Application for Working with Musical Notes Using Artificial Intelligence

Viktoriia Fuks[1], Anastasiia Tsurkan[1], Viktoriia Zhebka[2] and Yuriy Novikov[3]

[1] *National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", 37, Prospect Beresteiskyi, Kyiv, 03056, Ukraine*
[2] *State University of Information and Communication Technologies, 7, str. Solomyanska, Kyiv, 03110, Ukraine*
[3] *Institute of Software Systems of the National Academy of Sciences of Ukraine, Akademik Hlushkov Avenue, 40, building 5, Kyiv, Ukraine, 03187*

Abstract

In the work, existing software solutions and successful IT projects were analyzed and their advantages and disadvantages were identified, which helped determine the requirements for a product that would be competitive and meet the requirements of the modern market. Modeling and designing of the software were carried out, the client-server architecture of the application was described, as well as the interaction of subsystems. The mobile application was developed and tested, and further directions for improvement and development of the application were determined. The ap-plication processes a PDF file with a given metronome speed in mp3 and mp4, which gives the user the opportunity to see and listen to the sheet music. The project includes an Android application with a clear and convenient interface, integration with external utilities and libraries. In the work, the processing of files from pdf format to such music and playback files as midi, musicxml, mp3, mp4 is collected in one stream. The process of parsing and playing with full-cycle processing of music files has been improved, by providing the user with all software modules, and the process of processing visual notes and bringing them to easy-to-use files, such as videos that combine notes with sound, has been improved. The work is important because it contributes to the development of digital music processing methods. The introduction of modern technologies for note recognition and visualization of musical elements contributes to techno-logical progress in the field of music development.

Keywords

mobile application, sheet music processing, interpretation, score, metronome, client-server architecture, computer musicology; music recommendation system; music therapy

1. Introduction

In today's high-tech world, where artificial intelligence is defining new horizons of possibility, the music industry is not only adapting to these changes, but actively using them to achieve higher standards of creativity and efficiency. In this context, the development of a universal tool aimed at working with musical notes represents an important step in the automation of tasks related to the creation and mastering of music.

The relevance of this work is determined by the urgent need to adapt the music industry to modern requirements through the use of advanced technologies. The use of artificial intelligence in musical creativity opens up new opportunities for artists and audiences, making the creative process more accessible and exciting.

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* Corresponding author.
† These authors contributed equally.
fuksvik@gmail.com (V. Fuks); nastianegrienko@gmail.com (A. Tsurkan); viktoria.zhebka@ukr.net (V. Zhebka); ynovikov@gmail.com (Y. Novikov)
0009-0007-2721-2424 (V. Fuks); 0009-0002-6725-4198 (A. Tsurkan); 0000-0003-4051-1190 (V. Zhebka); 0009-0006-9800-8765 (Y. Novikov)

At the current stage of technology development, it is already possible to observe significant achievements in the use of artificial intelligence in the musical field [1-2]. Algorithms for analyzing musical structures, creating new compositions, and automating sound recording processes are important stages in the evolution of this field.

The current state of affairs is that there are not many resources with a full cycle of processing music files, so there is a need for a universal and convenient resource that would provide the user with all the software modules necessary for analyzing works and playing.

The new universal tool for working with musical notes can become not only an innovative solution for artists, but also a crucial element for analyzing, organizing and creating music. Its capabilities find application in various aspects of creativity, providing automation of key basic processes and space for creative disclosure of musicians. The mobile application is a step towards musicians, music teachers, composers; it is a help both for those who are just starting their career in the music world, and for those who have conquered the stage more than once with their playing. This development, by processing sheet music, enables a person to play a musical instrument without being distracted by extraneous tasks that this musical assistant will do for him.

The proposed work can find application in the field of music therapy. Music therapy is an area of research that has been greatly explored recently. This work can also be used to develop an intelligent multimedia tool that can be applied in the field of health care. As part of this work, a digital music library can be created. Developed a multimedia-based mobile application that can play music by sheet music. This application, which should be expanded with a music recommendation system based on a mobile application, can be used for various purposes, including education, entertainment and healthcare.

2. Artificial intelligence in music

Humanity has always counted on artificial intelligence to facilitate many aspects of our lives, including managing systems, solving complex mathematical problems, programming, and diagnostics. However, few could have imagined that AI could show creative abilities, becoming a poet, artist, writer or musician. Such a turn in the development of technology emphasizes that the boundaries between what was considered exclusively human are constantly being erased, and artificial intelligence turns out to be not only a tool in our hands, but also a real creator, capable of surprising with its creative achievements.

Today, the music industry is willing to experiment with the use of AI in their creative processes.

Many people who are interested in music, even those who are considered to be experienced musicians, can face difficulties in learning new pieces of music, enriching their musical experience or finding creative inspiration. In particular, the constant distraction of flipping notes, the difficulty in recognizing them, the use of separate applications for a metronome or listening to compositions, and the need for a convenient place to store creative efforts become factors that require an elegant and functional solution. In an effort to simplify and facilitate the musical process, there is a need for a universal application that combines all these aspects.

Let's consider in more detail the main advantages of such an application:

- Note recognition and learning: The application includes functionality for note recognition, which will make learning new pieces of music much easier. It can provide visual and audio processing for correct performance of notes and chords.
- Metronome and tempo: The built-in metronome and the ability to adjust the tempo will allow musicians to keep a stable rhythm while performing works. This is especially important for training and practice.

- Storage and organization of works: The application can store recordings and creative works of a musician in an organized format. This allows you to quickly find and replay previous versions or variations of works.
- Organization of the creative process: The application can include functions for creating lists of compositions, tracking activity and progress. This will make it easier to organize and motivate the musician.
- Playback and listening: The built-in ability to play audio files will allow you to listen to variations of works, which will facilitate experiments and creative development.
- Intuitive and accessible design: A clear and intuitive design that makes it easier for users to navigate and use the various features of the application.
- Personalization of the interface: The possibility of personalizing the interface according to the individual preferences of the user, such as choosing a theme, setting the activity, etc.
- Graphic indicators and animations: Use of graphic indicators, instructions for visual display of application status.

3. Application of the mobile application in music therapy

The music recommendation system plays an important role in music therapy. A music recommendation system recommends music for users based on various factors such as human mood, human behavior, choice, similarity, fundamental frequencies, time intervals, etc. Figure 1 depicts the general connection between the music recommendation system and music therapy [3].

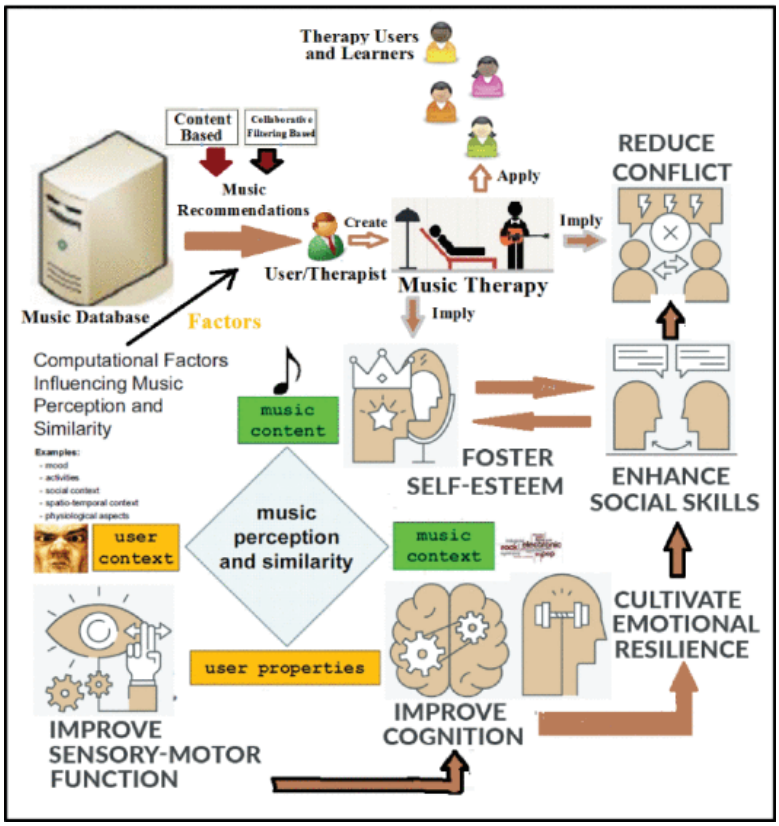

Figure 1: General relationship between music recommendation system and music therapy.

Music has the ability to heal some diseases of the human body [4]. Therefore, they say that music has therapeutic properties [5]. Music therapy is an area of the paramedical field in which music is used for a variety of therapeutic purposes. Music therapy can be used to treat even

psychological and physiological problems such as mesothelioma, peritoneal mesothelioma, asthma, asbestos cancer, depression, etc. [5-6].

In turn, such a mobile application can be used in the field of electronic healthcare. The developed application can act as an electronic health care system for certain purposes based on music therapy.

Music and emotions are directly related to each other and this has already been established. In [7], a model of a music recommendation system based on a specific culture was proposed. Article [8] describes a research project that aims to develop a music analysis system that represents the analysis of clinical music therapy. Music is a very effective way of mental healing, and the management of a person's psyche can be controlled through music therapy

Article [9] is a link to a website that illustrates the different raga names and their respective healing powers. The work described in [10] presents a music recommendation technique based on the analysis of content and context information. The work described in [11] presents a context-sensitive mobile music recommendation system.

The work described in [12] is a modeling technique and a useful tool that formalizes the rules of music composition; the technique increases the speed of music analysis using musical Petri nets that introduce Schoenberg's rules. The work presented in [13] is a method of generating a list of songs for listening; songs can be downloaded according to the age factor of online users. It is a web application that recommends different songs based on the listener's choice and also based on their age group. Songs are downloaded from the music library and unknown songs are classified based on user feedback.

The work presented in [14] presents a model of musical creativity rather than algorithmic musical variations using genetic algorithms. The implementation of this model is based on the Genome software. A statistical approach was used to find similar song patterns using the coefficient of variance [15]. Using neural networks, a time-based recommendation system was developed in [16]. [17] describes a music recommendation system that classifies different songs suitable for different times of the day. An intelligent mechanism for automatic identification of the density of a certain musical rhythm and the complexity of this musical rhythm was proposed in [18]. Various areas of music research and their applications are illustrated in [19]. A reference to the chi-square table is given in [20].

The music recommendation system was studied in [19]. The robot provides a personalized music recommendation service using polyphonic musical objects using the MIDI (Musical Instrument Digital Interface) format. User analyzes profiles to group users based on user behavior and interests. They use the pitch density to select the track that contains the melody, which can be calculated as:

$$Pitch\ Density = \frac{NP}{AP}, \tag{1}$$

where NP – the number of different tones in the track, AP – the number of all different tones in the MIDI standard.

The pitch entropy (PE) can be obtained as follows:

$$PE = -\sum_{j=1}^{NP} \left(P_j log P_j\right), \tag{2}$$

where P_j presented as follows:

$$P_j = \frac{N_j}{T}, \tag{3}$$

where N_j – the total number of notes with the corresponding pitch in the representative track, T – the total number of notes in the representative track.

A music group containing widely accessible music objects has a higher weight than other groups. The weight of a musical group (GW_i) can be calculated as:

$$GW_i = -\sum_{j=1}^{n} TW_j \times MO_{j,i}, \quad (4)$$

where TW_j – the weight of the transaction T_j, n - the number of the last transactions used to analyze MO_j, i – the number of music objects that belong to the music group G_i in the transaction T_j.

Different numbers (R_i) of musical objects from musical groups are calculated (also recommended) according to GW_i as follows [11]:

$$R_i = \left\lceil N \times \frac{GW_i}{\sum_{k=1}^{m} GW_k} \right\rceil. \quad (5)$$

There are quite a lot of research works that encourage us to work further and even discover new dimensions of musicological research. Computational musicology is the fastest growing field and depends on various concepts of computer science.

4. Analysis of known algorithmic and technical solutions

Modern requirements for software for processing musical notes require developers to carefully study existing algorithms, their adaptation for use in specific conditions. This section will analyze advanced algorithms and technical solutions that ensure a high level of accuracy and productivity in working with musical data. Let's consider the key aspects that shape the technical landscape in this industry.

MIDI (Musical Instrument Digital Interface):

1. Used to encode musical information, such as sheet music, into a technical format.
2. Allows you to store and transfer information about notes, their dynamics, tempo, etc.
3. Widely used in music programs and applications.

MusicXML:

Defines a standard for exchanging musical information in text format.
Allows you to save and transfer data about notes, chords, tempo, but in text form.
Provides a clear structure for analyzing and processing notes.

Optical Music Recognition (OMR):

Used to recognize notes and other symbols on paper sheet music using an image.
Requires the use of computer vision to analyze the sheet music image.
It is used in situations where it is necessary to recognize notes from physical sheet music.

Operational Note Recognition (OCR):

Uses optical recognition algorithms to convert sheet music images into text with notes.
Requires accurate imaging for effective operation.
Algorithms are used to recognize frequencies and time parameters of sound.
Can take into account the dynamics and characteristics of various musical instruments.

FFT (Fast Fourier Transform):

It is used to analyze the frequencies in the audio signal and determine the main notes.
Helps in converting the audio signal from the sheet music file into frequency characteristics.

Wavelet Transform:

Used to analyze amplitudes and frequencies at different levels of deployment.

Provides detailed audio signal analysis results.

These algorithmic and technical decisions are important for the development of a mobile application for note recognition and interpretation, as they determine the efficiency, accuracy and functionality of such an application. The combination of these methods can provide a high-quality and versatile tool for musicians and creative individuals.

This project focuses on the implementation of optical musical note recognition (OMR), software for editing and playing music, image rendering based on music files, and technologies for sound synthesis and video creation based on audio tracks and images. Key tools covered include Audiveris for OMR, MuseScore as a tool for editing MusicXML files, and SoundFont for sound synthesis.

Audiveris is defined as an advanced OMR tool capable of converting scanned sheet music into digital formats. This is especially useful for musicians, composers and music archivists who work with large volumes of paper sheet music.

MuseScore is an intuitive and powerful sheet music editing tool used by musicians, composers and arrangers around the world. This software makes it easy to make changes and visualize musical works, making it ideal for detailed work on musical compositions after their initial recognition, for example with Audiveris. In this development, MuseScore was used to make changes to the MusicXML format file.

SoundFont is a key tool in the field of digital audio, as it provides diverse and high-quality sounds for music synthesis. It is a technology that allows musicians and producers to use an extensive set of sound libraries that simulate various musical instruments, from traditional to electronic. In this development, SoundFont is used to sound the notes, which were originally submitted by the user in PDF format.

Each of these instruments plays a key role in various stages of the development of a musical project. Taking into account the specifics of the project, Audiveris was used for initial note recognition, MuseScore for further music editing, and SoundFont for final sound synthesis. This combination provides an efficient workflow from sheet music scanning to music playback.

5. Software requirements

Development of reliable software systems requires effective activities for implementing of software development lifecycle processes. One of the activities, which helps to raise an effectiveness of software development lifecycle processes (requirement analysis, software designing, development and testing), is reusing of software development artifacts [21-22]. Technologies of voice assistants or assistants are actively used in modern solutions. They are implemented on the basis of software that can perform tasks or provide services based on given voice commands by processing and interpreting human speech [23-24]. The main function of the software is to process musical notes for further playback in response to a given metronome speed. More features can be viewed in Figure 2.

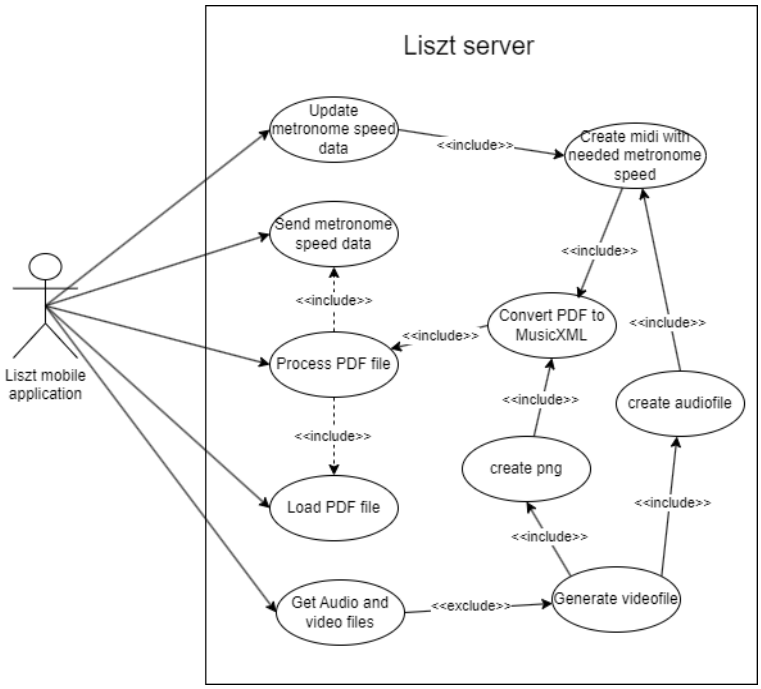

Figure 2: Use case diagram.

The process of developing functional requirements is a key stage in the creation of software focused on the implementation of specific functions and tasks. In this section, we will take a

detailed look at the necessary functions and properties that our mobile application for processing musical notes should have.

Based on the analysis of the subject area, a list of requirements was determined:

Note recognition:

a. Ability to recognize sheet music from PDF files.
b. Recognition accuracy at a high level.

Metronome:

c. Integrated metronome with the ability to adjust the tempo and rhythms.

Storage and Organization of Creative Works:

d. Ability to create and store music notes, as well as listen to them.
e. Cataloging and easy searching by name, description, etc.
    i. Sorting your own library of works.
    ii. Customization of saved files.

Interactive User Interface:

f. Convenient and intuitive interface for users of different experience levels.
g. Ability to personalize settings and appearance.

Innovative Functions:

h. Additional features to enhance the creative process and provide unique functionality.

Free feature list:

i. Availability for all users, providing all features for free.

This list of requirements forms the basis for the development of a software system that not only meets the needs and expectations of users in this subject area, but also offers a comprehensive and advanced tool for improving and developing musical skills.

Let's consider the non-functional requirements for the application. The implementation must satisfy the following theses:

- The application should be easy to use and have a pleasant design;
- The application must be adapted to different mobile devices;
- The application should be adapted for different latest versions. The software should be adaptable to easily add new functionality;
- The interface should be simple, intuitive for the user;
- The interface must support ways of behaving in case of internal service failures or user errors;
- The interface should display the library in a convenient format (divided into subcategories).
- Through a detailed study of the research area, a list of requirements was determined, which is an important component in the development of a software system. The analysis of these requirements is a key stage in the formation of the characteristics and scope of the future product. This list of requirements covers both the functional and non-functional aspects necessary to successfully implement business objectives and respond to user needs. The analysis carried out at this stage lays a solid foundation for further steps in the design and development of the software system.

6. Software modeling and analysis

The UML Sequence Diagram shown in Figure 3 is used to define and further describe the software business process.

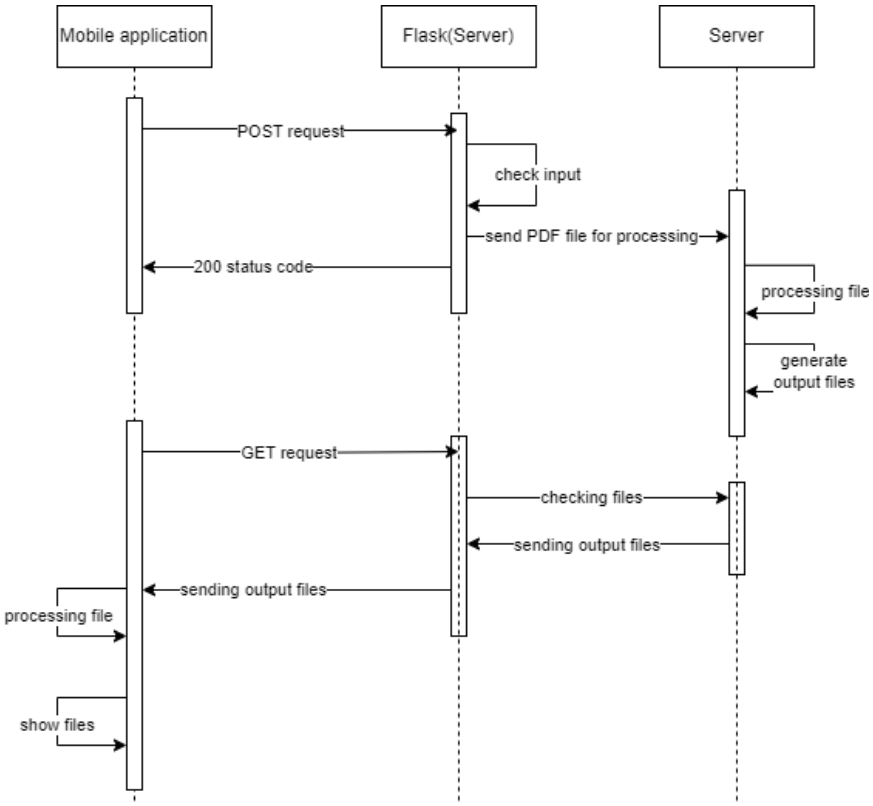

Figure 3: UML Sequence Diagram.

Description of the sequence of the basic communication flow of the server and the mobile application:

- The application sends a request with the file and metronome speed for processing
- The server checks the correctness of the input data
- The server (Flask) processes the file according to the set speed
- The server sends a confirmation that the file was processed successfully
- The mobile application sends a request to receive data
- Server (Flask) checks data availability
- Data is sent to the mobile application
- The application unpacks the archive with files
- The application displays ready-made files on the user's screen.

This system is an example of a client-server architecture where the server is implemented using the Flask web framework and hosted on localhost. To provide access to the server from the outside, Ngrok is used, a service that allows you to tunnel external requests to a local web server. The mobile application acts as a client interacting with the server through HTTP requests.

Let's consider the components of the developed system.

Mobile Application (Client):

- Sends requests to the server.
- Uses the API provided by the Flask server to send and receive data.

Flask Server (localhost):

- Accepts and processes HTTP requests from the client.

Server Processor:

- The main component that handles server logic.

- Processes PDF files sent by the mobile application.

Ngrok:

- Tunnels requests from the Internet to the Flask server on localhost.
- Provides the public URL that the mobile application uses to access the server.

The architecture is visually depicted in Figure 4.

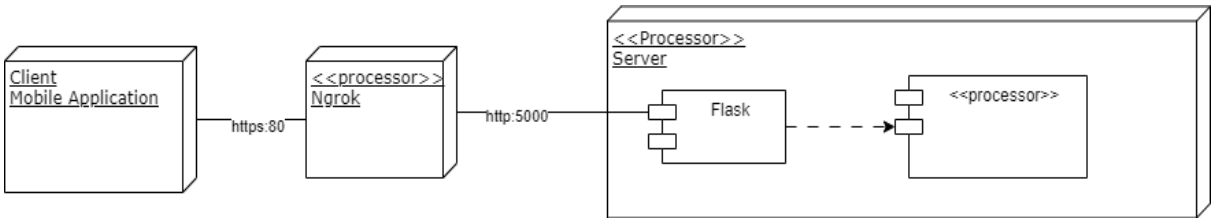

Figure 4: Application architecture.

Interaction between Components

Client-server interaction:

- The mobile application initiates HTTP requests to the server via the URL provided by Ngrok.
- The Flask server takes the request, processes the data, and sends the response back to the client.

Using Ngrok:

- Ngrok creates a secure tunnel from the public domain to localhost.
- Allows a mobile application to interact with a server that is physically located locally.

This architecture allows for flexible and efficient interaction between a mobile application and a server located locally. Using Ngrok facilitates access to a local server without the need to deploy it to an external environment. Flask as a lightweight web framework provides flexibility and ease of development of server-side logic.

Next, we will provide a detailed description of utilities, libraries and other third-party software used in the development of this client-server system. Using these tools, you can efficiently convert musical notes from PDF to various digital formats, process music data, and generate audio files.

The main utilities covered in this section include Audiveris, MuseScore, and SoundFont.

Audiveris is a high quality Optical Music Recognition (OMR) that converts scanned sheets of music into MusicXML format. It is a software that can automatically recognize, analyze and convert musical notes from PDF files.

PDF to MusicXML conversion: Audiveris efficiently converts scanned sheet music or PDF files to MusicXML format, a standard for music data exchange.

Accuracy and Reliability: The program has a high accuracy of recognition of musical symbols, which ensures high-quality conversion of notes.

Automation: Audiveris is able to automate many steps of the conversion, minimizing the need for manual intervention.

CLI: Audiveris provides convenient commands for use via the command line or in subprocesses of another application

MuseScore is one of the most popular notation programs that allows you to work with MusicXML files. It is used in this system for further processing of MusicXML files received from Audiveris.

Let's consider the key features of MuseScore:

Editing MusicXML: MuseScore allows you to conveniently edit and export MusicXML files.

CLI: provides the ability to access the program through subprocesses with commands

SoundFont is a technology used to play MIDI files. It contains recordings of real instrument sounds that can be used to generate audio files from MIDI.

Let's consider the main aspects of SoundFont.

Sound Quality: SoundFont provides high-quality sound that is close to real instruments.

Use with MIDI: Ideal for converting MIDI files into realistic audio files.

Compatibility: Compatible with many audio processing programs.

These utilities and technologies play a key role in the process of converting, processing and playing music on the system. They allow you to efficiently process music data, convert it between different formats and create high-quality audiovisual materials.

Figure 5 shows a diagram of the components of this developed server.

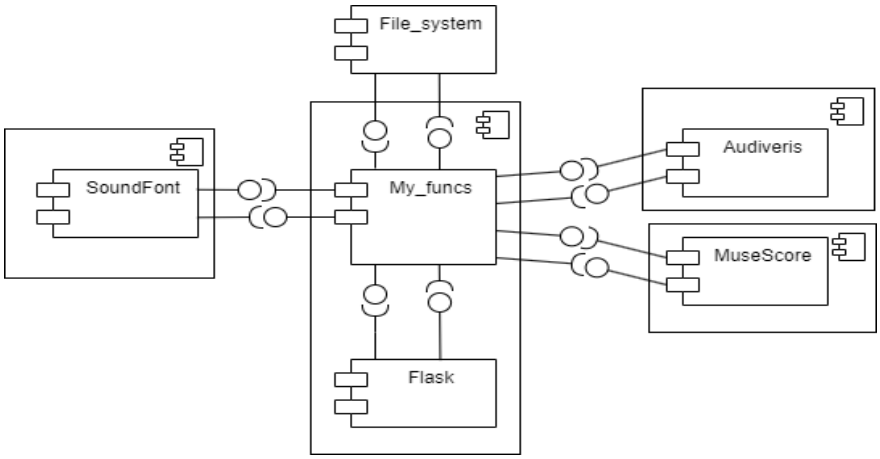

Figure 5: Diagram of components.

The component diagram shows the architecture of the server, which includes the Flask web server and the my_funcs module, as well as interactions with external components such as the file system, SoundFont, Audiveris, and MuseScore. Each of these components plays a role in the overall system architecture.

Since the server uses a file system to store files, we need to be clear. Which files the program has access to and which files it sends to the client. This control involves the creation of a unique code based on a timestamp, which is updated and assigned to each new PDF file submitted for processing. A directory is created for all files for a specific case, files are stored under this unique number.

7. Directions for further research

At this stage, there are many areas of development of the proposed application. There are plans to expand the application in the direction of a larger number of file formats, additional auxiliary functions (tool calibration, etc.), adding a community and the ability to share developments. Regarding the software itself, it is primarily an acceleration of operations, improvement of visualization and the way of interaction with the server. Also, an important aspect is the further improvement of music processing algorithms to increase accuracy and efficiency.

The direction of further research may be the development of an approach for determining musical patterns and recommending songs for music therapy.

Develop a music recommendation system that takes into account the general connection between the music recommendation system and music therapy. The music recommendation system plays an important role in music therapy. A music recommendation system recommends

music for users based on various factors such as human mood, human behavior, choice, similarity, fundamental frequencies, time intervals, etc.

8. Conclusions

As a result of this work, the mobile application "Liszt" musical assistant for note recognition and musical interaction was developed. The application processes a PDF file with a given metronome speed in mp3 and mp4, which allows the user to see and listen to the musical notation. The project includes Android applications with a clear and convenient interface, integration with external utilities and libraries. Research results can contribute to the development of technologies for working with music data on mobile devices. This may include improving note recognition algorithms, improving the accuracy of music playback, and other technical aspects.

The state of solving the tasks. All defined tasks in the work were successfully completed. After implementation, the application was tested on a mobile device and in test programs that were used to interact with the server.

Evaluation of the obtained results. The obtained results prove the competitiveness of the application, compliance with the specified requirements and the level of compliance with technical knowledge in the field of software development. The system successfully operates with data and skillfully visualizes them.

Scientific and socio-economic significance. The work is important because it contributes to the development of digital music processing techniques. It also has socio-economic significance, simplifying processes that traditionally require considerable effort and time, and opening opportunities for wider access to musical culture. Ensuring accessibility for all interested persons, regardless of the level of musical training.

Using the application can become part of music education in educational institutions and additional courses. This tool can be used to improve the process of learning music and provides opportunities for creative expression. The introduction of modern technologies for note recognition and visualization of musical elements contributes to technological progress in the field of music development. Creates a positive music learning experience that can support and maintain users' interest in the world of music for a long time.

Using a mobile application can facilitate the process of creating music, arranging, learning new compositions, and also facilitate quick access to sheet music and other musical resources.

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