

# Final Project Report: Collaborative Java Swing Piano Application

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## 1. Abstract

This project delivers a networked piano application built in Java that enables two users to play and chat in real time, record the piano session to a file, and replay it with accurate timing. The implementation addresses four core topics from the course requirements—thread concurrency with synchronization, file I/O, networking via sockets, and GUI graphics—in distinct modules to ensure clarity, modularity, and maintainability.

The project repository can be accessed at [Github](#)

## 2. Introduction

This project application architecture comprises the following components:

**Graphics:** Java Swing-based piano keyboard GUI with Metronome using graphical methods.

**Networking (sockets):** TCP socket communication for music note events and text messages.

**Thread concurrency:** Multi-threaded management of audio playback, recording, network I/O, metronome, and GUI events.

**File IO:** File-based storage and retrieval of recorded sessions, real piano sample sound loading.

## 3. Implementation Details

### 3.1 Graphics

#### Java Swing/AWT Foundation

I built the entire UI using the standard Swing toolkit (JFrame, JPanel, JButton, JSpinner, etc.).

#### Vector-Based Drawing with Graphics2D

Cast to Graphics2D to draw a virtual metronome with a shape, simulated pendulum, and a balance weight.

#### Affine Transforms for Animation

I also learned to use AffineTransform (translate + rotate) on the Graphics2D context to handle pendulum rotation about its pivot, rather than manually computing rotated coordinates. Because the metronome rotates fast and this method can achieve a good effect.

## 3.2 Networking (sockets)

### Client-Server Architecture

**Server:** a dedicated ServerSocket listening on port 5190; accepts incoming Socket connections and spawns a handler thread for each client.

**Client:** connects via new Socket(host, port), then wraps InputStream/OutputStream with DataInputStream/DataOutputStream for framed, chat and event messages.

**Communication:** All messages are encoded in JSON in two kinds: "MUSIC" and "CHAT". The server relays each incoming event to all other clients to keep GUIs and audio playback in sync.

## 3.3 Thread Concurrency

### Playback

For each incoming noteOn event, spawns a new Thread (or submits a task to a fixed-size ExecutorService) that:

1. Opens the appropriate SourceDataLine.
2. Streams audio buffer until note-off or release.
3. Closes line.

### Network Synchronization

Each socket connection uses its thread to read JSON messages and enqueueing them on a thread-safe queue.

### Local Synchronization

Shared state (e.g. activePlaybackNotes) stored in ConcurrentHashMap and ConcurrentSkipListSet to avoid explicitly synchronized blocks.

Timers and playback timestamps are also tracked to account for pause/resume delays safely across threads.

## 3.4 File IO

### Loading & Saving Recordings

The notes are saved in format: note,startTime,endTime, timbre, which is easy to code and modify outside. RecordingManager logs every note event (including note, timbre and timestamp) to a local file, using BufferedWriter over FileWriter.

On "Save", flushes buffer and closes stream; on "Load", reads file line by line with BufferedReader, reconstructs events, and replays them in order.

### Piano Sample Files

Piano samples (.wav) are loaded at startup and cached in memory for low-latency playback.

### Soundplay Details:

A thread is started for each note during the initialization process, and then the thread will listen for the signal to play the sound.

For the electronic timbres, the frequency of each note was stored in advance, and the tone generator could make up certain kinds of waves(sine, square, etc.) with the corresponding frequency.

Waveform	Formula
Sine	<code>Math.sin(phase)</code>
Square	<code>Math.signum(Math.sin(phase))</code>
Triangle	<code>(2.0 / Math.PI) * Math.asin(Math.sin(phase))</code>
Sawtooth	<code>(2.0 * (phase / (2.0 * Math.PI))) - 1.0</code>

For the real piano sound, an open-source sound pack [TEDAgame's Piano Pack](#) was used as the sound sample.

A metronome is also built into this App. A thread is responsible for playing beep sounds from

the metronome, hence avoiding conflict with the piano keyboard.

The chord is implemented by a map to indicate the pitch difference between different chords.

## **4. Conclusion and Future Work**

This project integrates concurrency, file I/O, socket networking, and GUI graphics in a cohesive Java application. Future enhancements could include:

- Adding JDBC support to store session metadata in a database, like login information, timbre preset and so on.
- Enabling multi-room support and user authentication.
- Enabling importing new timbre and chord map.

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