to other services.

A wide array of media rental services already exist for books, movies/films, music and other media, so there are many sources to draw inspiration from. In addition, media rental services do not necessarily have to be run by private companies. Some institutions (like libraries⁴) offer similar services for citizens.

A service does not necessarily have to focus on one kind of media (like Netflix), as evidenced by Apple's iTunes Store[7].

In addition to subjects concerning normal users of the service, the project description also mentions administrators. Administrators can upload, delete and edit movie information on the service. Because these types of administrator users provide content, we have decided to refer to them as **Content Providers**. We make this distinction because we have a user type we called **Admins**⁵.

2.2 Assumptions and decisions

In order to narrow down the focus and requirements for our system, we make some assumptions and decisions in addition to the points raised in the problem analysis.

2.2.1 Choosing a service type

As described in the problem analysis, the existing types of media rental services can be narrowed down to a) free public library rental type and b) paid media rental. They can be very similar (depending on development choices) and both types present some security issues (user information, credit cards, etc.).

¹Blockbuster LLC[2] is an example of a successful company in the media rental industry.

²Piracy is a major concern, and if the service does not provide something that is (at least) just as easy to use, people would rather be inclined to download illegally rather than pay for content from a service[5].

³Rarely a problem with piracy, but if one services provides the same amount of media, support and access, price is certainly a factor.

⁴Roskilde Bibliotek is an example of a danish library providing similar functionality[6].

⁵Admins are explained in further detail in our Design chapter (page 14).

We decided to develop a paid media rental system, as we felt it had more options (such as payment models) in terms of functionality that could be implemented. While adding payment options is not necessarily a core requirement, we feel we should design our system with payment options in mind.

2.2.2 Choosing a media type

At first we wanted to make a streaming service for TV shows. This could involve paying for a single episode of a TV show or for a full season.

After doing some research on what streaming would involve (compared to just downloading and saving a file), we changed the way we let users access our content. Instead of doing streaming, we decided to just let users download movie files and store them on their system.

In addition we changed our media type. While we felt it could have been more interesting to do TV shows (compared to other types of media), we decided to pick a slightly less complex system and instead focus on designing the service to offer movie rentals.

We decided on this less complex system, because we wanted to make a compromise with the SMU students⁶ and still something that had a close relation with TV shows, but simpler.

2.2.3 Digital Rights Management

Digital Rights Management (DRM) is an issue we will most likely run into. While we may limit how long users have active rentals on the service, there is a technical challenge in making sure users cannot view the downloaded files after rentals have expired. We do not consider DRM functionality core in the service, but we do have it as an optional goal for our service.

2.2.4 Author rights

Author rights is another concept to consider. When we give Content Providers the rights to upload movie files, they may be able to abuse this by uploading files they do not have author rights to. We do not consider this a central focus point in our system, but in order to ensure a great quality service in a broader perspective, some sort of validation of uploaded material should be considered.

⁶Described in our ?? chapter on page ??

3 Requirements

This chapter describes the requirements (and optional features) for our system and project. We have translated the required features and some of the optional features into use cases. We create tests¹ and workflows for our system from the use cases, so that we can document and make sure that our system fulfills our requirements. The use cases are described on page 8.

3.1 Required system features

The project descriptions lists a number of requirements for the design and implementation of the service and client.

- The service must use a SQL server database.
- The system must run in multi-user environments.
- The service must be implemented in *c#* using Windows Communication Foundation(WCF).
- The client must enable users to access, administrate, upload and download medias.
- The graphical user interface of the client must be implemented in *c#* using Windows Forms, ASP or Windows Presentation Foundation(WPF).

Core Features The features listed below are the core features of our system. For us to deliver an acceptable system, we feel these features must be implemented, both on the service and the client, and must be thoroughly tested.

- User
 - Create a new user account.
 - Login.
 - Rent media.
 - Edit profile.
 - Download media.
 - View a list of all movies.
- Content provider
 - Login
 - Upload media.
 - Edit uploaded media.
 - Delete media.

3.2 Optional system features

Section 3.1 described the core features of our system. We consider those features the "bare bones" of our system. In addition to the core features, we have a number of optional features.

Some of these features are involve bigger design decisions than others. This means we may decide not to pick up a "High priority" feature before a "Medium" priority feature, due to time constraints or other other

¹Further described in our Testing chapter on page 26.

reasons.

The optional features we have decided to implement are in **bold**.

- High priority
 - **Searching for movies.**
 - **View movielists with different sorting.**
 - **Movie release dates.**
 - **Logout.**
 - **View rental history..**
- Medium priority
 - **Movie editions (SD, HD, Director's Cut, etc.).**
 - Implement cost for rentals.
 - Let users rate/review media.
 - Store information (Service-end) for analytical and statistical work².
- Low priority
 - Stream media from the browser (no download necessary).
 - Social network integration.
 - Allow users to buy products instead of renting them.
 - Instructions and/or tooltips.
 - Age ratings.
 - User banning.
 - Trailers.
 - "Featured" movies.

High Our high priority features are largely quality of life, yet almost core features. Users are used to being able to search for what they want, so we feel this should be one of the first things we do beyond the core. Additionally we feel that release dates gives the user more information and more ways to sort the movie lists.

Medium The medium priority features are expansions of our core features.

The implementation of rental costs is the most interesting one, yet also what we feel is the most advanced of the options. Because we want our system to handle paid media rental³, rental costs should be a priority. On the other hand, we feel that if we go for implementing rental costs, we should also design payment options, GUI for the payment and more.

In contrast, the other options are much on the same scale, but do not necessarily have the same amount of extra design time.

Low Low priority features are nice to have but not necessary.

Integrating social networks and streaming media in the browser are cool features, but we risk taking development time away from the core features to add optional features that do not really add much to the system as a whole.

Instructions, manuals, online help and tooltips are nice usability features and they may improve the product as a whole, but if we take development time away from the core features to create these usability features, we may end up with a manual for buggy/non-functional software.

²We have implemented a distinction between a users current rentals and rental history.

³Discussed in section 2.2.1 on page 4.

3.3 Additional project requirements

In addition to our required and optional features, we have a number of project requirements to make sure we deliver a good product.

- Collaboration
 - Use a version control system.
 - Document design decisions.
 - Use an iterative development strategy.
 - Feature freeze May 8th After this date, no new "features" can be added..
 - Code freeze May 18th.
- Quality Assurance⁴ (QA)
 - Use cases must be covered by tests⁵.
 - Test code coverage must be thorough⁶.
 - * Minimum overall coverage of the service project: 50%
 - * Goal for overall coverage of service: 85%
 - * Critical sections of service: 80%
 - All code must be documented⁷.
 - User interface must be usability tested⁸.

3.4 Use cases for the system

These are the use cases for our system. The use cases only include requirements that we have managed

User management

- A user wants to create a new account.
- A user wants to login.
- A user wants to edit his profile.
- A user wants to logout.

Browsing media

- A user wants to view a list of all offered movies.
- A user wants to browse movies by their release date.
- A user wants to search for a specific movie title.
- A user wants to view all movies of a specific genre.

⁴The requirements listed here are what we feel need to be successfully covered so that we can say we deliver a well tested product.

⁵Functionality must be tested on both the service and the client if possible.

⁶See chapter 8 Testing for reasoning behind numbers.

⁷XML headers for classes, fields, constructors and methods. Additional comments if deemed necessary.

⁸

Media rental

- A user wants to rent a specific movie edition.
- A user wants to view all of his previous rentals.
- A user wants to view his current rentals.
- A user wants to download a current rental,

Content management

- A content provider wants to register and upload a movie.
- A content provider wants to register a movie.
- A content provider wants to upload an edition to an already registered movie.
- A content provider wants to edit information about a movie.
- A content provider wants to delete a movie.

4 Collaboration

This chapter will focus on how we worked together as a group, how we worked with the SMU team, what problems we ran into and what could have been done differently.

4.1 Collaboration

When we began the project, we decided on using the agile form for development known as "SCRUM". SCRUM is a development form where the team works in "sprints", which are a period of time in which the team is supposed to work on certain features. These features are called "user stories", which consist of a name, a short description and an estimation of how much time it takes to complete the story. Each user story describe a feature that the team is supposed to develop over the current sprint, and they can be prioritised by the product owner if the product owner wants a certain feature finished before another feature.

SCRUM also contains daily meetings/stand-up meetings, in which everyone from the team stands up and tells what they have been working on since the last meeting, what they intend to work on until next meeting and if anything can prevent them from doing this work. These meetings gives the team a good overview of what's been finished, and what still needs finishing. Furthermore, it gives the team an opportunity to discuss problems that have been encountered, and how to solve these problems.

Another important part of SCRUM is the so-called "retrospective". At the end of every sprint, each team-member writes down some good and bad things that happened during the sprint. These points are all gathered, and discussed by the team, after which the team decides on what points to improve during the next sprint. This allows the team to become improve over time, which, in the end, leads to a better project, both in terms of finished product, but also in terms of how the team works together.

4.2 ITU group structure

Having decided upon using SCRUM for our project, we had to distribute the roles we wanted to use. More precisely, we had the following 4 roles to distribute:

Product Owner The Product Owner is the person/company who has ordered the product. Normally, this would be a specific person or company, but in our case that isn't entirely true. Technically, our lector is the one who has "ordered" the product, which normally would make him te product owner. However, we also had the Singaporeans to take into account, as they had a say in how the product was supposed to work, as they were supposed to be able to use it as well.

In the end, we decided that the Product Owner should be a combination of our lector along with out Team Leader, as they are the ones who confirm whether the product lives up to the demands.

Team Leader The Team Leader is responsible for making sure that people get their stuff done on time, making sure that people show up to the agreed time, making sure that the team is functioning well, etc. The Team Leader is basically responsible for the whole team. If the Product Owner has a problem with regards to the team, he should contact the Team Leader and let the Team Leader take care of it.

In our team we had two candidates for the Team Leader; Niklas Hansen and Jakob Melnyk. After some talking, Jakob decided to let Niklas get the Team Leader role, as it turned out that it wasn't something he was very interested in anyways.

SCRUM Master The SCRUM Master is responsible for ensuring that the SCRUM process is used as intended. A key part of his role is to keep the team focused on the user stories, and make sure that the team isn't distracted by outside influences. In our group, we also decided to let the SCRUM Master take control during the daily meetings, the sprint plannings and the retrospectives.

For our SCRUM Master role, we decided upon Frederik Lysgaard, as he was the one who showed the most interest in the role.

QA Responsible The QA Responsible is responsible for taking a look at stories that have been finished, and making sure that they work as intended. This includes running tests that have been written for the story by the team member who was responsible for the development of that specific story. The QA role was given to Jakob Melnyk because he is very good at making sure that things work as they are supposed to.

The second thing we had to do with regards to roles, was to decide whether we wanted the roles to rotate on a certain basis, or just let people keep the roles until the end of the project. After some discussion, we decided to keep the roles static. Had we changed them every so often, it would cause confusion for both us and the other group, which is why we decided to keep the roles static.

4.2.1 Meetings

As mentioned in the description of SCRUM, meetings are an important part of SCRUM. This meant that we had a lot of focus on meetings, which will be discussed in this section.

In the beginning, we decided to meet on Mondays from 12.00 to 14.00, and Tuesdays and Thursdays from 12.00 to 16.00. Later on, we decided to meet every day except Friday and Sunday, from 10.00-16.00. When we met during these times, we'd start off with a stand-up meeting, where we told each other what we had been working on since the last meeting, and what we intended to work on until the next meeting. After the stand-up meeting we would begin working on our tasks.

Stand-up meetings weren't the only kind of meeting we had, though. Every second Tuesday we would have our retrospective meeting, in which we would discuss how the sprint had gone, and what we could improve on. Using these meetings, we kept improving our work, both with regards to how we worked, but also with regards to the quality of our product.

The last type of meetings we used, were the sprint planning meetings. On these meetings we would take a look at new stories, estimate them and prioritise them, according to which stories our product owner wanted finished first. We would then assign the stories to team members, after which we would work on them. The sprint planning meetings were also used to take a look at our status, see how many stories we had completed in the previous sprint, and how many that were left. The ones left would be prioritised higher in the next sprint, so we could have them finished and begin working on new ones.

4.3 SMU cooperation

We were to work in teams on the ITU side, but that wasn't the only teamwork that was to be done in this project. It was planned that we should collaborate with a group from Singapore Management University during the project. This meant that another "dimension" was added to the project, as we suddenly were to communicate with people whom we had never met, and whose skills we knew nothing about. It turned out to be more of a challenge than expected, as we learned during the course.

We were introduced to the SMU team the 6th of March, where we agreed on using Google+ Hangout (video conference tool) as our method for communicating during meetings. For communication that did not relate to the meetings, we agreed on using email, as it's an efficient tool for communication. It also has the advantage

that everything that is sent back and forth is documented, and thus can be looked at at a later date, if need be.

4.3.1 Meetings

The abovementioned meetings were scheduled to be every Thursday around 13.00-15.00 depending on the day. We had a total of 5 meetings with the SMU team [reference to meetings in appendix], in which would update each other on how we were doing, after which we would begin talking about what our plans were until the next meeting. The meetings were also used for sharing ideas about what both groups wanted the service to be able to do.

4.3.2 Conflicts

Working with the SMU team was quite a new experience for us, as no one from our team had worked with a team from that far away before. The only expectations we had, were from what we had been told during the lectures. Therefore, we had hoped that working with the SMU team would be relatively painless, and it looked like that was the case at the beginning. But as time went by, we ran into different problems with regards to working with the SMU team, which will be discussed here.

Mood Changes

The use of Google+ Hangout as a video conference tool improved our communication during the meetings. Unfortunately, it did not mean that we were able to predict some of the “mood changes” that the Singaporeans had. During our meetings we’d agreed with them on something, and the next day we’d receive a mail saying “can we do it this way instead? ”, with their suggestion usually being something completely opposite of what we had agreed on. Whenever this happened, we’d end up having an email conversation with the Singaporeans, and in the end we would come to a solution that both sides would agree on.

Wrong API

This wasn’t the only problem we encountered with regards to communication. They had spent some time looking at an API over before they sent us an email with questions about it, and when we received the questions we had no idea what they were talking about. Somehow, they had managed to find an API that wasn’t ours, and they had been looking at that one instead of ours. This led to confusion and a mail conversation, but in the end we managed to make them look at the correct API.

Misconception

On our end there was also some misconception with regards to what they were capable of, with regards to programming. We thought that they were about our level when it came to programming, but it turned out that they weren’t. This meant that some things were not done correctly on their end, which resulted in extra work for both ends, along with a lot of extra emailing between the two groups.

Behind schedule

This is not to say that they created all the problems, as we had some problems on our side as well, problems which impacted their side. For example we had some database issues at the beginning of the project, which pretty much prevented us from developing anything for a week. The database issue put us behind schedule, and because of that, the Singaporeans were put behind schedule.

Error reporting

The fact that the Singaporeans were put behind schedule turned out to be a major problem, as they were rather slow to report when they encountered problems. Towards the end of their schedule, they were unable

to make our service work for them, and they didn't tell us until they were approaching their own deadline. We managed to solve the issue, though it could have been handled a lot better and faster if we had received their report earlier.

4.3.3 What we could have done differently

All of the abovementioned problems can be said to have happened because of one problem: Bad communication. Not only in the sense that there wasn't much communication between the groups in general, but also in the sense that we talked "past" each other. As stated at the beginning of this chapter, we use SCRUM on the ITU side, and from our second meeting with the SMU team, we thought they were using SCRUM as well. However, during the process, it felt like they were using another form for SCRUM than we were, if even that, as they wanted to implement the full service at once, instead of working on it over time.

This problem, along with a lot of the abovementioned problems, arose because of bad communication, and could easily have been prevented. If we had spent an hour talking with the SMU team, we would have been able to figure out how exactly they were running their project, and we could have told them how we ran our project. This way we'd know what to expect from each other, and we would have an easier time figuring out how to help each other when needed.

Another thing we could have done as well, was simply to communicate more. We didn't have that much communication with the SMU team overall. The largest part of our communication happened during the meetings, and over the email conversations after each meeting, where questions were asked and answered. Between the meetings, the amount of conversation was fairly small, which of course meant that we didn't know how the SMU team was doing.

The last thing we could have done differently, was to be more insistent when it came to getting updates from them. We sent some mails to them once in a while, asking for status on their end, without receiving an answer. This led us to believe that everything was fine on their end, which it turned out that it wasn't.

In short, more, and better, communication from the beginning would have done wonders for the project as a whole.

5 Design

5.1 Database

A good designed database can help out a lot in development. If adding foreign keys and unique constraints, the integrity of the data in the database will be high, and we can trust that data when implementing our service. We don't have to worry about whether or not a movie still exists, when we receive a movie ID from another table.

This is why we decided to put a lot of effort into our database, as we knew we would benefit from it in the long run.

5.1.1 Analysis

Decisions

When we started designing our data model, we had to decide on how much data we want to contain in our databases. We could go all-in IMDB-style, and keep information about actors and cast of each individual movie. Or we could do the exact opposite, and only keep the relevant data for the user to identify a movie.

We decided not to include actors, as IMDB provides this functionality brilliantly for free. Of course it would be nice to have these information, so that our users wouldn't have to go to two different services, to get the job done. But this isn't crucial for the service to work properly, so we decided to just include enough information for the users to identify the movies, and if they need more information than that, they can use IMDB.

We decided to focus on simplicity and feature completeness in general, instead of adding a lot of half-done feature and/or untested functionality. In our experience it is better to have a program with limited functionality that does what it is designed to do quite well, instead of having a lot of features, which aren't finished and isn't properly tested. This of course meant a very simple data model, that would evolve over time, to only fit those requirements we ended up implementing properly.

ER-model

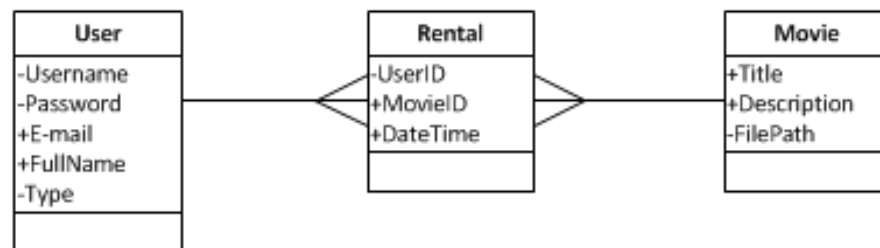


Figure 5.1: Initial datamodel

Figure 5.1 displays our simple initial data model. This captures the basic information about users, such as username, password, email address and the user's full name. We also have a field called type, representing whether a given user is a normal user, a content provider or a system administrator.

To begin with we also only wanted to capture the basic information about the movies, like title, description, genre and the file path. To finish it off, we added a table for capturing movie rentals. This basically was a junction table, with references to the user renting the movie, the movie being rented and the time of the rental.



Figure 5.2: Final datamodel

Since we were using scrum and were working in sprints, our data model was constantly evolving. Figure 5.2 shows our final data model. We only added elements to the code and the data model when it was needed. This of course means that our data model changed quite a lot over the time of the project, where we could probably have designed it up front and let it be through out the project. But since it can be hard to figure out what features we actually wanted to implement two months into the future, we did it this way.

The most important changes are the Genre and Edition tables. The problem with genres beforehand, was that in order to add multiple genres to a movie, they must all be added to the same string, split by a pre-defined delimiter. Besides that, it was complicated to add and remove genres, and genres couldn't be re-used. That's why we separated it from the Movie table, and joined them by a junction table called HasGenre.

We decided to make it possible to add several editions of a movie (like SD, HD, Director's Cut and so on), and these should have their own files. That's why we made the Edition table and movie file path from Movie to Edition. We also changed Rental to reference a specific Edition instead of a Movie.

SMU involvement

The SMU team didn't impact our data model a lot directly, as the database is an element behind the scenes of the service, and the data model doesn't directly affect a client team (such as SMU), as long as everything works as it should. But to be safe we did send our data model to them, for them to review and give ideas.

One of the suggestions, that we actually ended up implementing, was the release date. They suggested adding a release year, and after a little talk back and forth, we ended up expanding the idea. We ended up adding a release date to movies, and decided that movies with a release date in the future could not be rented before that date, giving greater flexibility to content providers.

They also suggested adding a price to movies and adding an end date for rentals. These suggestions were put in the product backlog, to be implemented if we got the time.

5.1.2 Tables

User

user_id The user's unique ID number.

username The user's unique username - used for login.

password The user's password - hashed and salted.

email The user's email address.

full_name Full name of the user.

type User, Content provider or System administrator.

token Unique session token generated at login and cleared at logout.

The User table contains data about our users. To provide some security to the passwords, we salt and hash (with the SHA512 algorithm) the passwords before putting it into the database. This means that if the database is hacked, then, unless they know the salt, they will still have a hard time figuring out the password of the users. The value in the password field will be useless to them, so they only find out the usernames and they will need to try and login to our service with all possible passwords in a bruteforce attack, to try and figuring the passwords of our users. The problem comes up if they get access to our codebase, as they will also get access to the salt. This will make them able to bruteforce the passwords locally (and not using the login feature on our service), which will be much faster.

The "Type" field is an integer (since SQL Server 2008 doesn't have enum support) between 1 and 3. A value of 1 means that a given user is "just" a normal user, where a value of 2 means that the user is a content provider. A value of 3 indicates a system administrator.

The "token" field is a session token. We didn't look much into the different WCF bindings, but we found a binding with streaming support, but with no session support. So we created our own sessions, by generating a session key upon login. This session token is then stored in the "token" field, and is cleared upon logout. This session token has to be provided at every service call (that requires the user to be logged in).

Movie

movie_id The movie's unique ID number.

title Title of the movie.

description A more or less detailed description of the movie.

owner_id Reference to the user creating the movie.

release_date The release date when the movie is available for rental.

The Movie table is quite straight forward. A movie has a title and a description to help identify the movie. The "owner_id" is a reference to the User table, to a content provider that created that movie. The release date is quite important. We took a decision to view all movies (also the ones not yet released) to the user, but it is only possible to rent a movie that has been released, and a movie has only been released if the release date has been set and is a time and date before the current time and date.

Edition

edition_id The edition's unique ID number.

movie_id Reference to the movie the entry is an edition of.

name Name of the edition.

file_path Relative file path to the video file.

An edition belongs a movie, and is referenced by the “movie_id” field. An edition can only belong to one movie, as it wouldn't make much sense to share editions between movies, as an edition has its own file path, and these are not shared between movies. The file path is a relative path, based from the movie root folder. Currently it is only a file name, but it is called “file_path” if this was to be changed later on.

Genre

genre_id The genre's unique ID number.

name The name of the genre.

We changed this to be its own table, when we discovered that a movie very easily can be of several genres, and instead of putting all these together in one string with a delimiter in between, we decided to move it to its own table. It also makes it easier to re-use genres, which will make it easier when searching for a specific genre, as it is quite easy to misspell a genre. So when the most genres already have been added, and the system suggests genres for a given movie upon creation, genres are re-used, which makes it easier to browse genres.

HasGenre

hasgenre_id Unique ID.

movie_id Reference to a movie in the Movie table.

genre_id Reference to a genre in the Genre table.

Junction table used to associate genres with movies. Contains references to a specific movie (by the “movie_id” field) and a reference to a specific genre (by the “genre_id” field). This is a many-to-many relationship, as a genre can belong to multiple movies (which is the reason we did it this way), and a movie can easily have multiple genres.

Rental

rental_id The unique ID number of the rental.

user_id Reference to a user in the User table.

edition_id Reference to an edition in the Edition table.

time Time of rental.

This is probably the most important database in a rental system: the tracking of rentals. This has been made quite simple. We capture the user renting the movie edition, the movie edition being rented and the time of rental. As our rental period is 7 days, we don't need to save the end time of a rental, but if we were to make it more dynamic, this would be a field to add.

5.1.3 Entity Framework

We used Entity Framework version 4.1 as an ORM (Object-Relational Mapping), which is Microsoft's ORM to compete with NHibernate and the like. With Entity Framework it is possible to query data with LINQ (the so-called LINQ-to-Entities), but where Entity Framework really shines, is that it focuses on code over configuration. There isn't any need to do a lot of configuration to get it working.

There are four different ways of getting started with Entity Framework, where the two last ones mentioned below are more or less the same approach, but in a different order:

Model-First Drag and drop. You get a visual editor where you can create new boxes (which will end up as tables and entities) and put lines between them, to model how the different entities interact with each other. An XML-file is created automatically, and the database and entities are created from this.

Database-First The other way round compared to Model-First. You start with creating the database, and then Entity Framework creates the XML file from the database. Then, just like Model-First, entities are created.

Code-First With code-first you start out from the code. You create your own entities, which are a lot simpler than the generated entities in the two previous modes. These are called POCO-classes, which means "Plain Old CLR Objects", referring to the simplicity of these classes. When the POCO entities are created, you get Entity Framework to create the database for you.

Code-First The final way of doing it is also called Code-First, but you start out with the database. Code-First doesn't refer to what component you start out with, but it means that you are "code-centric". Just like Database-First you start out with creating the database, and then use a simple tool for Visual Studio to generate the POCO entities from this database. This is also nicknamed "Code-Second".

We chose to use Code-Second, as we really wanted to get the simple POCO entities. The reason being that we wanted to send these entities back and forth over the service to transport data, but without any trace of Entity Framework. The reason we chose Code-Second over Code-First, is that we have more control over the database with Code-Second. Entity Framework doesn't add any indices or unique constraints by itself, so to get these, we had to create the database ourselves.

This has proved to be a bit more difficult than first expected, as no-one in our team had experience with SQL Server 2008, which is different from MySQL in certain areas. If we used Model-First, anyone in the team could have changed the data model, where as with Code-Second either the entire group had to read up on SQL Server and T-SQL or one team member should be responsible for the database part all by himself. We chose to pick one person as the database responsible, to make sure the rest of the group could continue working on the service in the meantime. This meant that only that person could alter the data model, but we did get complete control over our data model and database, which we felt was a big advantage.

5.2 Service

5.2.1 Analysis

5.2.2 Architecture

5.2.3 Interface

SMU involvement

5.3 Client

This section covers design decisions we made regarding the client implementation and Graphical User Interface (GUI) design.

5.3.1 Analysis

We looked into what architectures were commonly used and suggested when developing a client with a GUI front-end and a WCF-service backend. We have seen (and used) the **Model-View-Control** (MVC¹) before this project, and we felt it fit nicely with having a model (the service), a view (GUI) and a controller to make it all work.

While looking into MVC and how we could apply to our client, we found the **Model-View-Viewmodel** (MVVM²) architecture pattern. The MVVM pattern is based largely on MVC, but is targeted at modern UI development platforms (such as HTML5, Windows Presentation Foundation and Silverlight).

Because we decided to use Windows Presentation Foundation (WPF)³, we decided that trying out the MVVM-pattern felt like a good idea. MVVM offers a complete separation of the model (in our case the WCF service) and GUI. The viewmodels serve as translators (and sometimes logic functionality, depending on implementation).

5.3.2 Our version of the MVVM Architecture

Having decided on using the MVVM architecture, we decided to implement⁴ our own version of it (instead of using frameworks set up to use MVVM). It gave us more control over what we wanted to do with the architecture, as well as letting us make our own twist on it.

The biggest change we have made to the usual architecture⁵ is our interpretation of models. Instead of having models be the actual database, we use it as a communicator with the service. The MSDN blog post on the MVVM architecture [11] and how it can be used with WPF and a WCF service, the model is described as being the actual service.

In our approach, we design the models as being separate classes with an interface that the view models can use. This completely separates the viewmodels from the service calls (meaning the model could actually be anyway, as long as it implements the same interface). We will still use classes and objects from the service reference in the view models, but to change the data/service the model accesses, one could simply use the model to translate the types into the types from the service reference. This allows a modular approach to the system.

¹Wikipedia description of Model-View-Control[9]

²References on Wikipedia [10] and MSDN [11]

³Decision described in section 6.2 on page 21.

⁴How we implement this is described in section 6.2.1 on page 21.

⁵View(GUI)-Model(database/datafiles)-ViewModel(translator).

Because we have a modular approach to the model-viewmodel relationship, we feel the view-viewmodel relationship should be modular as well. Because of this, the implementation of the view models could change vastly without having any real effect on the views (except if it changes interface).

5.3.3 Graphical User Interface

Designing the GUI we had two different approaches. One where we opened a new window each time the user would access a new functionality, and one where we had one window in which all the functionalities would be shown. The design team tried out both options and found that having multiple windows to show the functionalities in was to clumsy and would disturb the users more than help them. We therefore went with the one window solution, since it felt naturally and we could represent new functionalities without disturbing or confusing the user. With the one window design we had each functionality page consist of three areas: In the top we had shared buttons for the user type, in the middle we represented the page content associated with the functionality and in the bottom we had the buttons associated with the page content. See figure 5.3 on page 19 for graphical representation.

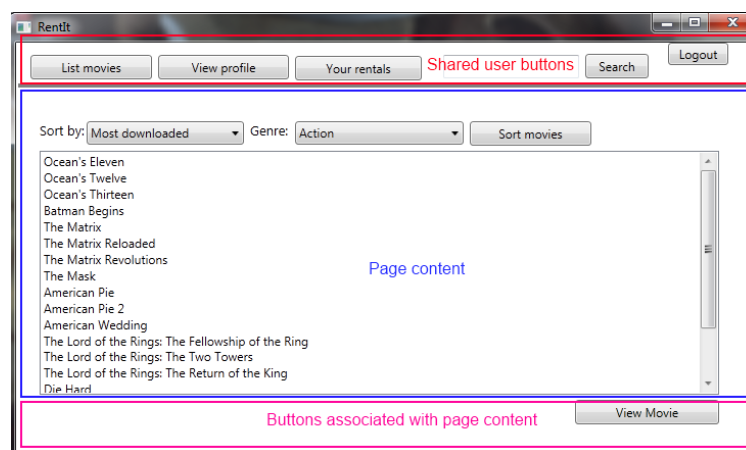


Figure 5.3: Graphical representation of the overall GUI design

Usability

When we began designing our GUI, we felt that it was important it was user friendly. Therefore, we choose to make usability tests (see 8.1.3), since they always will grant some degree of usability if performed correctly. In total we conducted two usability tests.

From the first of the tests, the feedback told us that we didn't have enough user confirmation in the GUI. We discussed this in the design team and came up with a solution, which added dialog and confirmation boxes to a lot of our buttons which contained a save function (see figure 5.4on page 20).

In the second usability test, we went from testing on a papermockup of our client, to testing on our client prototype, which incorporated the design changes from the first test. In this test, we received no feedback concerning the lack of conformation in the client, which meant that we had sovled the problem from test one. We did however get feedback on the navigation of the client. Our test users found it hard to navigate to the correct pages during tests. They said that either they had to navigate through too many pages to get to the correct one or the buttons were named ambiguously. For example, one of the users thought that the view movie button would play the selected movie when clicked.

Unfortunately, the second usability test was carried out too late in the process, which meant that we didn't have time to incorporate changes to the client. If we had had time, we would have done the following: We

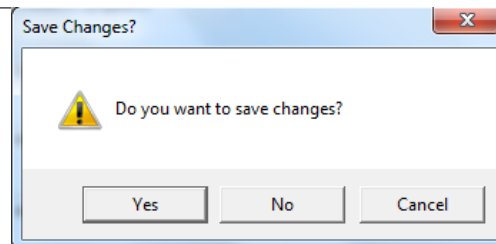


Figure 5.4: Confirmation box

would have revised the naming of our buttons, such that there would be no confusion with regards to their functionality. In addition, we would make changes to our "menu bar" at the top of the client, such that the user would always have more pages to navigate to. This would make unnecessary navigation through other pages redundant.

6 Implementation

6.1 Service

6.1.1 Architecture implementation

Issues, workarounds and fixes

6.1.2 Error handling

6.2 Client

6.2.1 Architecture implementation

Model-View-ViewModel

Windows Presentation Foundation

Issues, workarounds and fixes

6.2.2 Error handling

7 Manual

7.1 Client

7.1.1 Navigating the client

The following section will be a short manual on how to use the client when trying to perform two standard tasks: to rent a movie from the service, and to upload a movie to the service.

Renting a movie

The first thing you see when you start the client is a login page that requires your username and password, if you are not already a user you can press the signup button which will navigate you to registration page where you can sign up for the service, when this is done you will be returned to the login page. If you login as a user a new page will open see figure ?? on page 22

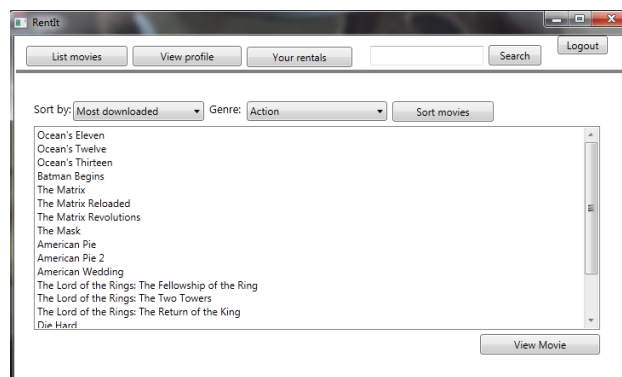


Figure 7.1: List of movies on service

and a different if you are a content provider but more on that later.

When logged in as a user you want to rent a movie let's say "Batman begins". You now have two options either to sort your movie list after action genre or you can search after it by typing in the name in the search field and hitting the search button.

If you use the search option you will then be navigated to a new page where the result of the search will be shown like in figure ?? you can then choose "Batman begins" and press the view movie button which in turn then will open this page, see figure ?? on page 23

where you will be able to see information about the movie, and also be able to choose which edition to rent. You then choose an edition you want to rent, in this case we will choose the HD 1080p edition of "Batman begins" we then select it in the list and click select edition, this will prompt us to a page similar to the view movie page, the only exception being that we can now press "Rent edition" which will then add the movie to your account for seven days and then navigate to the download page where you can press the "Download movie". Here you will be able to download the movie and choose a filepath to save it in. See figure 7.3 on page 23

When done you can then press the logout button to logout and return to the login page or you can press the close button (X) which will then log you out and close down the application completely.

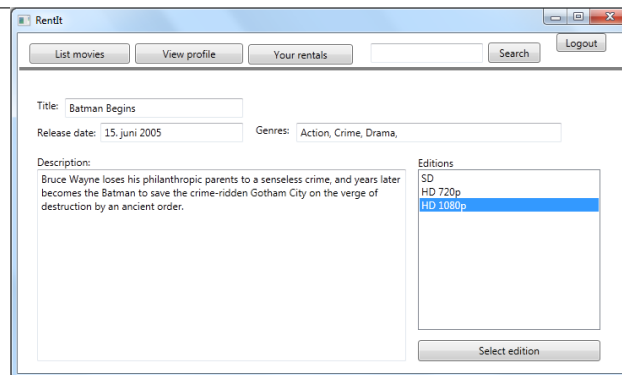


Figure 7.2: View movie

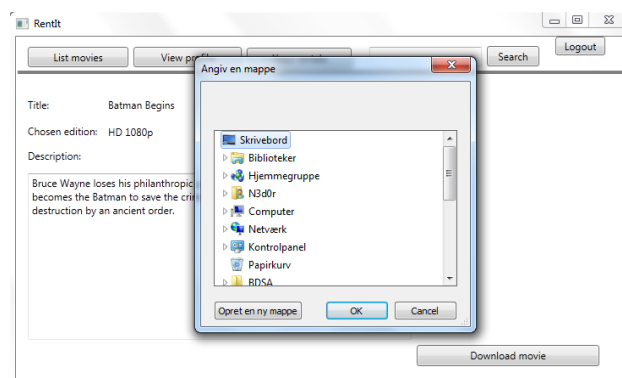


Figure 7.3: Download movie

Uploading a movie

In the case where you login as a contentprovider, you get a startscreen where you can see a list of your uploaded movies, see figure ?? on page 23

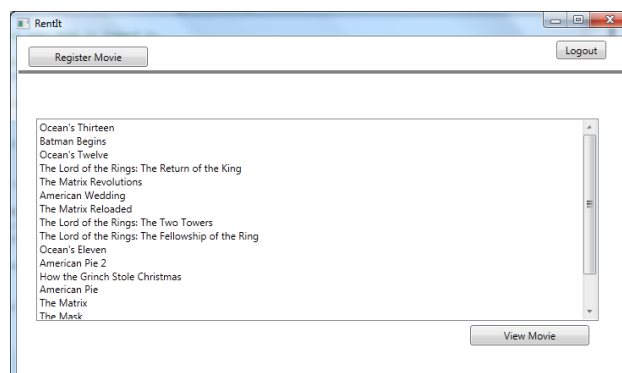


Figure 7.4: List of uploaded movies

you also have the ability to register new movies. To register a new movie you press the " Register movie" button this will then open this image, see figure 7.5 on page 24

The screenshot shows the 'RentIt' application window. At the top, there are buttons for 'Your Movies' and 'Logout'. The main form contains the following fields:

- Title:** A text input field containing 'RentItMovie'.
- Release date:** A date input field showing '26-05-2012'.
- Description:** A text area containing 'This is a test movie!'.
- Genre:** A list of genres with checkboxes:

Genre	Add?
Action	<input type="checkbox"/>
Adventure	<input type="checkbox"/>
Comedy	<input checked="" type="checkbox"/>
Crime	<input type="checkbox"/>
Drama	<input checked="" type="checkbox"/>
Family	<input type="checkbox"/>
Fantasy	<input type="checkbox"/>
Romance	<input type="checkbox"/>
Sci-Fi	<input type="checkbox"/>
Thriller	<input type="checkbox"/>

At the bottom right of the form is a 'Register movie' button.

Figure 7.5: Register movie

here you can give the movie a title, release date, genres and a short description. You can then register the information by pressing "Register movie", when doing so a dialogbox will appear, see figure 7.6 on page 24

The screenshot shows a dialog box titled 'Upload edition?'. The text inside reads: 'You have successfully registered a movie. Would you like to upload an edition right away?'. At the bottom, there are two buttons: 'Yes' and 'No'.

Figure 7.6: Upload edition popup box

prompting you if you want to upload editions right away aswell.

If you press yes, the window will then navigate to this page, see figure 7.7 on page 24

The screenshot shows the 'RentIt' application window with the 'Upload edition' form. At the top, there are buttons for 'Register Movie', 'Your Movies', and 'Logout'. The form contains the following fields:

- Movie title:** A text input field containing 'Batman Begins'.
- Edition name:** An empty text input field.
- File to upload:** A text input field next to a 'Browse' button.

At the bottom right of the form is an 'Upload edition' button.

Figure 7.7: Upload edition

which allows you to upload an edition of the movie with a name and a file, when you press the "Upload edition" button, the edition will be uploaded to the service and you will be returned to your start screen.

7.2 Service

7.2.1 Using the API

The following section is a short manual on how to use the service API in custom client applications. It will follow the same two tasks as those in the client manual, only focusing on the service calls.

All methods in the API have the same format. The return type is always a boolean, which is true if the input was valid, but false if the input was invalid. All objects to be sent to the client is sent through either an out or ref parameter.

All methods are places in 4 different classes: `ContentBrowsing`, `UserManagement`, `RentalManagement`, and `ContentManagement`.

7.2.2 Renting a movie

The first step to using the service is always either log in or sign up for a new user. The `Login` method in `UserManagement` takes a username and password, and sends back the logged in user object. The `SignUp` method takes a referenced `User` object, where at least username, password and email is filled out. The returned user object for both methods will contain a token property, which will be used in all subsequent method calls.

After login, there is several ways to get movies, all using the `ContentBrowsing` class. The `GetMovies` method can get all movies, newest movies, and most downloaded movies in either all or a specified genre. The genres can be retrieved with the `GetGenres` method. Alternatively, you can search for movie titles with the `Search` method.

To rent a movie, the `RentMovie` method in the `RentalManagement` class is used. This takes a movie edition. The list of editions for a movie can be retrieved with the `GetMovieInformation` method in the `ContentBrowsing` class. When a movie edition has been rented, it can be downloaded with the `DownloadFile` method.

7.2.3 Uploading a movie

When you log in as a content provider, you get the ability to upload, edit and remove movies through the `ContentManagement` class. The `RegisterMovie` method registers a new movie in the system. It takes a referenced movie instance, which has to at least have a title. A release date can also be set, and if it's a day in the future, the movie won't be visible in the system before then. A movie can afterwards be edited and removed using the `EditMovie` and `DeleteMovie` method.

After a movie has been registered, versions of it can be uploaded with the `UploadEdition`, and afterwards be removed with the `DeleteEdition` method.

8 Testing

8.1 Strategy

8.1.1 Test types

Scenario-level tests

Service-level tests

Graphical user interface tests

Testing that the service works is not the only important thing to do. It is also important to make sure that the graphical user interface works, because otherwise the user will not be able to use the service for anything. We split the testing of the graphical user interface into two parts: Automatic tests, and manual tests. These will be further described below.

Automatic GUI tests The automatic gui tests have been made through the use of the Coded UI Tests in Visual Studio 2010. When one creates such a test, one can record all the actions that are taken, and save these. When a test has been recorded, it can be run any amount of times, and it will take the same actions every time. Using this, we made automatic tests for all the basic features, such as signing in, logging in, searching for movies, etc.

Manual GUI test While we could automate some tests, there were others that were not worth automating. Automating things like upload/download would be too hard, as file directories change from computer to computer. This meant that we had to test certain functionalities manually, simply by opening the client and going through the necessary steps.

8.1.2 Regression tests

8.1.3 Usability tests

When designing a user interface you have to take into account that not all users is equally proficient in navigating IT systems, therefore we have to design a interface which is easy to use. To accomplish this we did a couple of usability tests. Usability tests, is a testing technique which focuses on the usability of a user interface, this is measured in non-functional requirements. For usability testing you need a mockup to test against, you then make a list of usability goals¹ if these goals is fulfilled then you have the user interface that you wanted. For the usability test itself you make a list of scenarios that your user shall go through², while performing the scenarios, the user is asked to think aloud, such that the overseer of the test can take notes on how to improve the system.

The way we went about doing our usability tests, was to first set down as a team and create some paper mockups, which we found user friendly and had high ease-of-use. We then made some usability goals which if fulfilled, would ensure us that our interfacd was indeed user friendly and had a high ease-of-use. With these we made our first usability test on the paper mockups, we then got the feedback that even though our

¹See appendix for our usability goals

²See appendix for our usability scenarios

interface was easy to navigate through, we lacked user confirmation all our test users felt uncertain that their actions was saved in the database.

For the second usability test we created a digital version of our paper mockups, but this time we added some dialog and confirmationboxes to ensure that the user didn't feel that their changes would go unsaved. Besides that we change abit of the design but without deviating to much from the paper mockups. We then went about doing the second usability test with the same goal and scenarios as before, this time we got no comment on the missing of confirmation in the program, but we did get the feedback that some of our paths was to obscured and not very intuitively. Generally the feedback told us that we needed to do something about our navigation and of our and how it was prestended to the user.

8.2 Test results

8.2.1 Code coverage

8.2.2 Usability results

8.2.3 Results of GUI workflows

8.3 Reflection on test strategy

8.3.1 Ideas for improvement

9 Conclusion and reflection

9.1 Issues and potential fixes

9.1.1 Issues we would prioritise

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Appendices

A Who did what?

This appendix describes who did what parts of the project. It is split into two sections - code and report.

A.1 Code

Who did what in the code part of the project. Includes writing code, tests, database setup and maintenance.

Frederik Lysgaard	
	GUI design
	Usability testing
Jacob Grooss	
	GUI tests
	Scenario tests (a few)
Jakob Melnyk	
	Client(Code-behind GUI)
	Client(Logic and architecture)
	Scenario tests (a few)
Niklas Hansen	
	Database
	Entity Framework
	Service
	Test Platform (Base test classes)
	Scenario tests
Ulrik Damm	
	Search(Levenshtein)
	Service
	Service tests
	Scenario tests (a few)

A.2 Report

Describes who wrote what in the report.

Frederik Lysgaard	
	Design (Client/GUI)
	Design (Usability)
	Manual (Client)
	Testing (Usability)
Jacob Grooss	
	Collaboration
	Testing (GUI)
	Test Appendix
Jakob Melnyk	
	Preface

	Project overview
	Requirements
	Design (Client/Architecture)
	Implementation(Client)
	Testing (Except GUI and Usability)
	Conclusion
	Report design (Latex preamble, document structure, etc.)
	Written Review
	Use cases
	Test Appendix
	Test running (Pass/fail + code coverage)
Niklas Hansen	
	Design (Database)
	Design(Entity Framework)
	Service
Ulrik Damm	
	Implementation (Search)
	Manual (Service)
	Test Appendix
	Service

B Written Review

B.1 Layout

Even though the first draft is only ten pages, it feels odd not to have a table of contents (ToC). A ToC would have made it easier to navigate the document.

Section/subsection titles were not very distinct from the standard text. Either some form of numbers or letters could be used to show that a new section begins. Italics could also be considered.

The description of the data model and the web-service felt quite clustered and had no real distinction between when one ended and the other began. Again sectioning could alleviate this issue.

Bullet points (or some other “fancy” representation) of the methods in the web-service description would have been good. It was not very clear what was a method and what was not.

The communication section could have been improved by splitting it into subsections. There are three or four subjects discussed in the section and each of them could have had their own subsection.

B.2 Content

The ER-model notation is mentioned (and Søren Lauesens book referred to) in the communication section, but not in the data model section. It probably should be, as the data model section lacked an explanation of how to read the ER-models.

The test report section could have been improved by showing (and explaining) a template, then giving an example of an actual report log entry. Another option could be to just explain the report log snippet you have actually included, instead of just leaving it in there with no explanation.

The text has a lot of poorly argued for decisions. One of particular note is “Revised ER_model. If your smart you will notice that there is no distinction between admins and normal users, but just use your imagination and trust us n this one.”

Another example of poor argumentation: “The way we have been testing out system is far from the most optimal way, but it is the only way to do it.” A tool such as Pex is mentioned, but it would be nice if there were a more detailed explanation as to why your system is designed in such a way that only manual testing is possible. It seems weird because it is possible to make tests that do exactly what you are doing in your system. They can just do it automatically. Spamming could be avoided by just being sensible about how often/when you test.

Grammar and spelling errors: We assume this is because of no proofreading being done, but this should be a priority come the final hand-in. One example is the label for the revised data model as quoted previously. Just that label has two spelling errors.

The use cases could use some elaboration (in terms of describing each use case), but the illustration works quite well, and you could possibly just explain the more complicated ones (what does it mean to update a movie?).

You have a good problem introduction (besides the spelling and grammar problems).

Description is a bit lacking on the data models, but the way you present them is quite good.

C SMU meeting logs

C.1 Meeting 1

Date: 6th March 2012

Venue: Video conference

Denmark Time: 9:30 – 9:45

Present: Niklas, Frederik, Jacob, Ulrik, Amritpal, Leonard, Satoshi

Topics covered:

- Introduction
- Communication
 - Skype
 - GoogleHangout+
- Sharing of Information
 - Wiki
 - Facebook group
- Next meeting time
 - Thursday, 3pm Denmark Time
- Expectations
 - As good as we can
 - Good communication

Task to be completed before next meeting:

- Read project scope

Immediate Goals

- Formulate requirements

Next meeting

Date: 8th March 2012

Venue: VoIP

Denmark Time: 15:00 – 17:00

Agenda:

- Roles and Responsibilities
- Project requirements
- Confirmation of from of contact

C.2 Meeting 2

Date: 8th March 2012

Venue: VoIP

Denmark Time: 11:00 – 11:45

Present: Niklas, Frederik, Jacob, Ulrik, Jakob, Amritpal, Leonard, Satoshi

Topics covered:

- Requirements gathering
- Use Case development
- Scope of Project
 - Movie: By ITU
 - Music: By SMU

Task to be completed before next meeting:

- Scope of Movie Rental by ITU side
 - Requirements
 - Use Case
- Scope of Movie Rental by ITU side
 - Requirements
 - Use Case

Next meeting

Date: 15th March 2012

Venue: VoIP

Denmark Time: 13:00 - 14:00

Agenda:

- Refining of Requirements and Use Cases
- Web services
- UI design
- Coding

C.3 Meeting 3

Date: 15th March 2012

Venue: VoIP

Denmark Time: 13:00 - 14:00

Present: Niklas, Frederik, Jacob, Ulrik, Jakob, Amritpal, Leonard, Satoshi

Topics covered:

- Sprint 1
 - Started on Tuesday 13 March 2012
 - End 27 March 2012
 - Sprint planning in progress
- Sprint 2
 - Start 28 March 2012
 - End somewhere between 5th-8th March 2012
- Project Specific
 - Database to be used – MS SQL Server
 - ITU will create backend web services and application with basic UI
 - SMU will modify UI and implement some client-side functionalities
 - No shopping cart will be implemented
 - * Instead each user will have a profile that has a list of rented items
 - * Each user has to create an account and renting of videos will be done in single “transactions” updating user profiles automatically with a list of rented items
 - * This will be done client-side by SMU
 - Users: 3 types of users
 - * Admin
 - Has admin rights on other 2 users
 - * Content Provider
 - Can upload cannot rent
 - * Public User
 - Can rent cannot upload
 - Testing
 - * Will be done during each sprint together with functionality development
 - * SMU will also conduct testing upon receipt of solution from ITU and provide more documentation for report
 - Sharing on facebook functionality – SMU will implement Client Side
 - Facebook login – not a priority
- Project Backlog
 - ITU to provide a project backlog (without ranking) to get both SMU and ITU updated on functionalities to be implemented
- Metric
 - Project Burndown Chart
 - * Weekly updates

Task to be completed before next meeting:

-
- Stories from ITU
 - ITU to provide a basic solution with some functionalities and a simple interface for SMU
 - Deployment instructions
 - Access to database

Next meeting

Date: 22nd March 2012

Venue: VoIP

Denmark Time: 13:00 - 14:00

Agenda:

- Review solutions and stories for remainder of sprint
- De-conflict any issues
- Discuss advanced features
- Review overall schedule

C.4 Meeting 4

Date: 27th March 2012

Venue: VoIP

Denmark Time: 11:15 - 11:20

Present: Niklas, Frederik, Jacob, Ulrik, Jakob, Amritpal, Leonard, Satoshi

Topics covered:

- Sprint 1 Recap
 - Web services are somewhat done
 - SMU team will send list of questions regarding various methods and variables of the web services to ITU for clarification
 - Web service reference address needed to be communicated
- Sprint 2
 - Started
 - Stories of ITU needs to be uploaded to wiki
 - Will end early late next week
- Project Specific
 - Database just re-established on servers
- Project Backlog
 - Needs to be uploaded onto wiki by ITU
- Metric
 - Project Burndown Chart
 - * Needs to be uploaded onto wiki by ITU

Task to be completed before next meeting:

- Stories from ITU
- Web reference address
- ITU to reply to SMU's email

Next meeting

Date: 29th March 2012

Venue: VoIP

Denmark Time: 13:00 - 14:00

Agenda:

- Review solutions and stories for remainder of sprint
- De-conflict any issues
- Review overall schedule

C.5 Meeting 5

Date: 29th March 2012

Venue: VoIP

Denmark Time: 15:45 - 16:45

Present: Niklas, Frederik, Jacob, Ulrik, Jakob, Amritpal, Leonard, Satoshi

Topics covered:

- Web Services
 - Token
 - * Checks if these guys is an admin or publisher
 - Register new user
 - * Class instances
 - Upload and download of movies
 - * Name of file
 - * Length of stream
 - * 2gb space limit
- Sprint 2
 - Movie ownership
 - Retrieve entire list of movie

Task to be completed before next meeting:

- Web Services API

Next meeting

Date: 5th April 2012

Venue: VoIP

Denmark Time: 13:00 - 14:00

Agenda:

- Review solutions and stories for remainder of sprint
- De-conflict any issues
- Review overall schedule

D System Diagrams

D.1 Class diagrams

D.2 Service API

E Test results

This appendix describes the results of all our tests. Our handwritten, automated tests are arranged in tables in section E.1. Our usability tests are described in section E.3.

E.1 Automated test results

This section shows the result of running our automated tests the day following the code freeze.

E.1.1 Scenario tests

Test title	Test Purpose	Result
AddGenreTest	Verify that you can add a genre to a movie	Pass
AddOne	Verify that if I add a new movie, the first movie to be returned is the new one	Pass
AddOneInFuture	Verify that movies with a release date in the future, will not appear in the newest movies	Pass
AddOneWithoutReleaseDate	Verify that movies without a release date, will not appear in the newest movies	Pass
AdminRentalHistory	Verify that a admin has no rental history	Pass
BrowseKnownGenreTest	verify that when the user browses for a specific known genre, all movies with that genre gets returned	Pass
ContentproviderRentalHistory	Verify that a contentProvider has no rental history	Pass
DeleteMovieEdition	Verify that it is possible to delete a movie edition	Pass
DeleteMovieEditionFromOtherProvider	Verify that it is not possible to delete a movie edition, from another content provider	Pass
DeleteMovieFromOtherProvider	Verify that it is not possible to delete a movie that belongs to another content provider	Pass
DeleteMovieTest	Verify that deletion of a movie is possible	Pass
EditMovieFromOtherProvider	Verify that it is not possible to edit a movie uploaded by another content publisher	Pass
EditMovieInformationInvalidMovieIdTypeTest	Verify that the method throws the correct exception when called by an account with an insufficient user type	Pass
EditMovieInformationInvalidUserTypeTest	Verify that the method throws the correct exception when called by an account with an insufficient user type	Pass
EditMovieInformationValidTest	Verify that the method changes the values of the movie	Pass
EditMoviePartOfInfo	Verify that it is possible to only update part of the information about a movie	Pass
EditMoviePartOfInfoInvalidValues	Verify that a field is only updated, if the new value is valid	Pass
EditMoviePartOfInfoMixedValidInvalid	Verify that fields with new valid values will be updated, even when other fields will not be updated, because of invalid values	Pass
EditPartOfProfileInfoTest	Verify that it is possible to edit only part of a user's profile	Pass
EditPartOfProfileOnlyPasswordTest	Verify that it is possible to edit a user's password, and nothing else	Pass

EditProfileTest	Verify that it is possible to edit a user profile	Pass
GetAllGenresTest	verify that all genres in the database gets returned by GetAllGenres	Pass
GetAllMovies	Verify that All work as intended	Pass
GetCurrentRentalsTest	Verify that the user only gets current rentals and that they all belong to him	Fail
GetMovieInformationInvalidMovieIdTest	Verify that the method returns null when called with a movie ID that doesn't corospond to a movie in the database	Pass
GetMovieInformationValidTest	Verify that the method returns the correct data	Pass
GetUnreleasedMovieInfoFutureRelease	Verify that even though editions have been added to a movie, they will not appear / be passed to the clients, if the movie is not released	Pass
GetUnreleasedMovieInfoNoReleaseDate	Verify that even though editions have been added to a movie, they will not appear / be passed to the clients, if the movie is not released	Pass
InsufficientAccessDeleteMovieTest	Verify that only Content Providers can delete movies	Pass
InvalidValuesRegisterMovieTest	Verify that it is not possible to use invalid values in the method	Pass
Limiting	Verify that it is possible to limit the amount of movies returned	Pass
LoginWithDifferentUsernameAndPassword	Verify that even though a user with a given username exists, and a user with a given password exists, login will fail if those two users are not the same	Pass
LoginWithExistingUser	Verify that login is possible when using the right username and password	Pass
LoginWithNonExistingUser	Verify it is not possible to login, when no users with the given username and password exists	Pass
LoginWithWrongPassword	Verify that even though a user with a given username exists, login will fail if the password is wrong	Pass
LoginWithWrongUsername	Verify that even though a user with a given password exists, login will fail if the username is wrong	Pass
LogoutValidToken	Verify that it is possible to logout, when specifying a valid token	Pass
MostDownloadedMultipleEditions	Verify that even though the rentals are split between multiple editions, the right movies in the right order is still returned	Pass
MostDownloadedWithRentals	Verify that when trying to get the most downloaded movies, the right movies are returned in the right order	Pass
MultipleRentalHistory	Verify that a user wtih serveral movies in rental history and with multiple instance of the same movie will return the correct list	Fail
NotAUserRentMovieTest	Verify that only users can rent movies	Pass
NullTokenRegisterMovieTest	Verify that it is not possible to call the method with a null token	Pass
RegisterMovieTest	Verify that a content provider is able to register movies in the database	Pass
RemoveGenreTest	verify that you can remove a genre from a movie	Pass

RentalHistoryNoRentals	Verify that you will get a empty list from a user with no rental history	Pass
RentalHistoryTest	Verify that it is possible to retrieve list of the user rental history	Pass
RentalOfMovieWithFutureRelease	Verify it is not possible to rent a movie with a release date in the future	Pass
RentalOfMovieWithoutRelease Date	Verify it is not possible to rent a movie without a release date	Pass
RentMovieTest	Verify that it is possible to rent a movie	Pass
SearchBadSpelling	verify that search results includes movies with spelling errors in the title	Pass
SearchDifferentCase	verify that a movie is returned when a user searches for the title but with incorrect case	Pass
SearchExactTitle	Verify that a movie gets returned when the user searches for its exact title	Pass
SearchLimit	verify that putting a limit on the search results actually limits the number of returned movies	Pass
SearchMoreTokens	verify that a movie will be returned, even if tokens not in the name is part of the search string	Pass
SearchOrder	verify that the exact movie title match will be ordered before a partly match	Pass
SearchPartlyTitle	verify that a movie is returned when a user searches for a part of the title	Pass
SearchTokenMatchCountOrder	verify that the search results is ordered by the number of token matches	Pass
SearchVeryBadSpelling	verify that the search result does not include words that are too badly spelled	Pass
SearchWithoutResult	verify that an empty collection is returned when the user searches for a title not in the database	Pass
SignUpWithEmptyEmail	Verify that email has to be set	Pass
SignUpWithEmptyPassword	Verify that password has to be set	Pass
SignUpWithEmptyUsername	Verify that username has to be set	Pass
SignUpWithExistingUsername	Verify that it is not possible to signup with a username that is already in use	Pass
SignUpWithInvalidInfo	Verify that type is automatically set to user, token is reset and ID is auto-generated when trying to set those settings to invalid values	Pass
SignUpWithValidInfo	Verify that it is possible to sign up	Pass
WrongUserTypeRegisterMovie Test	Verify that it is not possible to use the method as a user of type User	Pass

E.1.2 Service tests

Test title	Test Purpose	Result
AllGenresValidServiceTest	Verify that GetGenres return some genres	Pass
AllGenresWithoutTokenService Test	Verify that without a token, GetGenres doesn't return anything	Fail
DeleteEditionValidServiceTest	Verify that you can delete a movie edition	Fail

DeleteMovieValidServiceTest	Verify that you can delete a movie	Fail
EditMovieInsufficientRightsServiceTest	Verify that normal users cannot edit movies	Pass
EditMovieValidServiceTest	Verify that you can edit movies	Fail
EditUserNullServiceTest	Verify that EditUser fails on invalid input	Pass
EditUserValidServiceTest	Verify that you can edit a user	Fail
GetAllMoviesGenreServiceTest	Verify that movies can be limited to a specific genre	Fail
GetAllMoviesLimitServiceTest	Verify that you can limit the number of movies returned	Fail
GetAllMoviesMostDownloadedServiceTest	Verify that movies can be sorted by number of rentals	Fail
GetAllMoviesNewestServiceTest	Verify that movies can be sorted by newest	Fail
GetAllMoviesValidServiceTest	Verify that movies are returned on valid input to GetMovies	Fail
GetAllMoviesWithoutTokenServiceTest	Verify that a token is needed to browse movies	Pass
GetMovieInformationUnknownMovieServiceTest	Verify that GetMovieInformation doesn't return anything when an unknown movie is referred to	Fail
GetMovieInformationValidServiceTest	Verify that GetMovieInformation gets information about a movie	Pass
GetMovieInformationWithoutTokenServiceTest	Verify that without a token, GetMovieInformation doesn't return anything	Pass
GetRentalsNullServiceTest	Verify that GetRentals fail without a user token	Pass
GetRentalsValidServiceTest	Verify that you can get a users rentals	Fail
LoginValidServiceTest	Verify that you can log in	Pass
LoginWrongPasswordServiceTest	Verify that the user won't get logged in, if using a wrong password	Fail
LogoutValidServiceTest	Verify that you can log out	Pass
RegisterMovieInsufficientRightsServiceTest	Verify that normal users cannot register movies	Pass
RegisterMovieValidServiceTest	Verify that you can register a movie	Fail
RentMovieContentProviderServiceTest	Verify that content providers cannot rent movies	Fail
RentMovieValidServiceTest	Verify that users can rent movies	Fail
SearchValidServiceTest	Verifies that movies are returned from a search	Fail
SearchWithoutQueryServiceTest	Verify that nothing is returned for a null query	Pass
SearchWithoutTokenServiceTest	Verifies that nothing is returned without a user token	Pass
SignupMissingInfoServiceTest	Verify that you cannot create a user without basic information	Pass
SignupValidServiceTest	Verify that you can create a new user	Pass

E.1.3 Graphical User Interface tests

Test title	Test Purpose	Result
GuiTest01CreateNewUser	See if it's possible to create a new user account	Pass
GuiTest02UserLogin	See if it's possible for the user to log in	Pass
GuiTest03UserEditUser Information	See if it's possible for the user to edit his/her information	Fail
GuiTest04UserLogout	See if it's possible for the user to log out	Fail
GuiTest05UserViewAllMovies	See if it's possible for the user to view all the offered movies	Pass

GuiTest06UserViewMoviesBy Newest	See if it's possible for the user to sort all movies with the newest movie first	Fail
GuiTest07UserSearchForMovie	See if it's possible for the user to search for a movie	Pass
GuiTest08UserViewMoviesBy Genre	See if it's possible for the user to see all movies from a specific genre	Fail
GuiTest09UserRentSpecific MovieEdition	See if it's possible for the user to rent a specific movie edition	Pass
GuiTest10UserRentAndView Rentals	See if it's possible for the user to rent a movie and find it in his/her rental list	Fail
GuiTest12CPLoginLogout	See if the content provider can log in and log out	Fail
GuiTest13CPRegisterMovie	See if the content provider can register a movie	Pass

E.1.4 Failed automatic tests

This section describes which of our automatic tests that fail and what error they fail with.

Test title	Fail reason
GetCurrentRentalsTest	Threw exception: "ArgumentNullException: Value cannot be null. Parameter name: String"
MultipleRentalHistory	Threw exception: "System.InvalidOperationException: There is already an open DataReader associated with this Command which must be closed first."
DeleteEditionValidServiceTest	Threw exception: "System.ServiceModel.FaultException"
DeleteMovieValidServiceTest	"Assert.IsTrue failed. DeleteMovie failed"
EditMovieValidServiceTest	Assert.AreEqual failed. Expected: <New title>. Actual:<Ocean's Eleven>. Movie title wasn't changed
EditUserValidServiceTest	System.ServiceModel.Dispatcher.NetDispatcherFaultException: The formatter threw an exception while trying to deserialize the message: There was an error while trying to deserialize parameter
GetMovieInformationUnknownMovie-ServiceTest	Assert.IsFalse failed. GetMovieInformation didn't fail
GetAllMoviesGenreServiceTest	System.ServiceModel.Dispatcher.NetDispatcherFaultException: The formatter threw an exception while trying to deserialize the message: There was an error while trying to deserialize parameter
GetAllMoviesLimitServiceTest	Assert.IsTrue failed. Result is false
GetAllMoviesMostDownloadedService-Test	Assert.IsTrue failed. Result is false
GetAllMoviesNewestServiceTest	System.ServiceModel.Dispatcher.NetDispatcherFaultException: The formatter threw an exception while trying to deserialize the message: There was an error while trying to deserialize parameter
GetAllMoviesValidServiceTest	System.ServiceModel.Dispatcher.NetDispatcherFaultException: The formatter threw an exception while trying to deserialize the message: There was an error while trying to deserialize parameter
GetRentalsValidServiceTest	Assert.IsTrue failed. GetRentals failed
LoginWrongPasswordServiceTest	Assert.IsFalse failed. Login didn't fail.

RegisterMovieValidServiceTest	System.ServiceModel.Dispatcher.NetDispatcherFault-Exception: The formatter threw an exception while trying to deserialize the message: There was an error while trying to deserialize parameter
RentMovieContentProviderServiceTest	System.ServiceModel.Dispatcher.NetDispatcherFault-Exception: The formatter threw an exception while trying to deserialize the message: There was an error while trying to deserialize parameter
RentMovieValidServiceTest	Assert.AreEqual failed. Expected any value except:<0>. Actual: <0>. rentals is null
SearchValidServiceTest	Assert.IsTrue failed. Result is false
GuiTest03UserEditUserInformation	Could not find 'Close application' control
GuiTest04UserLogout	Could not find 'Close application' control
GuiTest06UserViewMoviesByNewest	Could not find 'MovieListBox' control
GuiTest08UserViewMoviesByGenre	Could not find 'Close application' control
GuiTest10UserRentAndViewRentals	Could not find 'Close application' control
GuiTest12CPLoginLogout	Could not find 'Close application' control

E.2 Manual GUI test

Test 3 - User, edit user profile (GuiTest03UserEditUserInformation).

Tests whether it's possible for the user to edit his/her information or not.

This test covers the requirement "User - Edit profile".

1. Login as the user "Smith"
2. Navigate to the Edit Profile Page
3. Change Full Name to "Neo Smith"
4. Click the "Save changes" button
5. See that the full name now is "Neo Smith"
6. Close the window

Test 4 - User, logout as user (GuiTest04UserLogout).

Tests if the user can log out from the service.

This test covers the requirement "Optional - High priority - Logout".

1. Login as the user "Smith"
2. Click the "Logout" at the top right of the screen
3. Close the window

Test 6 - User, view list of all movies sorted by release date (GuiTest06UserViewMoviesByNewest).

Tests if the user can see all movies sorted by their release date.

This test covers the requirement "User - View a list of all movies" and "Optional - High priority - View movielists with different sorting".

1. Login as the user "Smith"
2. Navigate to the View Movie List Page
3. Sort by Newest and All

-
4. View Movie for Ocean's Eleven
 5. Click the "List Movies" button
 6. View Movie for The Matrix
 7. Assert that the release date is earlier than Ocean's Eleven
 8. Close the window

Test 8 - User, view all movies of a specific genre (GuiTest08UserViewMoviesByGenre).

Tests if the user can see all movies of a certain genre.

This test covers the requirement "Optional - High priority - View movielists with different sorting".

1. Login as the user "Smith"
2. Navigate to the View Movie List Page
3. Sort movies by Newest and Sci-fi
4. Assert that The Matrix, The Matrix Reloaded and The Matrix Revolution are in the list
5. Close the window

Test 10 - User, view current rentals (GuiTest10UserRentAndViewRentals).

Tests if the user can see his/her current rentals.

This test covers the requirement "Optional - High priority - View rental history".

1. Login as the user "Smith"
2. Rent the movie "The Lord of the Rings - The Fellowship of the Ring - SD"
3. Click the "Your Rentals" movie
4. Assert that "The Lord of the Rings - The Fellowship of the Ring - SD" is in the list
5. Close the window

Test 12 - CP, login & logout (GuiTest12CPLoginLogout).

Tests if the content provider can log in and log out.

This test covers the requirement "Content Provider - Login" and "Optional - High priority - Logout".

1. Login as Universal (test content provider)
2. Assert that the "Logout" button exists
3. Click the "Logout" button
4. Assert that the Welcome screen is shown

Test 13 - CP, register and upload movie.

Tests if the content provider register a movie and upload a file.

This test covers the requirement "Content Provider - Upload media", "Optional - High priority - Movie release dates" and "Optional - Medium priority - Movie editions".

1. Login as Universal (test content provider)
2. Click the "Register movie" button
3. Fill the information and click the "Register movie" button
4. Click the "Upload Movies" button
5. Fill the textboxes
6. Click the "Upload movie" button

Test 15 - CP, upload new edition to already registered movie.

Tests if the content provider can upload an edition to a movie that has already been registered.

This test covers the requirement "Content Provider - Upload media" and "Optional - Medium priority - Movie editions".

1. Login as Universal (test content provider)
2. Select a movie
3. Click the "Upload new edition"
4. Browse for a file
5. Click the "Upload" button

Test 16 - CP, edit information about a movie.

Tests if the content provider can edit the information about a movie.

This test covers the requirement "Content Provider - Edit uploaded media".

1. Login as test content provider
2. Click the "Your Movies" button
3. Find the movie that is to be edited
4. Fill out the information and click the "Save changes" button

Test 17 - CP, delete movie.

Tests if the content provider can delete a movie that he/she has registered.

This test covers the requirement "Content Provider - Delete media".

1. Login as Universal (test content provider)
2. Click the "Your Movies" button
3. Find the movie that is to be deleted
4. Click the "View Movie" button
5. Click the "Delete movie" button

E.3 Usability tests

This section describes the results of our usability tests. What influence the usability tests had on our graphical user interface and how we performed them is described in the report¹.

¹The influence is described in section 5.3.3 on page 19 and how we performed the tests is described in 8.1.3 on page 26

F GUI images

F.1 Hand-drawn sketches

F.2 GUI prototype

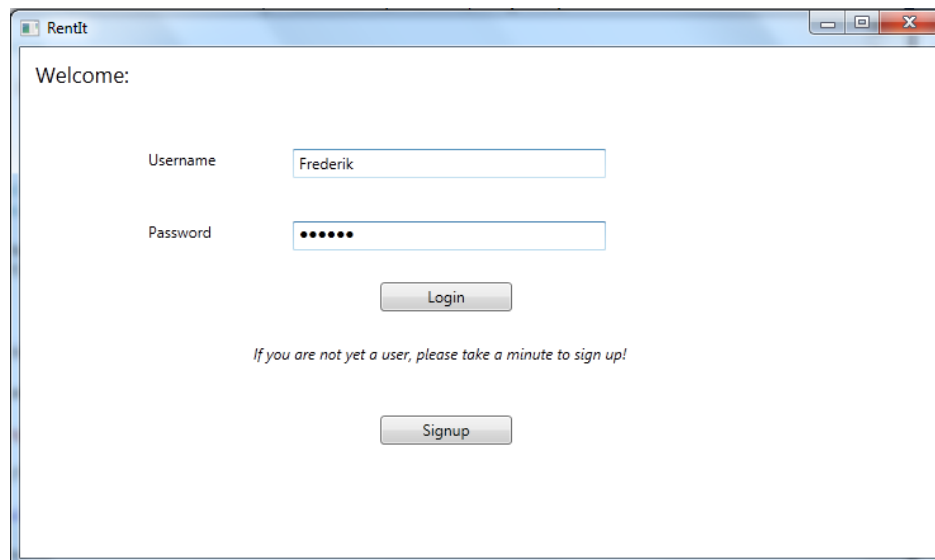


Figure F.1: The main login screen

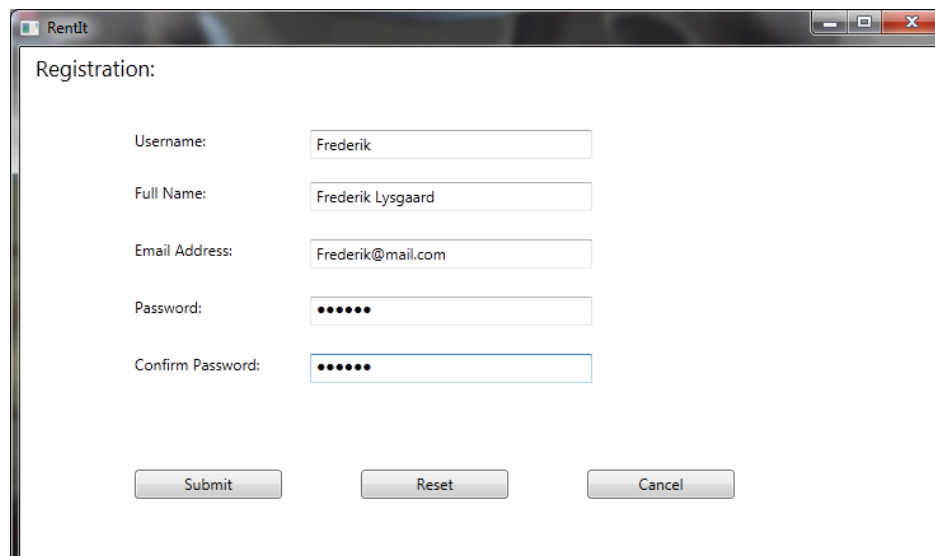


Figure F.2: The screen that is used for creating a new user account

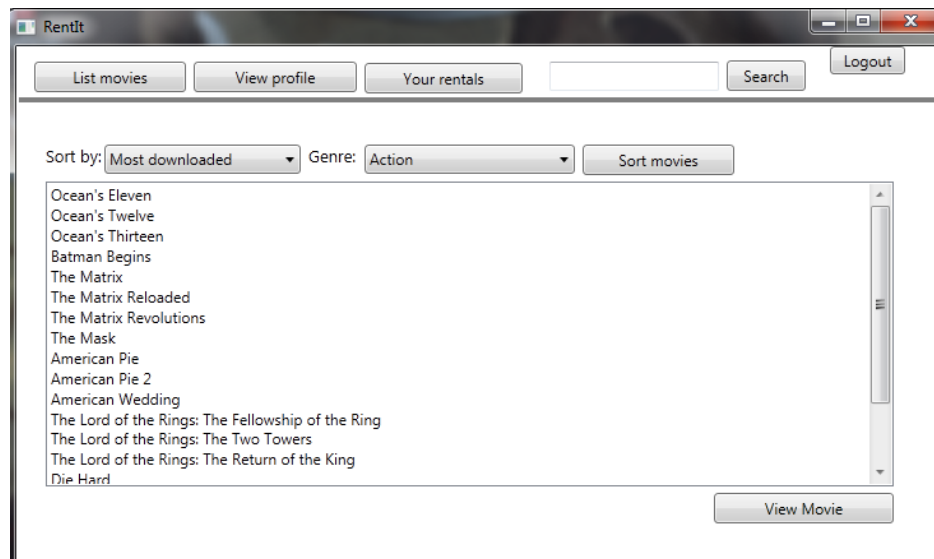


Figure F.3: The list of all the movies that the service has

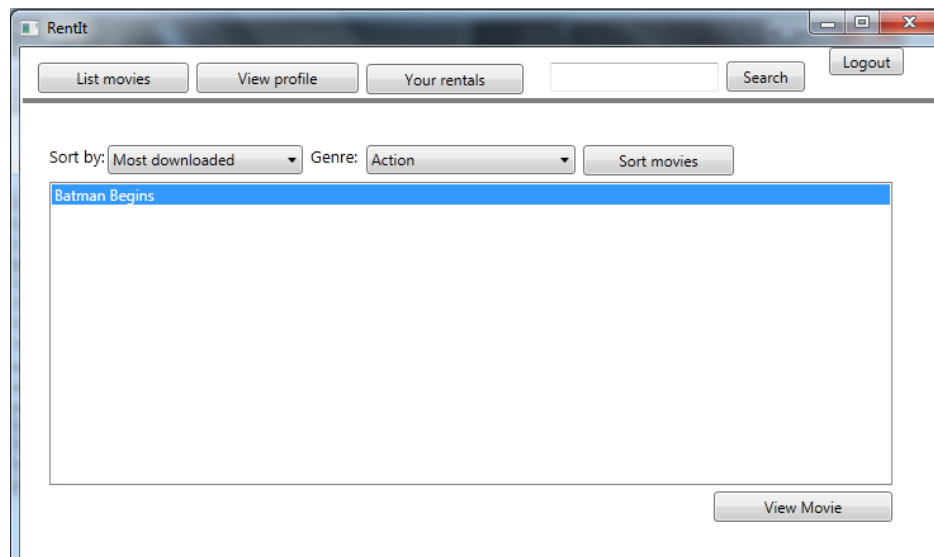


Figure F.4: The screen that shows the search results

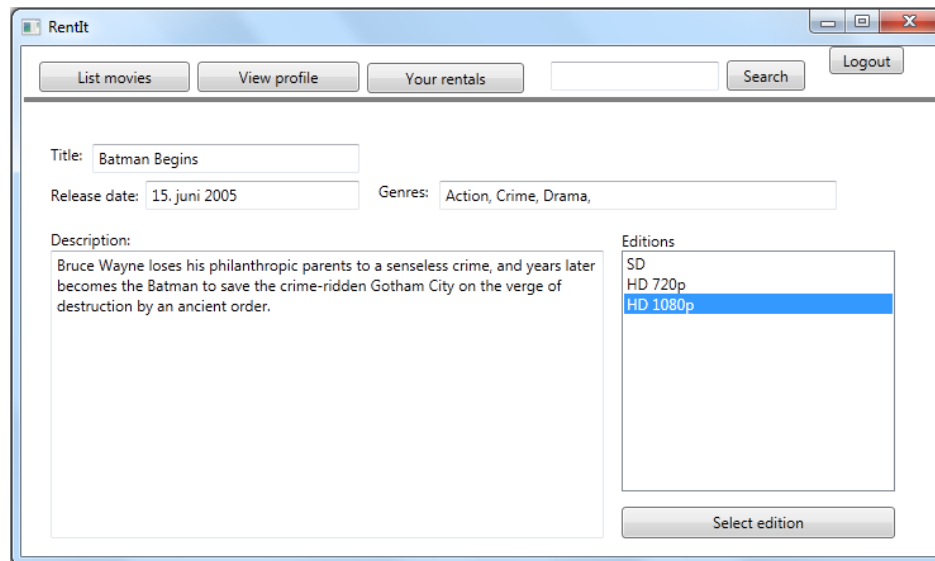


Figure F.5: The screen that shows the information about a movie

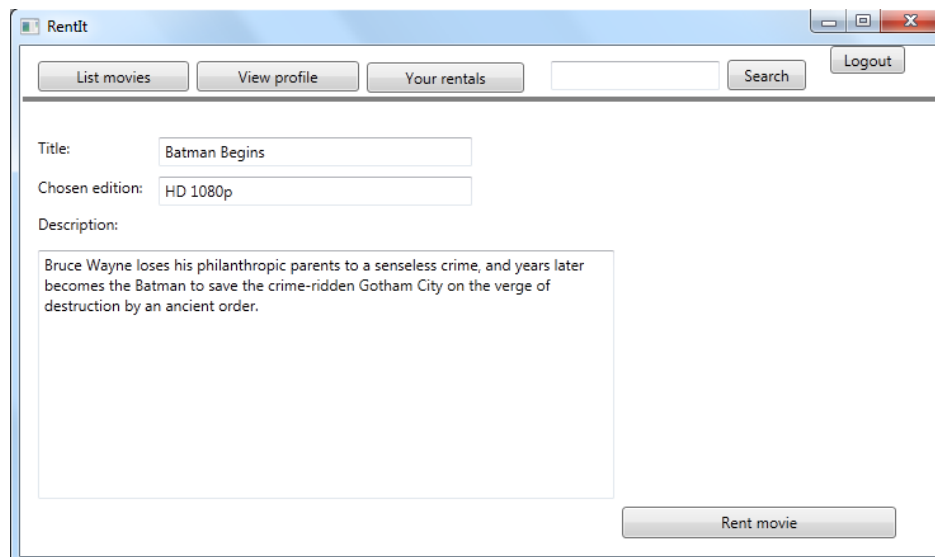


Figure F.6: The screen that lets the user rent an edition

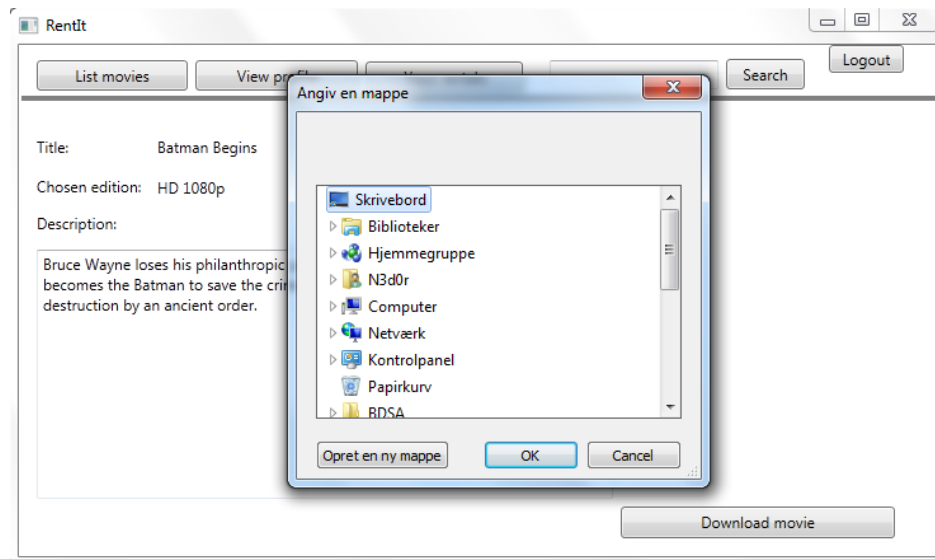


Figure F.7: The screen that lets the user download a movie he/she has rented

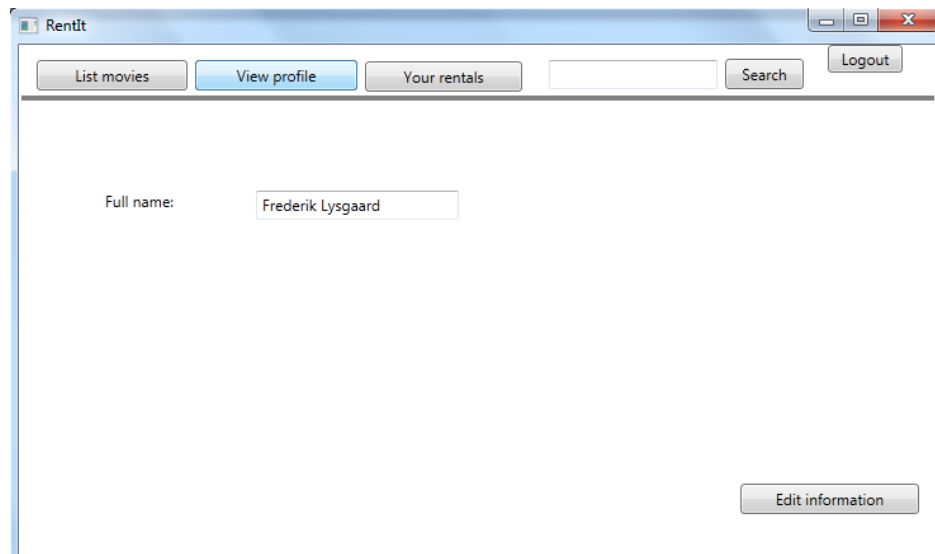


Figure F.8: The screen that lets the user view his/her profile information

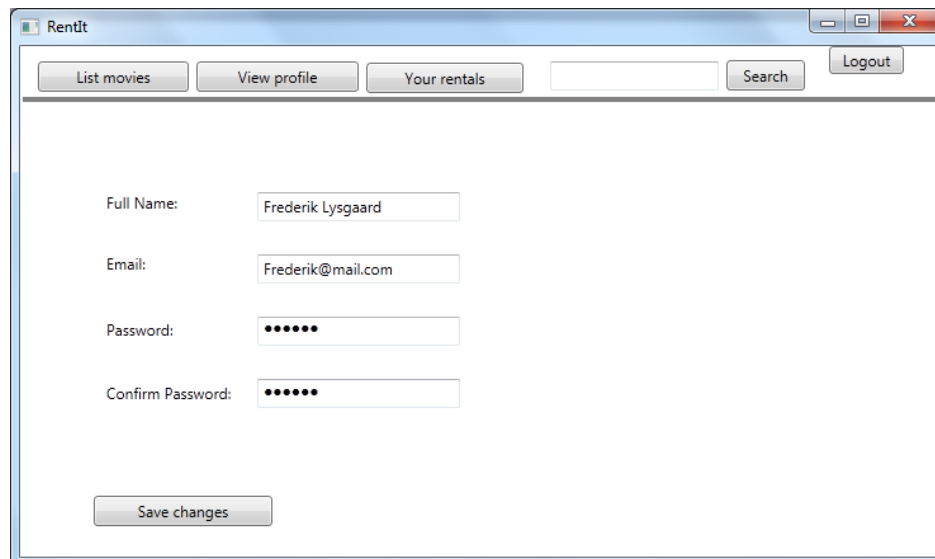


Figure F.9: The screen that lets the user edit his/her profile

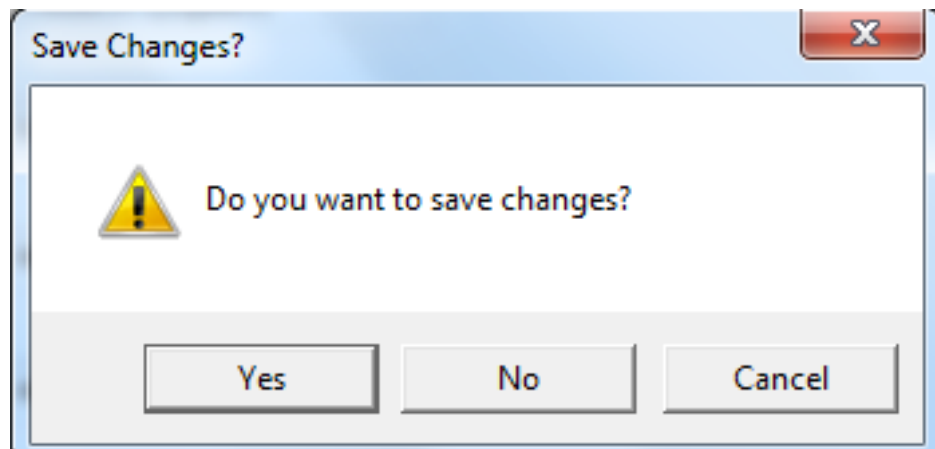


Figure F.10: The confirmationbox that asks if the user wants to save the changes

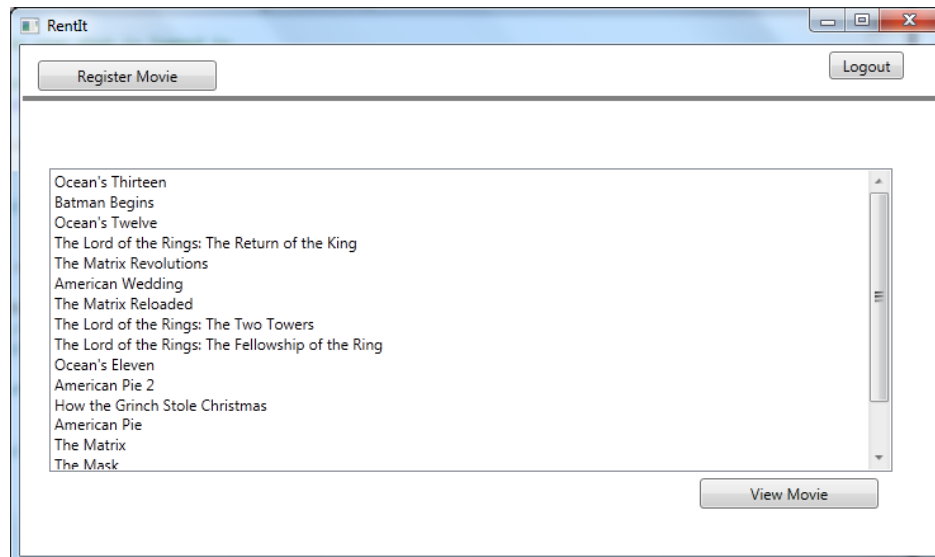


Figure F.11: The screen that lets the content provider see all the movies that he/she has registered

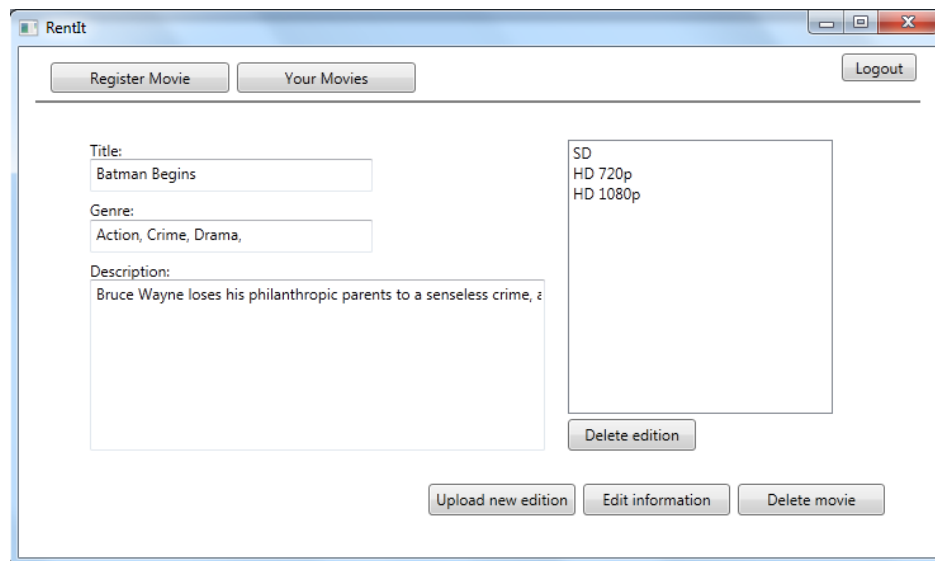


Figure F.12: The screen that lets the content provider see the information about a movie he/she has registered

Register Movie Your Movies Logout

Title: Batman Begins Release date: Select a date 15

Genre	Add?
Action	<input checked="" type="checkbox"/>
Adventure	<input type="checkbox"/>
Comedy	<input type="checkbox"/>
Crime	<input checked="" type="checkbox"/>
Drama	<input checked="" type="checkbox"/>
Family	<input type="checkbox"/>
Fantasy	<input type="checkbox"/>
Romance	<input type="checkbox"/>
Sci-Fi	<input type="checkbox"/>
Thriller	<input type="checkbox"/>

Description: Bruce Wayne loses his philanthropic parents to a senseless crime, and years later becomes the Batman to save the crime-ridden Gotham City on the verge of destruction by an ancient order.

Save changes

Figure F.13: The screen that lets the content provider edit a movie that he/she has registered

Your Movies Logout

Title: RentItMovie Release date: 26-05-2012 15

Description: This is a test movie!?

Genre	Add?
Action	<input type="checkbox"/>
Adventure	<input type="checkbox"/>
Comedy	<input checked="" type="checkbox"/>
Crime	<input type="checkbox"/>
Drama	<input checked="" type="checkbox"/>
Family	<input type="checkbox"/>
Fantasy	<input type="checkbox"/>
Romance	<input type="checkbox"/>
Sci-Fi	<input type="checkbox"/>
Thriller	<input type="checkbox"/>

Register movie

Figure F.14: The screen that lets the content provider register a new movie

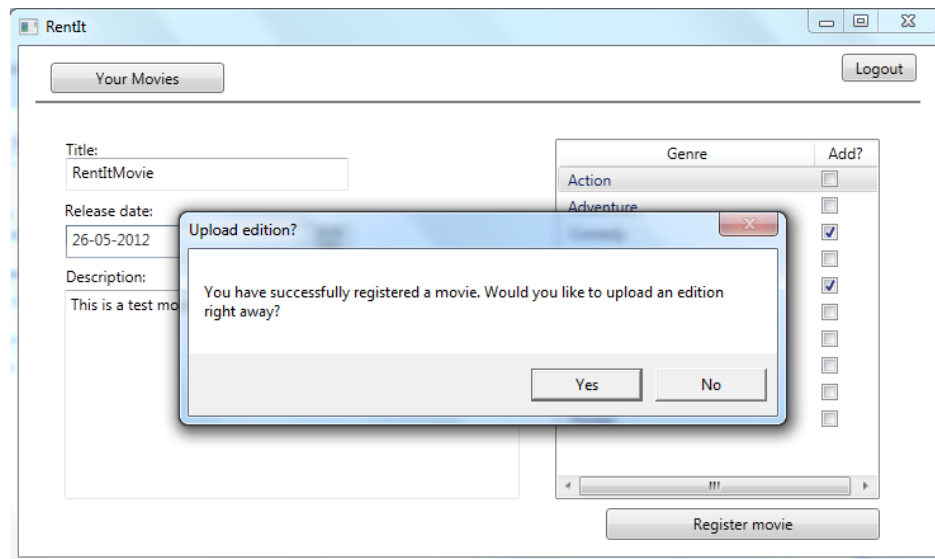


Figure F.15: The popup box that shows up when the content provider has registered a movie

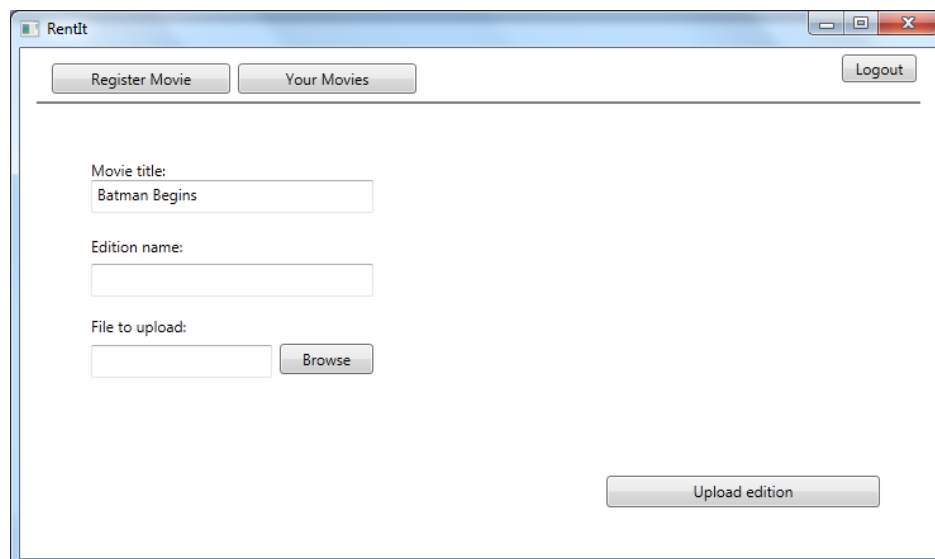


Figure F.16: The screen that lets the content provider upload an edition to a movie that he/she has registered

G Original Use Cases

The use cases here are the first list of use cases we agreed on with SMU. These later changed into what can be found in our Requirements chapter in section 3.4 on page 8.

G.1 User account management

- A user is signing up for the service.
- A user log in to the service.
- A user edits his/her personal information.

G.2 Media browsing

- A user is browsing the newest added movies.
- A user is browsing the most downloaded movies.
- A user is browsing movies by genre.
- A user is browsing all movies and sorts them by their name or genre.
- A user is browsing all movies he/her previously rented.
- A user is searching for at movie by its name.

G.3 Media rental

- A user is renting a movie.
- A user is viewing information about a movie.

G.4 Content management

- A content manager uploads a new movie, and enters information about that movie.
- A content manager edits information for a movie.
- A content manager deletes a movie.

G.5 System management (?)

- A system manager browses all the content managers.
- A system manager creates a new content manager.
- A system manager deletes a content manager.
- A system manager browses all the users.
- A system manager deletes a user.

H F# Handins

This chapter of the appendix contains our handins for the F# assignments. To make sure they could fit on the pages, we had to break up some of the lines in the code. We do feel that we have been able to make it look decent, however. The original .fs files have also been included on the DVD including with the report.

H.1 F# Handins - Frederik Lysgaard

H.1.1 HandIn 1

```
(* Student name: Frederik Roden Lysgaard
   Mail: Frly@itu.dk *)
module Module1

//Opgave 1
let sqr x = x*x

//Opgave 2
let pow x n = System.Math.Pow(x, n)

//Opgave 3
let dup x : string = x+x

//Opgave 4
let rec dupn (s : string) (x : int) = if x = 1 then s else s + dupn s (x-1)

//Opgave 5
let timediff (hh1, mm1) (hh2, mm2) = (hh2*60 + mm2) - (hh1*60 + mm1)

//Opgave 6
let minutes (hh, mm) = timediff (00, 00) (hh, mm)
```

H.1.2 HandIn 2

```
(* Student name: Frederik Roden Lysgaard
   Mail: Frly@itu.dk *)
module Handin2

//Opgave 7
let downTo (n : int) = if n < 1 then [] else [n .. -1 .. 1]

let downTo2 (n : int) =
    match n with
    | n when n < 1 -> []
    | _ -> [n .. -1 .. 1]

//Opgave 8
```

```

let rec removeEven (list :int list) =
  match list with
  | [] -> []
  | [x] -> [x]
  | a :: b :: rest -> a :: removeEven rest

//Opgave 9
let rec combinePair (list :int list) : (int*int) list =
  match list with
  | [] -> []
  | [x] -> []
  | a :: b :: rest -> (a, b) :: combinePair rest

//Opgave 10
let explode (s :string) : char list = List.ofArray (s.ToCharArray())

let rec explode2 (s :string) : char list =
  match s with
  | s when s.Length < 1 -> []
  | _ -> [s.[0]] @ explode2 (s.Substring 1)

//Opgave 11
let implode (s :char list) : string =
  List.foldBack (fun elem acc -> string (elem) + string(acc)) s ""

let implodeRev (s :char list) : string =
  List.fold (fun elem acc -> string (acc) + string(elem)) "" s

//Opgave 12
let toUpper s =
  implode (List.map System.Char.ToUpper (explode s))

let toUpper1 =
  explode >> List.map System.Char.ToUpper >> implode

let toUpper2 s :string =
  explode s |> (implode << List.map System.Char.ToUpper)

//Opgave 13
let palindrome (s :string) =
  (explode s |> List.map System.Char.ToUpper |> implodeRev) = toUpper s

//Opgave 14
let rec ack (m, n) =
  match (m, n) with
  | (m, n) when m < 0 || n < 0 -> failwith "The Ackermann
      function is defined for non-negative numbers only"
  | (m, n) when m = 0 -> n + 1
  | (m, n) when n = 0 -> ack (m - 1, 1)
  | _ -> ack (m - 1, ack (m, n - 1))

```

```
//Opgave 15
let time f =
  let start = System.DateTime.Now in
  let res = f () in
  let finish = System.DateTime.Now in
  (res, finish - start)

let timeArg1 f a = time (fun () -> f a)
```

H.1.3 HandIn 3

H.1.4 HandIn 4 & 5

H.2 F# Handins - Jacob Claudius Grooss

H.2.1 HandIn 1

```
module HandIn1
//Exercise 1
let sqr x = x * x

//Exercise 2
let pow x n = System.Math.Pow(x, n)

//Exercise 3
let dup (s:string) = s + s

//Exercise 4
let rec dupn (s:string, x) = if x = 0 then s else s + dupn(s, x - 1)

//Exercise 5
let timediff (hh1, mm1)(hh2, mm2) = (hh2 * 60 + mm2) - (hh1 * 60 + mm1)

//Exercise 6
let minutes (hh, mm) = timediff (00,00)(hh,mm)
```

H.2.2 HandIn 2

```
//Exercise 7
let rec downTo n = if n < 1 then [] else n :: downTo(n - 1)

let rec downTo2 n =
  match n with
  | n when n < 1 -> []
  | 1 -> [1]
  | - -> n :: downTo(n-1)
```

```

//Exercise 8
let rec removeEven (xs: int list) =
    match xs with
    | [] -> []
    | [xs] -> [xs]
    | xs :: xy :: rs -> xs :: removeEven(rs)

//Exercise 9
let rec combinePair (xs: int list) =
    match xs with
    | [] -> []
    | [xs] -> []
    | xs :: xy :: rs -> xs :: combinePair(rs)

//Exercise 10
let explode (s:string) =
    s.ToCharArray() |> List.ofArray

let rec explode2 (s:string) =
    match s with
    | s when s.Length < 1 -> []
    | _ -> s.[0] :: explode2 (s.Substring 1)

//Exercise 11
let implode (s:char list) =
    List.foldBack (fun str ch -> string(str) + string(ch)) s ""

let implodeRev (s:char list) =
    List.fold (fun str ch -> string(ch) + string(str)) "" s

//Exercise 12
let toUpper (s:string) =
    implode (List.map (fun x -> System.Char.ToUpper x) (explode s))

let toUpper1 (s:string) =
    explode >> (List.map (System.Char.ToUpper)) >> implode

let toUpper2 (s:string) =
    explode s |> (implode << List.map System.Char.ToUpper)

//Exercise 13
let palindrome (s:string) =
    (explode s |> implodeRev |> toUpper) = toUpper s

//Exercise 14
let rec ack (m, n) =
    match (m, n) with
    | (m, n) when m < 0 || n < 0 -> failwith "The Ackermann function
        is defined for non negative numbers only."
    | (m, n) when m = 0 -> n + 1
    | (m, n) when n = 0 -> ack (m - 1, 1)

```

```
| (m, n) -> ack (m-1, ack(m, n-1))
```

```
//Exercise 15
let time f =
  let start = System.DateTime.Now in
  let res = f () in
  let finish = System.DateTime.Now in
  (res, finish - start);

let timeArg1 f a = time(fun () -> f(a))
```

H.2.3 HandIn 3

```
type 'a BinTree =
  | Node of 'a * 'a BinTree * 'a BinTree
  | Leaf;;

let intBinTree = Node(43, Node(25, Node(56, Leaf, Leaf), Leaf),
Node(562, Leaf, Node(78, Leaf, Leaf)));;
```

```
//Exercise 16
let rec inOrder tree =
  match tree with
  | Leaf -> []
  | Node (n, treeL, treeR) ->
    inOrder treeL @ n :: inOrder treeR;;
```

```
//Exercise 17
let rec mapInOrder (funct: 'a -> 'b) tree =
  match tree with
  | Leaf -> Leaf
  | Node (n, treeL, treeR) ->
    let left = mapInOrder funct treeL
    let value = funct n
    let right = mapInOrder funct treeR
    Node (value, left, right);;
```

(* They traverse the tree in different orders,
which can give different results. *)

```
//Exercise 18
//Doesn't have the right signature, but this was the closest I could get
//to it while getting the correct result
let rec foldInOrder funct acc tree =
  match tree with
  | Leaf -> acc
  | Node (root, treeL, treeR) ->
    funct (foldInOrder funct acc treeL) root (foldInOrder funct acc treeR);;

let func left root right = left + root + right;;
```

```

let seed = 1;;

let testingFol = foldInOrder func seed intBinTree;;

//Exercise 19 / 21 / 22
type expr =
| Const of int
| If of expr * expr * expr
| Bind of string * expr * expr
| Var of string
| Prim of string * expr * expr

let rec evaluate expr (dict:
System.Collections.Generic.Dictionary<string, expr>) =
    match expr with
    | Const(i) ->
        i
    | If(expr1, expr2, expr3) ->
        if ((evaluate expr1 dict) > 0 || (evaluate expr1 dict) < 0)
        then (evaluate expr2 dict) else (evaluate expr3 dict)
    | Bind(var, value, expr1) ->
        dict.Add(var, value)
        evaluate expr1 dict
    | Var(text) when dict.ContainsKey(text) ->
        evaluate (dict.Item text) dict
    | Var(text) ->
        failwithf "Unknown variable '%s'" text
    | Prim("-", expr1, expr2) ->
        evaluate expr1 dict - evaluate expr2 dict
    | Prim("+", expr1, expr2) ->
        evaluate expr1 dict + evaluate expr2 dict
    | Prim("max", expr1, expr2) ->
        (List.max [evaluate expr1 dict; evaluate expr2 dict])
    | Prim("min", expr1, expr2) ->
        (List.min [evaluate expr1 dict; evaluate expr2 dict])
    | Prim("=", expr1, expr2) ->
        if (evaluate expr1 dict).Equals(evaluate expr2 dict) then 1 else 0
    | Prim(opr, -, -) ->
        (printfn "Operation '%s' not supported" opr; 0);;

let eval expr =
    evaluate expr (new System.Collections.Generic.Dictionary<string, expr>());;

//Exercise 20
let testingMinus = eval (Prim("-", Const 10, Const 5));;
let testingPlus = eval (Prim("+", Const 10, Const 5));;
let testingMx = eval (Prim("max", Const 10, Const 5));;
let testingMin = eval (Prim("min", Const 10, Const 5));;
let testingEquals = eval (Prim("=", Const 10, Const 5));;

let testingIf1 = eval (If(Const 3, Const 20, Const 18));;

```

```

let testingIf2 = eval (If(Const 0, Const 20, Const 18));;

//Exercise 23
let testingBindVal1 = eval (Bind("troll", Const 20,
Bind("anti-troll", Const 42, Bind("super-troll", Var "troll",
Var "anti-troll"))));;
let testingBindVal2 = eval (Bind("what",
Bind("happens", Const 20, Var "happens"), Var "what"));;
let testingBindVal3 = eval (Bind("lol", Const 1337, Var "lol"));;
let testingVarFail1 = eval (Var("troll"));;
let testingVarFail2 = eval (Bind("fail", Const 117, Var "troll"));;

```

H.2.4 HandIn 4 & 5

```

(*-----*
 * The professor game is about placing 16 cards with two professor *
 * jackets and two professor trousers in different colors on a      *
 * square board.                                                    *
 * This program finds all solutions to a given set of cards.        *
 * Visit http://boardgamegeek.com/boardgame/15800/professorspillet *
 * to get an idea of how the game works.                            *
 *                                                                    *
 * 27/12/1995, Niels Hallenberg (Written i SML)                      *
 * 27/03/2009, Niels Hallenberg (Ported to F#)                      *
 * 09/04/2012, Niels Hallenberg (Adjusted to be used for exercise) *
 *-----*)

```

```

(* Do not change the two functions doImpl4 and doImpl5 – they are used
   to show where you put in your own code. *)

```

```

exception ToBeImplemented of string

```

```

let doImpl4 s = raise (ToBeImplemented ("Hand-in 04: " + s))

```

```

(* do not change *)

```

```

let doImpl5 s = raise (ToBeImplemented ("Hand-in 05: " + s))

```

```

(* do not change *)

```

```

(* listTake: returns a new list with first n items in the list xs. *)

```

```

let rec listTake n xs =

```

```

    match (n,xs) with

```

```

        (0,-) -> []

```

```

    | (n,x::xs) -> x::listTake (n-1) xs

```

```

    | _ -> failwith "listTake - n out of range"

```

```

(*-----*
 * Datatypes and simple operations.                                *
 *-----*)

```

```

(* Define a data type clothes representing the possible clothes.
   I.e. a red jacket, red trousers etc. *)

```

```

type clothes =

```

```

    | RED_JACKET

```

```
| RED_TROUSERS
| GREEN_JACKET
| GREEN_TROUSERS
| BLUE_JACKET
| BLUE_TROUSERS
| BROWN_JACKET
| BROWN_TROUSERS
```

(* Define a record type card to hold the piece of clothe at the top, buttom, left and right. *)

```
type card =
  {top:clothes;
   bot:clothes;
   left:clothes;
   right:clothes}
```

(* Define the 16 cards that you have to place in 4 rows and 4 columns *)

```
let cardSet =
  [{top= BLUE_TROUSERS; bot=BROWN_JACKET;
    left= BLUE_JACKET; right=BROWN_TROUSERS};
   {top=BROWN_TROUSERS; bot=GREEN_JACKET;
    left=BROWN_JACKET; right= RED_TROUSERS};
   {top=GREEN_TROUSERS; bot=GREEN_JACKET;
    left= RED_JACKET; right= BLUE_TROUSERS};
   {top=BROWN_TROUSERS; bot=BROWN_JACKET;
    left= BLUE_JACKET; right= RED_TROUSERS};
   {top=BROWN_TROUSERS; bot=GREEN_JACKET;
    left= BLUE_JACKET; right= RED_TROUSERS};
   {top=GREEN_TROUSERS; bot=BROWN_JACKET;
    left= RED_JACKET; right= BLUE_TROUSERS};
   {top=GREEN_TROUSERS; bot=BROWN_JACKET;
    left= BLUE_JACKET; right= RED_TROUSERS};
   {top=BROWN_TROUSERS; bot= BLUE_JACKET;
    left= RED_JACKET; right=GREEN_TROUSERS};
   {top=GREEN_TROUSERS; bot=BROWN_JACKET;
    left= RED_JACKET; right=GREEN_TROUSERS};
   {top=BROWN_TROUSERS; bot=GREEN_JACKET;
    left=GREEN_JACKET; right= BLUE_TROUSERS};
   {top=BROWN_TROUSERS; bot=GREEN_JACKET;
    left= BLUE_JACKET; right= RED_TROUSERS};
   {top= BLUE_TROUSERS; bot=BROWN_JACKET;
    left= RED_JACKET; right=GREEN_TROUSERS};
   {top=BROWN_TROUSERS; bot= RED_JACKET;
    left=GREEN_JACKET; right= BLUE_TROUSERS};
   {top=GREEN_TROUSERS; bot= RED_JACKET;
    left= BLUE_JACKET; right=BROWN_TROUSERS};
   {top=GREEN_TROUSERS; bot= BLUE_JACKET;
    left=BROWN_JACKET; right= RED_TROUSERS};
   {top=BROWN_TROUSERS; bot=GREEN_JACKET;
    left= RED_JACKET; right=GREEN_TROUSERS}]
```

```
(* Define the board. There are indeed many ways to represent the board.
You must use the below representation – not because it
is particular intelligent –
it certainly isn't – but because it is fairly easy to
understand and work with.
```

```
The board is represented as a
```

- a) list of cards
- b) current column number
- c) current row number

```
The idea is that we add one card at the time to the board and
increase col/row as we go along.
```

```
We only add valid cards, of course. If we, at some point, get
a board with 16 cards (4 rows and 4 columns),
then we have a solution. *)
```

```
type row = int
type col = int
type board = row*col*(card list)
```

```
(* Define the empty board, i.e., no cards added.
We start by column 0 and row 0. *)
```

```
let emptyBoard = (0, 0, [])
let colNo = 4 (* number of columns on board. *)
let rowNo = 4 (* number of rows on board. *)
```

```
(* Define four functions that given a card
with return one of the four clothes on the card. *)
```

```
let findBot (card:card) = card.bot
let findTop (card:card) = card.top
let findLeft (card:card) = card.left
let findRight (card:card) = card.right
```

```
(* Calculate index in list given row and column. *)
```

```
(* Define a function given row and column
to calculate the index of that coordinate in the list.
```

```
Notice, that the first row and column has index 0. *)
let findIndexInList (row, col) = row*colNo+col
```

```
(* Define a function add that given a coordinate (row,col)
```

```
finds a new coordinate (row',col')
n places to the right (if n is positive) and
n places to the left (if n is negative). *)
```

```
let add n (row, col) =
  let row' = (row*colNo+n+col) / colNo
  let col' = (row*colNo+n+col) \% colNo
  (row', col')
```

```
(*-----*)
* PrettyPrinting *
```

```

*-----*)

(* Define a function that as a string
returns a pretty print of the clothes. *)
let pp_clothes clothes =
  match clothes with
  | RED_JACKET      -> "RED_JACKET      "
  | RED_TROUSERS    -> "RED_TROUSERS    "
  | GREEN_JACKET    -> "GREEN_JACKET    "
  | GREEN_TROUSERS  -> "GREEN_TROUSERS"
  | BLUE_JACKET     -> "BLUE_JACKET     "
  | BLUE_TROUSERS   -> "BLUE_TROUSERS   "
  | BROWN_JACKET    -> "BROWN_JACKET    "
  | BROWN_TROUSERS  -> "BROWN_TROUSERS"

(* Define a function to output a string s on the console. *)
let output s = printf "%s" s

(* Define a function die, to output an error string s
on the console and afterwards raises
an exception to stop program execution. *)
let die s = (output("Professor_game - DIE with message: " + s);
             failwith s)

(* Define a set of pretty print functions to pretty print
a board containing a number of cards. *)
let pp_newline () = output "\n"
let pp_board_line () = output
  "+-----++-----+"
  +-----++-----+ "\n"
let pp_vertical xs = (List.iter (fun clothe -> output
  ("|      " + (pp_clothes clothe) + "      |")) xs; pp_newline())
let pp_horizontal xs = (List.iter (fun (l, r) -> output
  ("|" + (pp_clothes l) + "      " + (pp_clothes r) + "|")) xs; pp_newline())

let pp_row cards =
  let tops = List.map findTop cards
  let bots = List.map findBot cards
  let lefts = List.map findLeft cards
  let rights = List.map findRight cards
  let centerRow = List.zip lefts rights
  (pp_board_line();
   pp_vertical tops;
   pp_horizontal centerRow;
   pp_vertical bots;
   pp_board_line ())

(* Split list [x1,...,xN] in the lists [x1,...,xn-1] and [xn,...,xN] *)
(* where n >= 0 and n < N . *)
(* Fx: splitNth (0,[1;2]) gives ([], [1; 2]) *)
(*       splitNth (1,[1;2]) gives ([1], [2]) *)

```

```

(*      splitNth (2,[1;2]) gives ([1; 2], []) *)
(*      splitNth (3,[1;2]) should die : 3 outside range of list *)
(*      splitNth (-1,[1;2]) should die : -1 outside range of list *)
let rec splitNth (n, xs) =
  match (n, xs) with
  | (0, xs) -> ([], xs)
  | (n, x :: xs) -> let (a, b) = splitNth (n - 1, xs);
                     (x :: a, b)
  | _ -> failwith "The input is out of range"

(* IT IS REQUIRED THAT THE OUTPUT MATCHES THE EXAMPLES BELOW EXACTLY!!! *)
(* Please use the helper functions above: pp_horizontal, pp_vertical etc. *)
(* PrettyPrint all cards - colNo says number of columns on the board. *)
(* colNo is defined to be 4 above. *)
(* A few examples of output below. *)
let rec pp_cards (cards : card list) =
  match cards with
  | [] -> ()
  | card when cards.Length <= 4 -> pp_row (cards)
  | _ -> let (a, b) = splitNth(colNo, cards);
         pp_row a; pp_cards b

let _ = pp_cards (listTake 1 cardSet)
let _ = pp_cards (listTake 2 cardSet)
let _ = pp_cards (listTake 4 cardSet)
let _ = pp_cards (listTake 5 cardSet)
let _ = pp_cards cardSet

let pp_board (row, col, cards) =
  (output "New board\n";
   pp_cards cards;
   pp_newline())

let pp_boards boards = List.iter pp_board boards

(*-----*)
* Solving board *
(*-----*)

(* matchClothes: the valid combinations of clothe. *)
(* There are 8 valid combinations *)
let matchClothes clothe1 clothe2 =
  match (clothe1, clothe2) with
  | (RED_JACKET, RED_TROUSERS) -> true
  | (RED_TROUSERS, RED_JACKET) -> true
  | (GREEN_JACKET, GREEN_TROUSERS) -> true
  | (GREEN_TROUSERS, GREEN_JACKET) -> true
  | (BLUE_JACKET, BLUE_TROUSERS) -> true
  | (BLUE_TROUSERS, BLUE_JACKET) -> true
  | (BROWN_JACKET, BROWN_TROUSERS) -> true
  | (BROWN_TROUSERS, BROWN_JACKET) -> true

```

```

    | - -> false

(* matchTop: Given a coordinate, match that card
   with the card immediately above. *)
(* Notice, that cards the top row fulfils this automatically.
   *)
let matchTop (row, col, cards) card =
  if row > 0 then
    let topCard = List.nth cards ((findIndexInList (row, col))-colNo)
    matchClothes (findBot topCard) (findTop card)
  else true

(* matchLeft: Given a coordinate, match that card
   with the card immediately to the left. *)
let matchLeft (row, col, cards) card =
  if col > 0 then
    let leftCard = List.nth cards ((findIndexInList (row, col))-1)
    matchClothes (findRight leftCard) (findLeft card)
  else true

(* matchBot: Given a coordinate, match that card
   with the card immediately below. *)
(* Notice, cards at the bottom row fulfils this automatically.
   *)
let matchBot (row, col, cards) card =
  if row > 0 then
    let botCard = List.nth cards ((findIndexInList (row, col))+colNo)
    matchClothes (findTop botCard) (findBot card)
  else true

(* matchRight: Given a coordinate, match that card
   with the card immediately to the right. *)
(* Notice, cards at the rightmost column fulfils this automatically.
   *)
let matchRight (row, col, cards) card =
  if col > 0 then
    let rightCard = List.nth cards ((findIndexInList (row, col))+1)
    matchClothes (findLeft rightCard) (findRight card)
  else true

(* Given a coordinate, match with cards immediately to the left and above. *)
let Match ((row, col, _) as board) card =
  (matchTop board card) && (matchLeft board card)

(* There is ONE error in the code below – and it never terminates *)
(* If you correct this one error – everything will work just fine *)
(* You must explain the error as a comment here:
   The add function (line 256) was called with a 0 instead of a 1,
   so it never changed the position of where the cards were matched.
   This means that the cards constantly were matched on the first
   position (0, 0), where no other cards were around it. This would

```

```

    always succeed, and therefore it kept piling the cards on top of
    each other, and therefore it never terminated. *)
let rec findSol rest alreadyTried ((row,col,cards) as board) sols =
  match (rest,alreadyTried) with
  | ([],[]) -> board::sols
    (* No rest and alreadyTried is empty, that is, solution found *)
  | ([],_-) -> sols
    (* No solution if alreadyTried is non empty. *)
  | (x::rest, alreadyTried) ->
    let sols' =
      if Match board x then
        (* If there is a match, then go on with the rest of the cards *)
        let (row', col') = add 1 (row, col)
        findSol(rest@alreadyTried) [] (row', col', cards@[x]) sols
      else sols (* If no match then no new solutions found. *)
    (* Put the card x in alreadyTried and move on. *)
    findSol rest (x::alreadyTried) board sols'

(*-----*)
* Generating a board. *
*-----*)

let _ = printfn "Sequential version"
let res = findSol cardSet [] emptyBoard []
pp-boards res
let _ = printfn "Sequential solution with %d solutions" (res.Length)

let _ = printfn "Simple parallel version where we spawn one search
with each card chosen first."
let boards = List.map (fun card -> (0,1,[card])) cardSet
let rests = List.map (fun (_,_,[card]) ->
  List.filter (fun c -> c <> card) cardSet) boards

let work = List.map (fun (b,rest) ->
  (fun () -> findSol rest [] b [])) (List.zip boards rests)
let allWork = List.toArray work
let parRes' = Array.Parallel.map (fun f -> f()) allWork
let parRes = List.concat (Array.toList parRes')
pp-boards parRes
let _ = printfn "Parallel solution with %d solutions" (parRes.Length)

```

H.3 F# Handins - Jakob Melnyk

H.3.1 HandIn 1

```
module Module1
```

```
// Exercise 1
let sqr x = x*x
```

```
// Exercise 2
let pow x n = System.Math.Pow(x, n)

// Exercise 3
let dup s : string = s + s

// Exercise 4
let rec dupn (s:string) x =
    if x>=1 then (if x = 1 then s else s + dupn s (x-1)) else ""

// Exercise 5
let timediff (hh1, mm1)(hh2, mm2) = (hh2*60 + mm2)-(hh1*60 + mm1)

// Exercise 6
let minutes (hh, mm) = timediff(00, 00)(hh, mm)
```

H.3.2 HandIn 2

```
module Module2

// Exercise 7
let rec downTo x =
    if x < 1 then [] else (if x = 1 then [x] else x :: downTo (x - 1))

let rec downTo2 x =
    match x with
    | x when x < 1 -> []
    | 1 -> [1]
    | _ -> x :: downTo2 (x - 1)

// Exercise 8
let rec removeEven (x:int list) =
    match x with
    | [] -> []
    | [xs] -> [xs]
    | xs :: ys :: zs -> xs :: removeEven zs

// Exercise 9
let rec combinePair (x:int list) : (int * int) list =
    match x with
    | [] -> []
    | [xs] -> []
    | xs :: ys :: zs -> (xs, ys) :: combinePair zs

// Exercise 10
let explode (s:string) = List.ofArray (s.ToCharArray())

let rec explode2 (s:string) : char list =
    match s with
    | s when s.Length < 1 -> []
    | _ -> s.[0] :: explode2 (s.Substring 1)
```

```
// Exercise 11
let implode (cl:char list) : string =
    List.foldBack (fun elem acc -> string(elem) + string(acc) ) cl ""

let implodeRev (cl:char list) : string =
    List.fold (fun elem acc -> string(acc) + string(elem) ) "" cl

// Exercise 12
let toUpper (s:string) = implode (List.map System.Char.ToUpper (explode s))

let toUpper1 = explode >> List.map System.Char.ToUpper >> implode

let toUpper2 (s:string) = explode s |> (implode << List.map System.Char.ToUpper)

// Exercise 13
let palindrome (s:string) = (explode s |> implodeRev |> toUpper) = toUpper s

// Exercise 14
let rec ack (m, n) =
    match (m, n) with
    | (m, n) when m < 0 || n < 0 -> failwith "The Ackermann function
        is defined for non negative numbers only."
    | (m, n) when m = 0 -> n + 1
    | (m, n) when n = 0 -> ack (m - 1, 1)
    | (m, n) -> ack(m - 1, ack (m, n - 1))

// Exercise 15
let time f =
    let start = System.DateTime.Now in
    let res = f () in
    let finish = System.DateTime.Now in
    (res, finish - start)

let timeArg1 f a = time(fun () -> f(a))
```

H.3.3 HandIn 3

```
odule FSharpHandIn3

type 'a BinTree =
    Leaf
    | Node of 'a * 'a BinTree * 'a BinTree

let intBinTree =
    Node(
        43,
        Node(25, Node(56, Leaf, Leaf), Leaf),
        Node(562, Leaf, Node(78, Leaf, Leaf))
    )
```

```
// Exercise 16
let rec inOrder tree =
  match tree with
  | Leaf -> []
  | Node(n, treeL, treeR) -> inOrder treeL @ [n] @ inOrder treeR
```

```
// Exercise 17
let rec mapInOrder (f:'a -> 'b) (tree:'a BinTree) : 'b BinTree =
  match tree with
  | Leaf -> Leaf
  | Node(n, treeL, treeR) ->
      let left = mapInOrder f treeL
      let root = f(n)
      let right = mapInOrder f treeR
      Node(root, left, right)
```

(*Example:

The result tree should always be the same, as the function should access all the elements no matter what.

The reason the individual nodes may not contain the same information could be that the function depends on the order in which the elements are accessed.*)

```
// Exercise 18
let rec foldInOrder f a t =
  match t with
  | Leaf -> a
  | Node(x, leftTree, rightTree) ->
      let left = foldInOrder f a leftTree
      foldInOrder f (f x left) rightTree
```

```
// Exercise 19 & 21 & 22
```

```
type expr =
  | Const of int
  | If of expr * expr * expr
  | Bind of string * expr * expr
  | Var of string
  | Prim of string * expr * expr
```

```
let rec evalN expr (d:System.Collections.Generic.Dictionary<string, expr>) =
  match expr with
  | Const i -> i
  | Prim("-", expr1, expr2) ->
      evalN expr1 d - evalN expr2 d
  | Prim("+", expr1, expr2) ->
      evalN expr1 d + evalN expr2 d
  | Prim("max", expr1, expr2) ->
      List.max [evalN expr1 d; evalN expr2 d]
  | Prim("min", expr1, expr2) ->
      List.min [evalN expr1 d; evalN expr2 d]
  | Prim("=", expr1, expr2) ->
      if evalN expr1 d = evalN expr2 d then 1 else 0
```

```

| If(expr1, expr2, expr3) ->
    if evalN expr1 d < 0 then evalN expr2 d else evalN expr3 d
| Bind(var, value, expr1) ->
    d.Add(var, value)
    evalN expr1 d
| Var(name) when d.ContainsKey(name) ->
    evalN (d.[name]) d
| Var(name) ->
    failwithf "Unknown variable '%s'" name
| Prim(opr, -, -) ->
    (printfn "Operation %s not supported" opr; 0)

let eval expr =
    evalN expr (new System.Collections.Generic.Dictionary<string, expr>())

// Exercise 20
let testMinus =
    eval (Prim("-", Const(20), Const(30))) // Expected result = -10
let testPlus =
    eval (Prim("+", Const(20), Const(30))) // Expected result = 50
let testMax =
    eval (Prim("max", Const(20), Const(30))) // Expected result = 30
let testMin =
    eval (Prim("min", Const(20), Const(30))) // Expected result = 20
let testEqualFalse =
    eval (Prim("=", Const(20), Const(30))) // Expected result = 0
let testEqualTrue =
    eval (Prim("=", Const(20), Const(20))) // Expected result = 1

// Exercise 23
let testBindOne = // Expected result = 57
    eval (Bind("p", Prim("+", Const(13), Const(29)), Prim("+", Var("p"), Const(15))))
let testBindTwo = // Expected result = -16
    eval (Bind("x", Prim("-", Const(13), Const(29)), Prim("+", Var("x"), Const(15))))
let testBindThree = // Expected result = 97
    eval (Bind("x", Const(97), Bind("y", Const(3), Prim("max", Var("x"), Var("y")))))
let testBindFour = // Expected result = 0
    eval (Bind("x", Const(97), Bind("y", Const(3), Prim("=", Var("x"), Var("y")))))
let testBindFive = // Fail case
    eval (Bind("x", Prim("+", Const(13), Const(29)), Prim("+", Var("y"), Const(15))))

```

H.3.4 HandIn 4 & 5

H.4 F# Handins - Niklas Hansen

H.4.1 HandIn 1

```

// Author: Niklas Hansen <nikl@itu.dk>
module Handin1

```

```

// Exercise 1
let sqr (x:int) =
    x * x

// Exercise 2
let pow (x:float) (y:float) =
    x ** y

// Exercise 3
let dup (s:string) =
    s + s

// Exercise 4 - v1
let rec dupn (s:string) (n:int) =
    match n with
    | 0 -> ""
    | _ -> s + dupn s (n-1)

// Exercise 4 - v2
//let rec dupn (s:string) = function
//    | 0 -> ""
//    | n -> s + dupn s (n-1)

// Exercise 5
let timediff (h1:int, m1:int) (h2:int, m2:int) =
    ((h2 * 60) + m2) - ((h1 * 60) + m1)

// Exercise 6
let minutes (hh:int, mm:int) =
    timediff (00, 00) (hh, mm)

printfn "1. Sqr 3: %i" (sqr 3)
printfn "2. pow 3 2: %f" (pow 3.0 2.0)
printfn "3: dup \"Hi \": %s" (dup "Hi ")
printfn "4. dupn \"Hi \" 3: %s" (dupn "Hi " 3)

printfn "5a. timediff (12, 34) (11, 35): %i" (timediff (12, 34) (11, 35))
printfn "5b. timediff (12, 34) (13, 35): %i" (timediff (12, 34) (13, 35))

printfn "6a. minutes (14, 24): %i" (minutes (14, 24))
printfn "6b. minutes (23, 1): %i" (minutes (23, 1))

```

H.4.2 HandIn 2

```

// Author: Niklas Hansen <nikl@itu.dk>
module Handin2

// Exercise 7a
let rec downTo (n:int) =

```

```

    if n > 0
        then n :: downTo (n-1)
        else []

// Exercise 7b
let rec downTo2 (n:int) =
    match n with
    | n when n <= 0 -> []
    | _ -> n :: downTo2 (n-1)

// Exercise 7b v2
//let rec downTo2 = function
//    | n when n <= 0 -> []
//    | n -> n :: downTo2 (n-1)

// Exercise 8
let rec removeEven = function
    | [] -> []
    | [n] -> [n]
    | n :: m :: tl -> n :: removeEven tl

// Exercise 9
let rec combinePair = function
    | [] -> []
    | [n] -> []
    | n :: m :: tl -> (n, m) :: combinePair tl

// Exercise 10a
let explode (s:string) =
    let chars = s.ToCharArray()
    List.ofArray(chars)

// Exercise 10b
let rec explode2 (s:string) =
    match s with
    | "" -> []
    | _ -> s.Chars 0 :: explode2 (s.Remove(0, 1))

// Exercise 11a
let implode (c:char list) =
    List.foldBack (fun x y -> sprintf "%c%s" x y) c ""

// Exercise 11b
let implodeRev (c:char list) =
    List.fold (fun x y -> sprintf "%c%s" y x) "" c

// Exercise 12a
let toUpper (s:string) =
    implode (List.map (fun x -> System.Char.ToUpper(x)) (explode s))

// Exercise 12b

```

```

let toUpper1 (s:string) =
    (explode >> List.map (fun x -> System.Char.ToUpper(x)) >> implode) s

// Exercise 12c
let toUpper2 (s:string) =
    s |> (implode << List.map (fun x -> System.Char.ToUpper(x)) << explode)

// Exercise 13
let palindrome (s:string) =
    let org = s.ToLower().Replace(" ", "")
    let rev = new string (Array.rev (org.ToCharArray()))
    org = rev

// Exercise 14
let rec ack (m:int, n:int) =
    match m, n with
    | (0, n) -> n + 1
    | (m, 0) when m > 0 -> ack(m - 1, 1)
    | (m, n) when m > 0 && n > 0 -> ack(m - 1, ack(m, n - 1))
    | (m, n) -> failwith "Invalid input!"

// Addon for Exercise 15
let time f =
    let start = System.DateTime.Now
    let res = f ()
    let finish = System.DateTime.Now
    (res, finish - start)

// Exercise 15
let timeArg1 f a =
    time (fun () -> f a)

printfn "7a. downTo 5: %s" ((downTo 5).ToString())
printfn "7a. downTo -3: %s" ((downTo -3).ToString())
printfn "7b. downTo2 5: %s" ((downTo2 5).ToString())

printfn "8. removeEven [1; 2; 3; 4; 5]: %s" ((removeEven [1; 2; 3; 4; 5]).ToString())
printfn "8. removeEven []: %s" ((removeEven []).ToString())
printfn "8. removeEven [1]: %s" ((removeEven [1]).ToString())

printfn "9. combinePair [1; 2; 3; 4]: %s" ((combinePair [1; 2; 3; 4]).ToString())
printfn "9. combinePair [1; 2; 3]: %s" ((combinePair [1; 2; 3]).ToString())
printfn "9. combinePair [1; 2]: %s" ((combinePair [1; 2]).ToString())
printfn "9. combinePair []: %s" ((combinePair []).ToString())
printfn "9. combinePair [1]: %s" ((combinePair [1]).ToString())

printfn "10a. explode \"star\": %s" ((explode "star").ToString())
printfn "10b. explode2 \"star\": %s" ((explode2 "star").ToString())

printfn "11a. implode ['a'; 'b'; 'c']: %s" (implode ['a'; 'b'; 'c'])

```

```

printfn "11b. implodeRev ['a'; 'b'; 'c']: %s" (implodeRev ['a'; 'b'; 'c'])

printfn "12a. toUpper \"Hej\": %s" (toUpper "Hej")
printfn "12b. toUpper1 \"Hej\": %s" (toUpper1 "Hej")
printfn "12c. toUpper2 \"Hej\": %s" (toUpper2 "Hej")

printfn "13. palindrome \"Anna\": %s" ((palindrome "Anna").ToString())
printfn "13. palindrome \"Ann\": %s" ((palindrome "Ann").ToString())

printfn "14. ack(3, 11): %i" (ack(3, 11))

printfn "Extra. time: %s" ((time (fun () -> ack (3, 11))).ToString())
printfn "15. timeArg1 ack (3, 11): %s" ((timeArg1 ack (3, 11)).ToString())

System.Console.ReadKey(true)

```

H.4.3 HandIn 3

H.4.4 HandIn 4 & 5

H.5 F# Handins - Ulrik Flænø Damm

H.5.1 HandIn 1

```

KF 02
Handin 1
Ulrik Damm (ulfd@itu.dk)

let sqr x = x * x;;

let pow x n = System.Math.Pow (x, n);;

let dup s = s + s;;

let rec dupn s n =
    match n with
    | 0 -> ""
    | 1 -> s
    | n -> s + dupn s (n-1)
    ;;

let timediff (time11, time12) (time21, time22) = (time21 - time11) * 60 +
(time22 - time12);

let minutes (time1, time2) = timediff (0, 0) (time1, time2);

let Main =
    printfn "%i" (sqr 2);

```

```
printfn "%f" (pow 2.0 3.0);
printfn "%s" (dup "Hi ");
printfn "%s" (dupn "Hi " 3);
printfn "%i" (timediff (12,34) (11,35));
printfn "%i" (timediff (12,34) (13,35));
printfn "%i" (minutes (14,24));
printfn "%i" (minutes (23,1));
```

H.5.2 HandIn 2

```
let rec downTo n =
    if n < 2
    then raise (new System.Exception(" Invalid value"))
    else if n = 1
    then [1]
    else n :: downTo (n-1);;

let rec downTo2 = function
| n when n < 1 -> raise (new System.Exception(" Invalid value"))
| 1 -> [1]
| n -> n :: downTo2 (n-1);;

let rec removeEven = function
| [] -> []
| [n] -> [n]
| [n; _] -> [n]
| n :: m :: tl -> removeEven [n; m] @ removeEven tl;;

let rec combinePair = function
| [] -> []
| [n] -> []
| [n; m] -> [n, m]
| n :: m :: tl -> combinePair [n; m] @ combinePair tl;;

let explode (str : string) = List.ofArray(str.ToCharArray());;

let rec explode2 (str : string) =
    if str.Length = 0 then []
    else if str.Length = 1 then [str.Chars(0)]
    else str.Chars(0) :: explode2 (str.Remove(0, 1));;

let implode str = List.foldBack (fun x y -> sprintf "%c%s" x y) str "";;

let implodeRev str = List.fold (fun x y -> sprintf "%c%s" y x) "" str;;

let toUpper str =
    implode (List.map (fun x -> System.Char.ToUpper x) (explode str));;

let toUpper1 str =
    (explode >> (List.map (fun x -> System.Char.ToUpper x)) >> implode) str;;
```

```
let toUpper2 str =
    (implode << ((fun x -> System.Char.ToUpper x) |> List.map) << explode) str;;

let rec palindrome (str : string) =
    if str.Length <= 1 then true
    else if str.Chars(0) = str.Chars(str.Length - 1)
        then palindrome (str.Substring(1, str.Length - 2))
    else false;;

let rec ack = function
    | (0, n) -> n + 1
    | (m, 0) -> ack (m - 1, 1)
    | (m, n) -> ack (m - 1, ack (m, n - 1));;

let time f =
    let start = System.DateTime.Now in
    let res = f () in
    let finish = System.DateTime.Now in
    (res, finish - start);

let timeArg1 f a = time (fun x -> f a);;

let Main = printfn "lol";;
```

H.5.3 HandIn 3

H.5.4 HandIn 4 & 5