Design Milestone

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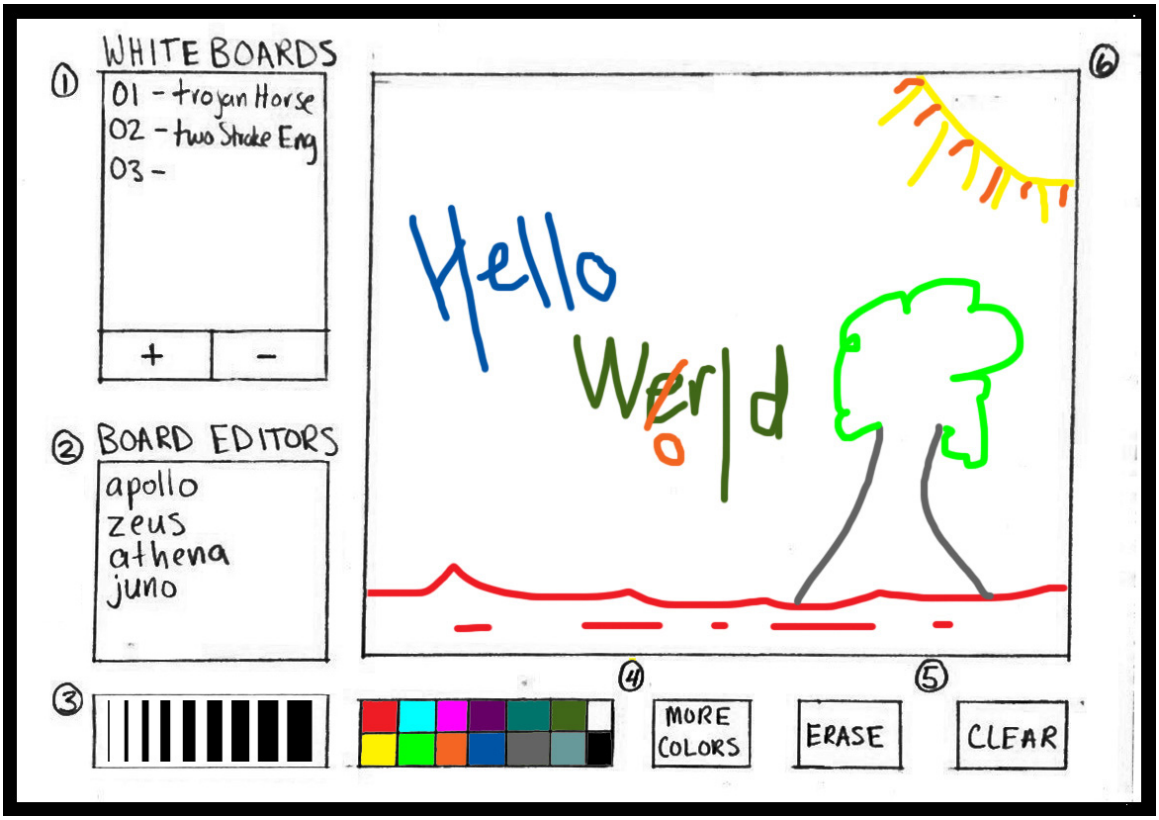
6.005 Software Construction - Fall 2013 - Project 2: "Collaborative Whiteboard"

I. User Functionality Overview

I. Components



I.1 Selector

The board selector in the left pane includes a list of all current whiteboards and appears the same for all users. Each line represents an individual board, which are numbered sequentially and named by the user. Upon clicking the "+" button, the user will be prompted to name the new board. When the board has been created on the server, it will be appended to the list for each user. Selecting a board in the list will download the board from the server, overwrite the local copy if one exists, and display the board in the canvas window.

I.2 Board Editors

Displays a list of users, including the viewer, who are currently modifying the selected board. This list will be updated as users enter and exit the board.

I.3 Thickness Selector

This tool allows the user to select a brush/eraser thickness for drawing on the whiteboard.

I.4 Color Selector

The main color palette displays a grid of colors from which the user can choose to paint with. The color currently in use will be highlighted. Clicking the "more colors" button will open Swing's built-in color chooser, which will offer a larger selection of colors.

I.5 Erasing Tools

The erase button will allow the user to toggle between erasing and painting. "Erasing" will be defined as drawing with a white selection. Erasing will happen in the same order as drawing, so whichever request reaches the server first will erase all that has been drawn under it. Toggling back to painting will restore the user's previous color choice.

I.6 Whiteboard Window

Displays the currently selected whiteboard, including all of its drawn strokes and erasures. The whiteboard be real-time interactive to allow users to collaborate simultaneously. Edits will be made in the order that modifications reach the server. In other words, a stroke logged on the server at a specific instant will be drawn over any strokes drawn before that instant.

II. Behavior

Erasing TEXT

Editing a Deleted Board TEXT

II. Server-Client Communication

I. Protocol

I.1 Grammar

The following grammar will facilitate the text-based communication between the clients and the server. The server will send `StoC_MSG` messages to the client, which will be able to send `CtoS_MSG` messages back to the server.

```
StoC_MSG :== (STROKE | BRD_INFO | BRD_DEL | USER_INIT | BRD_USERS) N

CtoS_MSG :== (STROKE | SEL | BRD_REQ | BRD_DEL | BRD_ALL | USER_REQ) N

STROKE :== "stroke" S BOARD_ID S THICK S COORDS S COLOR
COORDS :== X1 S Y1 S X2 S Y2
```

```
X1, Y1, X2, Y2 :== INT
COLOR :== [0-255] S [0-255] S [0-255]
THICK :== [1-10]

SEL :== "select" S BOARD_ID

BRD_REQ :== "board_req" S NAME
BRD_ALL :== "board_all"
BRD_INFO :== "board" S BOARD_ID S NAME
BRD_DEL :== "del" S BOARD_ID
BRD_USERS :== "board_users" S BOARD_ID (S USER_NAME)+

USER_REQ :== "user_req" S USER_NAME
USER_INIT :== "you_are" S USER_NAME

NAME :== [^N]
USER_NAME :== [A-Za-z]([A-Za-z0-9]?)+
BOARD_ID :== INT

INT :== [0-9]+
N :== "\r?\n"
S :== " "
```

I.2 Usage

Adding Users Upon entering a username in the client application, a `USER_REQ` message will be sent to the server to request the desired username. (Note that regex checking for `USER_NAME` occurs on the client side before this request is made.) The server responds with a `USER_INIT` message, signifying the acquired username for the client. If there is a username conflict, one is chosen for the client. When the client is ready to accept information about existing boards, it calls `BRD_ALL` to begin receiving `BRD_INFO` messages for all previously created boards.

Adding Boards When a client wants to create a new whiteboard, it sends a `BRD_REQ` request to the server with a desired `NAME` (duplicate names allowed). Once the server has initialized a new internal board object, it sends a `BRD_INFO` message to all connected users to inform them of the newly available board. Note that the `BOARD_ID` used is a number unique to each whiteboard and is never reused. This is a different number than the sequential board numbering in the GUI, although the order is preserved.

Removing Boards Deleting boards entails a process similar to adding them. A client sends a `BRD_DEL` request to the server, which forwards this requests to all other users. The server internally disassociates all connected users and removes the board, taking care to ignore drawing requests and selection requests for this deleted board.

Selecting Boards Upon selecting a different board, the client sends a `SEL` request to the server. The server clears all stroke messages queued to update the client's whiteboard before associating the requested whiteboard object to the user, if available. The `SEL` command also requests all

previously drawn strokes to be sent to the client. A `BRD_USERS` messages is sent to all users of the previous and current whiteboard to inform them of this change in editors.

Disconnecting Users When a client disconnects – by either severing the connection or closing the client application – the server closes the associated socket and streams, disassociates the user from its whiteboard, and removes the user from its main users list. A `BRD_USERS` message is sent to all users of the board that was being edited.

Drawing Strokes When a client draws a stroke in the selected whiteboard, a sequence of `STROKE` messages are sent to the server. The corresponding lines are logged as drawn in the order they are received by the server. The server proceeds to forward the `STROKE` messages to all users editing the same whiteboard, including the user who made the edit. Since the server sends the `STROKE` updates in the order they were made, the user's stroke will be covered by the echoed version from the server. This will not be visually apparent and will ensure that concurrently drawn lines appear constant across clients.

II. Data Transport

II.1 New Connections

The Whiteboard server will maintain a background thread that listens for new connections. Upon accepting a new socket, a new thread prompts the client for a username, and then instantiates a new User, which is then added to the ArrayList of all Users.

II.2 Request Streams

GUI: The GUI maintains two threads, one which listens for requests from the associated User, and another which contains a BlockingQueue containing requests to be sent to the User. Possible requests include creating a new Whiteboard, deleting a Whiteboard, selecting a different Whiteboard, or sending a Stroke.

User: Each User object holds the client-side socket. The User maintains two threads, one which listens for requests from either its MasterBoard or its GUI, and another which contains a BlockingQueue containing requests to be sent to the GUI. The request() method parses GUI requests and sends the appropriately formatted text protocol message to either the MasterBoard (when a Stroke is made) or the WhiteboardServer (for other User/Whiteboard requests).

MasterBoard: The MasterBoard maintains two threads, one which listens for requests from any of its associated Users, and another which contains a BlockingQueue containing requests to be sent to all of its associated Users. For example, the listening thread will accept a request to create a new Stroke to be added to its strokes ArrayList, and then send that updated ArrayList to all its Users.

WhiteboardServer: The WhiteboardServer is responsible for instantiating new Users with each new connection, and creating new MasterBoard objects in response to requests from Users. It maintains an InputStream to receive requests from the Users, but does not need an OutputStream.

III. Data Type

I. MasterBoard

I.1 Description

`MasterBoard` represents a single whiteboard on the server. The instance is held by several `User` objects editing the board, which are mutually stored in the `MasterBoard` object; in other words, the board is aware of its editors and the editors are aware of the board.

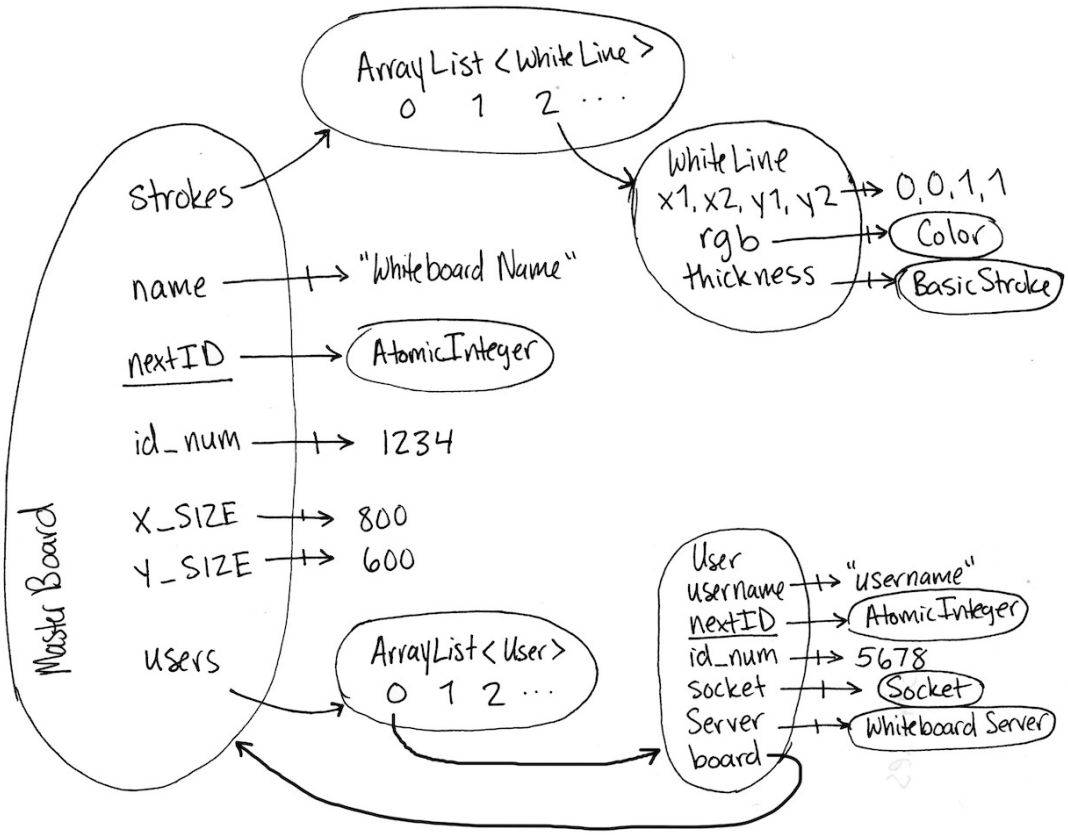
I.2 Fields

- `final String name` - The name of the board in the grammar format `NAME`.
- `final int id_num` - The unique identification number of the board.
- `static final AtomicInteger nextID` - The identification number of the successive board to be created.
- `final static int Y_SIZE, X_SIZE` - The X and Y dimensions of the whiteboard.
- `final ArrayList<WhiteLine> strokes` - A list of the strokes drawn on the whiteboard. The ordering of these strokes corresponds to the sequence in which modifications were made on the server and the layering of the segments.
- `final ArrayList<User> users` - A list of editors currently modifying the board.

I.3 Methods

- `WhiteLine[] allStrokes()` - Returns all the strokes that have been made on the board thus far by locking on `strokes` list.
- `void makeStroke(Stroke stroke)` - Adds the new `stroke` while locking on the `strokes` list. Proceeds to call `incorporateStroke()` on each user while locking on the `users` list.
- `void addUser(User user)` - Adds the new `user` while locking on the `users` list.
- `void removeUser(User user)` - Removes the user `user` while locking on the `users` list.
- `User[] getUsers()` - Returns all current editors while locking on the `users` list.
- `String getName()` - Returns the name of the whiteboard.
- `int getID()` - Returns the unique identification number of the board.
- `String toString()` - Returns the properties of the board in the form of a `BOARD_INFO` message.
- `boolean equals(Object other)` - Compares boards for equality on the basis of ID number.
- `int hashCode()` - Returns the identification number of board added to 1000.

I.4 In Action



II. User

II.1 Description

Each instance of `User` represents a separate client connected to the server. `User` is not only responsible for storing properties that pertain to the client; it also facilitates the socket communication and request handling for each client.

II.2 Fields

- `final Whiteboard Server` - The main server instance is stored for later global calls.
- `MasterBoard board` - The current board being edited by the user. A null value indicates that no board is selected.
- `final String username` - The unique acquired username assigned by the server after a username request has been made.
- `final int id_num` - The unique identification number of the user.

- `static final AtomicInteger nextID` - The identification number of the successive user to be created.
- `final Socket socket` - The socket corresponding to the client application represented by the `User` instance. The input and output streams are contained within.
- `BlockingQueue queue` - The queue containing all outgoing messages to the connected client.

II.3 Methods

- `void incorporateBoard(MasterBoard board)` - Queues a `BRD_INFO` message to be sent to the client with priority. This method is called by the main `WhiteboardServer` on all `User` instances once the request for a new board has been processed. `void forgetBoard(MasterBoard board)` - Queues a `BRD_DEL` message to be sent to the client with priority. This method is called by the main `WhiteboardServer` on all `User` instances once the request to remove a whiteboard has been processed.
- `void incorporateStroke(WhiteLine stroke)` - Queues a `STROKE` message to inform the client of a new stroke drawn on the current board.
- `void handleRequest()` - Runs in a background thread and takes care of all incoming requests from the client. Appropriate actions are taken for each request, either with the `server` or on the `board`.
- `void selectBoard(int boardID)` - This method is called upon receiving a `SEL` command from the client. The user removes itself from the current board by calling `removeUser(this)` on the locked `board`, replacing `board` with on acquired from `server.getBoard(boardID)` and calling `addUser(this)` on the new reference. All queued `STROKE` are removed since they pertain to the old board. The method finally calls `board.allStrokes()` to queue all previously drawn strokes for the new board to be sent to the client.
- `String getName()` - Returns the username of the connected client.
- `int getID()` - Returns the unique identification number of the connected client.
- `int compareTo(Object other)` - Compares users for ordering on the basis of usernames.
- `int equals(Object other)` - Compares users for equality on the basis of identification numbers.
- `int hashCode()` - Returns the identification number of the user added to 2000.
- `String toString()` - Returns the uername and ID number of the user in string format.

III. WhiteLine

III.1 Description

`WhiteLine` is a simple class designed to represent a drawn stroke on a whiteboard. It is used by the `MasterBoard` class on the server side. Due to the frequent need to work with lines and the neatness of working with a single object containing the multiple properties of the line – location, color, thickness – we decided to have a dedicated class. The class is immutable, as all its properties are themselves immutable and stored upon construction.

III.2 Fields

- `final int x1, y1, x2, y2` - The coordinates of the line, which spans from `(x1,y1)` to `(x2,y2)`.
- `final java.awt.Color color` - The color of the line. The `Color` object allows greater versatility over storing individual RGB values, as Java provides multiple methods for specifying colors. This is especially useful for using a `JColorChooser`.
- `final java.awt.BasicStroke thickness` - The thickness of the line will be specified as a number within the range [1,10]. Numbers from this qualitative scale will be mapped to floating-point thicknesses and a `BasicStroke` object will be constructed internally.

III.3 Methods

- `int getX1()` - Returns the X-coordinate of the origin of the line.
- `int getY1()` - Returns the Y-coordinate of the origin of the line.
- `int getX2()` - Returns the X-coordinate of the terminus of the line.
- `int getY2()` - Returns the Y-coordinate of the terminus of the line.
- `java.awt.Color getColor()` - Returns the `Color` object corresponding to the line.
- `java.awt.BasicStroke getThickness()` - Returns the `BasicStroke` object corresponding to the thickness value specified upon construction.
- `String toString()` - Returns the properties of the stroke in the form of a `STROKE` message with the `BOARD_ID` omitted.

IV. ClientBoard

IV.1 Description

`ClientBoard` is used by the client application to store basic properties about the active whiteboards, which include those created by the client and other users. A new instance is created each time the client receives a `BRD_INFO` message. The class is immutable, as the contained properties are never changed after initialization on the server side.

IV.2 Fields

- `final String name` - The user-assigned name of the board.
- `final int id_num` - The identification number assigned to the whiteboard. This number is assigned by the server in the order that whiteboards are created; it cannot be the same for any two boards.

IV.3 Methods

- `String getName()` - Returns the name of the board.
- `int getID()` - Returns the identification number of the board.
- `int compareTo(Object other)` - Compares two boards on the basis of their ID numbers. Overrides the default comparison method and follows its conventions.
- `String toString()` - Returns the properties of the board in the form of a `BOARD_INFO` message.

IV. Thread Safety

I. Processes

I.1 Adding New Users

Upon receiving a `USER_REQ` message, the WhiteboardServer calls `createNewUser` on the main server thread. This instantiates the new User object and adds it to the `users` ArrayList. This method locks on the `boards` field first, and then the `users` field. This ensures that only one User is created at a time, and that behavior that is dependent other User objects, such as username and ID assignment, is consistent.

I.2 Adding and Removing Boards

Upon receiving a `BRD_REQ` message, the WhiteboardServer calls `createBoard`, which instantiates the new MasterBoard object and adds it to the `boards` ArrayList. This method locks on the `boards` field first, and then the `users` field. If multiple requests for a new board are sent, the locks ensure that another board is not created until the current board is created, added to the ArrayList, and all Users are updated with these changes.

Upon receiving a `BRD_DEL` message, the WhiteboardServer calls `removeBoard`. This removes the board from the server's `boards` ArrayList, as well disassociating all Users currently active on that board. This method locks on the `boards` field and then the `users`, so that only one board can be deleted at a time, and so that one thread cannot be deleting a board from the ArrayList while another is attempting to add one.

I.3 Drawing Strokes

Each time a line is drawn on a client's Canvas, a request is added to the WhiteboardClient's output BlockingQueue. The queue then informs the MasterBoard of the new stroke, locking on the `strokes` ArrayList and appending it. The use of the threadsafe BlockingQueue ensures that all strokes are sent from the GUI to the MasterBoard in the correct order. Before releasing the lock, all Users associated with this board are informed of the newly added stroke.

I.4 Selecting Boards

When the client selects a new board, the server fetches the board to be sent. The User calls `allStrokes` to obtain all of the strokes associated with the new board. This method locks on the `strokes` ArrayList, so that no new strokes can be added before the User has received the entire ArrayList. The User also adds itself to the MasterBoard's `users` ArrayList, locking on that field to ensure that only one User is added at a time.

II. Averted Race Conditions

II.1 New Board and New User

Both `BRD_REQ` and `USER_REQ` messages are handled on the main server thread. Since only one of these requests can be processed at a time, there cannot be any racing between the two methods that would potentially cause a newly created board to be lost for some Users.

II.2 Remove Board and New User

Similar to the strategy in the previous section, both `DEL_BRD` and `USER_REQ` requests are handled on the main server thread. This eliminates any racing in which a new User would be created and still receive a board that had actually been deleted.

II.3 Concurrent Strokes

Because the GUI sends the new stroke messages through a BlockingQueue, the order is preserved. The MasterBoard then appends the strokes to its `strokes` in the order that they are received from the clients. (Note that this is not necessarily exactly the same as the order in which each stroke is sent from each GUI, but every User will receive strokes in the exact same order when receiving updates from the MasterBoard.) Because the `makeStrokes` method locks on `strokes` while it processes a request, only one stroke will be processed at a time, and the risk of losing strokes or having clients receive stroke updates in different orders is eliminated. Similarly, while a newly selected board is being transferred to a client, no new strokes can be added, to eliminate these same risks.

II.4 Atomic ID Generation

All object IDs are generated by a static AtomicInteger associated with each class. Because the AtomicInteger is threadsafe, any risks associated with interleaving integer operations are eliminated.

V. Testing

Overview Text

I. SS1

Section 1

II. SS2

Section 2

II.1 SSS 2-1

Subtopic of Section 2

II.2 SSS 2-2

Another Subtopic of Section 2

III. SS3

Section 3