Preliminary report - MetaTracks

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For evaluation in the course
IE303612 Bachelor Thesis - Automation and computer engineering

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1 Abstract

When choosing our final assignment, we set several criteria that had to be fulfilled in order to get the most value out of the assignment. We wanted to utilize all the knowledge gained through several subjects and assignments while being enrolled as computer engineering students, including system development, several programming languages, development methodologies and information security.

Our application was accepted by "MetaTracks", a start-up company from the Ålesund area. MetaTracks' main goal is to create an innovative web-based service for content synchronized with digital media such as movies and TV series. Working with a start-up company will hopefully give us many valuable experiences we would not otherwise get when working for a traditional "large corporation". These days, start-up companies are becoming increasingly popular, both in Norway and abroad.

MetaTracks was started and is run by Christian Strømmen, which will act as our employer for the course of the project. The project is financed by Innovation Norway and other external investors.

2 Terms

Acoustic (audio) fingerprint: A digital summary of audio signals. Acoustic fingerprints are usually generated by transforming and hashing *spectrograms*. There are no set rules or standards for *how* these fingerprints should be generated, and generation methods differ greatly.[1]

Spectrogram: A visual representation of the time-frequency spectrum in several types of signals. The intensity of the signal is also represented in a spectrogram.[4]

Fingerprint database: A centralized collection of acoustic fingerprints. The fingerprints are usually stored with a focus on quick access.

Scrum: An agile framework for software development of complex systems. Scrum focuses on incremental and interative work and delivery through the projects life-cycle.[12]

Multimedia: Defined as content using a combination of *content forms*, this could be a combination of audio, video, images, animation, and interactivity.[3]

Life cycle: The "system development life cycle" is a set of steps required to deliver a stable, finished software product. The cycle typically include five main phases: planning, analysis, design, implementation and maintenance.[15]

Signal processing: Signal processing revolve around representing signals in a digital format. Once digitally represented, a signal can be analyzed, modified, or have its digital information retrieved.[8]

3 Project organization

In this chapter of the report we present how we have planned the organization of the project group. Each group member will have different roles, with specific tasks and responsibilities. In the end of the chapter we present the supervising group for the project, which consist of the employer and the supervisor.

3.1 Project group

Student number	**Name**
120249	Kristoffer L. Nesvik
120170	Glenn S. Skjong
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Table 3.1: The student numbers and names for all the group members delivering the assignment for evaluation in the course IE303612.

3.1.1 Roles in the project group

Kristoffer L. Nesvik: Project leader
Glenn S. Skjong: Scrum leader
Kristian Støylen: Secretary

In addition to the roles defined above, each group member will be responsible for decisions relating to the project. This includes, but are not limited to; the planning, development and documentation of the product.

3.1.2 Project leader tasks

Area of responsibility:

- Enforcing group norms and rules, as described in chapter 4.3.
- Delegating responsibility and tasks to the project group members, for example specific tasks related to project development.
- Create a working environment with good morale and motivation.

Project leader specific tasks:

- Overall responsibility for making sure that partial goals and deliverables are finished on time and is delivered as a whole.
- Tasked with supervising the software development, making sure that good routines and standards related to software development is followed throughout the project.
- The project leader is participating in the planning, development and documentation work on the same level as the rest of the project group.

3.1.3 Secretary tasks

Area of responsibility:

- Overall responsibility for documentation and other written documentation, both internal documents for the project group and documents meant for the supervising group and/or the University.
- Responsible for logging project work and project advances.

Secretary specific tasks:

- Write summaries and documentation from meetings between the supervising group and the project group.
- Quality assurance of written documentation.
- The secretary is participating in the planning, development and documentation work on the same level as the rest of the project group.

3.1.4 Scrum leader tasks

Area of responsibility:

- Responsible for the agile development framework "Scrum", assuring that this framework is used in accordance with the methodology standards.
- Planning "sprints" and evaluating the "Product Backlog.", ref. chapter 5.3.

Scrum leader specific tasks:

- Responsible for assuring that the Scrum-team works as planned to meet the required amount of work described in the sprint log.
- The Scrum leader is participating in the planning, development and documentation work on the same level as the rest of the project group.

3.2 Supervising group

The supervising group consists of:

Project supervisor Kjell Inge Tomren at NTNU

Employer and product owner: Christian A. Strømmen at MetaTracks

4 Agreements

This chapter describes the agreed upon contract between the employer and the project group, in addition to group norms and rules that will be followed for the duration of the project.

4.1 Contract of employment

- The project group are to deliver continuous reports describing the ongoing process and milestones in the project to the employer. The reports should be delivered preferably every two weeks.
- Questions the project group might have relating to the products upcoming development should be directed at the employer.

4.2 Workspace and resources

The project group will mainly be working at the facilities of NTNU Ålesund. Professors and other specialists will be available at the University for consultation.

Notables resources the project group will have access to for the duration of the project is Atlassian's "JIRA", an advanced tool for planning and execution of development projects. A dedicated service for server- and database hosting will also be required for development and testing of the product, which will be provided by the University.

Resources related to testing, for example testing of specific variants and platforms, will be made available by the employer.

Most of the details surrounding the project will be withheld from public disclosure, where a non-disclosure agreement will be signed between the project group and the employer in the event that such information is presented to the project group.

Meetings related to the development of the project between the project group and the supervising group will be held preferably every two weeks.

4.3 Group norms and rules of cooperation

Group norms and rules of cooperation that will be the foundation for the project work includes:

- Project group meetings shall begin and end on time.
- All group members will take part in decisions relating to the project development.
- Cooperation and transparency shall be promoted during the project.
- A positive attitude towards the project and enforcing good learning behaviors shall make up the foundation of the work.

Perspectives and attitude towards the profession:

- Continuous "maintenance" of knowledge and abilities through continuous professional and hobbyist work.
- A profound focus on information security and secure operations of software systems, in accordance with applicable laws and regulations.

5 Project description

MetaTracks is a start-up company, aiming to create an innovative web-based service for content synchronized with digital media, such as movies and TV-series.

The project is financed both by Innovation Norway and other external investors.

5.1 Topics, goals and intentions

The project group will be working on a sub-project for MetaTracks. The project includes the development of a software solution that can detect which film or episode a user is watching. The software must also be able to identify where in the film or episode the user is at any given time. To make this possible, the employer means to use acoustic fingerprints sourced from the audio in the multimedia content presented to the end user.

The project consists of producing a system that can generate these acoustic fingerprints from movies and TV, as well as recognizing the audio from the content the user is currently watching to match this audio with fingerprints in a central database.

As a requirement set by the employer, an application for the Apple iPhone is required. As this application can be developed in either Objective-C or Swift programming languages, it can communicate directly with an ASP.NET server developed by the project group. The iPhone requires a standalone application as the native web browser Safari does not support direct microphone access.[5]

In addition to the iPhone application, the project group aims to develop a web application, runnable in traditional web browsers from a personal computer. Supported web browsers would include Google Chrome, Mozilla Firefox and Microsoft Edge, as these support microphone access natively. access.[5]

The project group plans on developing a back-end ASP.NET application and develop a front-end application for web browsers initially. Once the back-end server is complete, and the front-end application can communicate

with the server effectively, the Apple iPhone application can be developed. Web applications can easily be tested and debugged, and parts of the code can be reused for the iPhone application once the web application is complete.

It must be possible to generate fingerprints from a "pure" digital soundtrack in a multimedia file, as well as from a microphone in a mobile client such as a smart-phone. The fingerprints generated from a mobile client has to take into account any noise or distortion present on the channel When crowd-sourcing fingerprints, the system might need several applicable fingerprints before finally accepting them.

As required by the employer and requirements specifications, the fingerprints are to cover a duration not exceeding one second. The goal would be to generate acceptable fingerprints spanning 250 milliseconds. In effect, this means that close to 300 fingerprints would be required per minute of playback. A movie with a run-time of two hours would require up to 36 000 fingerprints. Efficient storage of fingerprints, taking into account the accommodation of the large amount of fingerprints, is also a problem that will be addressed by the project group.

5.1.1 Project challenges

Some of the challenges posed in the project include:

- Generating fingerprints from soundtracks in "pure" multimedia files.
- Generating fingerprints from a microphone on a mobile client, such as a smart-phone.
- When a mobile client is used, how do we compare that fingerprint with a "pure" fingerprint from a digital source?
- How many identical or acceptable fingerprints is required from the user before we can accept the fingerprint and be sure of the users location?
- Comparing the fingerprints from the user with the fingerprints in a centralized database.
- Continuous checks must be carried out to identify where the user is in a multimedia playback.
- When carrying out these checks, it must be possible to identify if the user has paused the playback or skipped either forward or backwards in the playback.
- Good resource utilization is paramount, both for generating the fingerprints and matching them to existing fingerprints. The service will first and foremost run in the background on mobile devices, where resources are limited.

5.2 Requirements specification

Purpose of the requirements specification

The following requirement specifications purpose is to give an overall description of the development of the product; including specifications and purpose of the actual product, requirements for the product and specific *functional* requirements for the product.

Purpose of the product

The product that the project group will develop will be integrated in the main "MetaTracks" product. This integration must be achieved in an effective and elegant manner.

Function of the product

- Effectively generating digital fingerprints from multimedia content.
- Utilizing these fingerprints to create an innovative web service with returning users.

Specific functional requirements

- Generating fingerprints must be possible on clients with limited resources, such as mobile clients.
- The system must be able to generate acceptable fingerprints in environments with potential sources of noise and distortion.
- The product must function on several platforms.
- Documentation with relevant test data must be included to decide on the feasibility of the product.

Programming languages and development

The software will likely be written in, or utilize, one or more of the following technologies:

- C#: Programming language developed by Microsoft for their .NET initiative.

- .NET: Software framework developed by Microsoft.
- ASP.NET: Web application framework, part of the .NET framework.
- Swift: Programming language designed for producing applications for Apple products.
- Objective-C: Similar to Swift, developed for Apple systems.
- HTML5: Markup-language for structuring websites.
- CSS: Stylesheet language for designing websites.
- JavaScript and WebRTC: Programming language and extension for adding functionality to websites.
- MATLAB: Technical computing language, used in the project for testing algorithm implementations.

Virtualization and development server

On our virtual server hosted by the University we will run the following services. The goal is to emulate the actual services that will run on the production server once the product is complete.

- Amazon DynamoDB: A flexible NoSQL database for storing the acoustic fingerprints. Focus on low-latency access, which is required when aiming for a 250 ms fingerprint duration.
- Windows Server 2012 R2: For hosting the ASP.NET-based application.
- A secure FTPS server or similar service for pushing changes to the development server.

The list of services is subject to change through the project life-cycle.

Solutions

As explained earlier in this document, audio is subject to noise and distortion from several sources. To address this problem in an effective manner, there are several solutions that might be worth exploring:

- Signal filtering techniques can be used, such as Elliptical, Butterworth and Chebyshev-filtering techniques.[13]
- Utilizing open-source software designed for these tasks, as explained in the next section.

Licensing

If the project uses libraries and modules from project with an open source license, these should be licensed under the LGPL license, MS-PL license or other similar licenses.[2]
Examples of relevant libraries that we can use in our project includes:

- NAduio
- CSCore

Both of these libraries are licensed under the MS-PL license.

Relevant patents to consider

There are several patents covering the generation and identification of acoustic fingerprints in digital media.
As the project group is developing the software solution, it is important to consider possible patents to avoid possible patent infringement from patent holders.
Some of the relevant patents include:

- US 7013301, granted to "AmpliFIND": Covering a similar service strictly for *music*, utilizing Fast Fourier Transforms and Singular Value Decomposition on matrices.[6]
- US 8949872, granted to "Yahoo! Inc.": Covering a similar service strictly for *television*, utilizing segmentation of the given multimedia and creating vectors based on these generated segments[14]
- US 7487180, granted to Holm, Frode & Hicken, Wendell: Covering the system implementation of the US 7013301 grant.[7]
- US 8380518, granted to "Samsung Electronics Co. Ltd": Covering a system for recognizing user "moods" in several music applications.[9]
- US 8886531, granted to Vogel, Brian K: Covering a technique for identifying possible duplicate entries in larger collections of audio.[16]
- US 7881931, granted to "Gracenote Inc.": Covering a system for equalizing different audio tracks through acoustic fingerprinting.[18]
- US 7873521, granted to "Nippon Telegraph And Telephone Corporation": A wide patent covering several audio recognition inventions, systems and signal processing mechanisms.[10]

This is by no means an exhaustive list, and will be expanded as the project planning continues. The list only include relevant *grants*, not pending applications.

5.3 Plan of action

For the duration of the project we have decided on using the agile development methodology "Scrum", the de-facto standard in agile development. After using this methodology for several other school-related projects, we have gained knowledge and experience related to this methodology. It is a fact that both large and small ICT-projects benefit from using an agile development methodology. This is mainly because it takes into account continuous change throughout the projects development, which is of utmost importance to projects where the requirements specification and technologies is likely to change throughout the project life-cycle.

Scrum is a flexible, agile methodology for handling the development of software. In agile methodologies like Scrum, incremental deliveries and a short planning horizon (typically two to four weeks) is recommended. Project starting and endings are clearly defined.[12]

The methodology recommends the project group to carry out short, daily project meetings. These meetings, called "scrum-meetings", usually span from ten to fifteen minutes. The meetings have a clearly defined structure, and the goal is to answer three important questions[12]:

- What has been done since the last meeting?
- What will be done until the next meeting?
- What obstacles was encountered, hindering the group member(s) from effectively implementing the planned functionality?

An efficient Scrum-process include three different roles[12]:

- *The product owner*, responsible for prioritizing the product queue.
- *The Scrum-master*, responsible for leading the team and acting as a gatekeeper, making sure the "Scrum team" is not disturbed by tasks not included in the ongoing sprint.
- *The Scrum-team*, responsible for carrying out the actual programming, writing documentation and delivering the actual product at the end of each sprint.

5.4 Information gathering

Several current systems and solutions utilize technology similar to the technology the project group is tasked with developing;

- MusicBrainZ (open-source)
- Shazam[17]
- SoundHound
- DejaVu (open-source)

Most of these systems focus solely on music, but similiar technology could be implemented partially, for example to identify opening themes or soundtracks in a film or series.

Further information the project group might need during the project will primarily be gathered through specialists from NTNU Ålesund.

5.5 Risk analysis and assessment

After a preliminary discussion of technologies and possible solutions, we deem the project completion likely, considering that some requirements are met.

- Effective communication between the project group and the employer.
- Proper planning and assessments, streamlining the development.
- Proper execution of development, with programming standards and documentation standards being followed for all applicable languages.
- Thorough testing and analysis of the solution.

In addition to success factors, there are several elements that might pose a risk to the project planning, execution or testing:

- Poor planning and communication, effectively threatening the project even prior to development.
- Non-standardized or poor programming habits would effectively make the project unmaintainable.
- Deficient testing could possibly ship an incomplete product to the users, threatening the profitability and the goal of the entire project.

5.6 Main activities in the project work

The activities presented in the table below will, according to plan, begin on 01/02/2016. A gantt-diagram representation and breakdown chart is included in the hand-in folder.

#	Activity	Responsibility	Cost	Timespan
A1	**Project planning and development environment setup**	Project group	N/A	**3.5 days**
A1.1	Preliminary report finished	Project group	N/A	N/A
A1.2	Configuration of development server	Project group	N/A	2 days
A1.3	Setup and configuration of development environment	Project group	N/A	1 days
A1.4	Collection of royalty-free multimedia material	Project group	N/A	0.5 days
A2	**First draft of the system**	Project group	N/A	**6 weeks**
A2.1	Generate library (database) with hashed media files	Project group	N/A	2 days
A2.2	Recognize audio from digital input (Web app)	Project group	N/A	2 weeks
A2.3	Recognize audio from microphone input (Wep app)	Project group	N/A	2 weeks
A2.4	Recognize audio from microphone (iPhone app)	Project group	N/A	2 weeks
A3	**Working system prototype**	Project group	N/A	**6-7 weeks**
A3.1	Complete standalone web application	Project group	N/A	2 weeks
A3.2	Complete standalone iPhone application	Project group	N/A	2 weeks
A3.3	Working pausing, jumping, cross-platform resume.	Project group	N/A	2 weeks
A4	**Test cases, upgrading and debugging**	Project group	N/A	**5 weeks**
A4.1	Data collection from users and test cases	Project group	N/A	1 week
A4.2	Analyzing the collected data	Project group	N/A	1 weeks
A4.3	Working system prototype	Project group	N/A	3 weeks
A5	**Deliverables: system documentation, reports**	Project group	N/A	**1 week**

Table 5.1: Main activities and partial activities

The project will not come with a cost extending the non-capital expenses related to work-hours put in by the project group.

5.7 Planning and project management

5.7.1 Primary plan

The main task of the project group is to test the *feasibility* of the system. In accordance with the milestones in table 5.1, the project group will eventually deliver an argued decision whether the project is feasible or not- including a functioning system prototype.

5.7.2 Project management tools

- Atlassian JIRA
- Microsoft Project Professional 2016

5.7.3 Development tools

- ShareLaTeX: An online tool for collaboration of scientific documents writte in the LaTeX markup language.
- GitHub: Web-based collaboration tool for software development.
- Several Integrated Development Environments (IDE), including Visual Studio, MonoDevelop and ReSharper.

5.7.4 Internal control and evaluation

Internal control and evaluation of the software solution development will happen together with the employer.

5.8 Decisions and the decision process

Based on the projects nature where continuous testing together with trial and error is central, the entire project is likely to change drastically during the projects life-cycle.

Limiting the scope of the project will happen in collaboration with the employer.

As the project will be subject to continuous change, we will utilize an agile development methodology which takes this into account, as explained in chapter 5.3. Using updated development standards and best-practice methods is of utmost importance to cope with these changes, and will create a foundation for the project development.

6 Documentation

This chapter describes the documents and reports that will be worked out and written by the project group for the duration of the project.

6.1 Reports and technical documents

The following documentation and reports shall be worked out by the project group over the course of the project[11]:

- Development routines.
- Acceptance in accordance with laws and regulations.
- Distribution and copying of materials.
- Justificable storage of materials.
- System maintenance documentation following the project.
- Full system documentation.
- Test and lab data.

7 Planned meetings and reports

Several meetings have to be held for the duration of the project. This is mainly to give the supervising group updates related to how the project is coming along. This chapter lists the planned meetings between the project group and the supervising group, as well as required periodic reporting.

7.1 Meetings

Meetings between the supervising group and the project group will preferably take place at the residence of InnoTown or at the University.

7.1.1 Planned meetings

28.01.2016: Meeting focusing on patents and upcoming project work.

15.02.2016: Development meeting with supervising group.

29.02.2016: Development meeting with supervising group.

14.03.2016: Development meeting with supervising group.

28.03.2016: Development meeting with supervising group.

11.04.2016: Development meeting with supervising group.

25.04.2016: Development meeting with supervising group.

09.05.2016: Development meeting with supervising group.

23.05.2016: Final planned meeting with supervising group.

All meeting dates are tenative and will be subject to change.

7.1.2 Project group meetings

Project meetings for the project group will find place every weekday, mainly from 08:00 to 15:30. The project meetings will include a "Daily Scrum", as well as development, planning and documentation work.

7.2 Periodic reporting

Periodic reports including documentation will be shared between the project group and the supervising group. Several periodic reports are also delivered to NTNU Ålesund for subject evaluation.

8 Project deviations

Handling deviations includes steps that must be carried out if project work is halted, or developed content is not in accordance with plans or visions for the product. These steps includes, but are not limited to:

- Deviating content must immediately be reworked to satisfy project requirements.
- Steps must be taken to ensure that such deviation does not occur again.
- Responsibility for continuous overseeing of potential deviations reside with the project group leader.

9 Required equipment

At different stages in the project, the project group might need equipment which is not typically available to the project group. Equipment for carrying out system tests will be required, mainly Apple products such as the Apple iPhone and possibly the Apple Mac(Book). These clients' behaviors can be difficult to emulate through software.

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