МИНИСТЕРСТВО НАУКИ И ВЫСШЕГО ОБРАЗОВАНИЯ РОССИЙСКОЙ ФЕДЕРАЦИИ
Федеральное государственное автономное образовательное учреждение высшего образования

НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ
ЯДЕРНЫЙ УНИВЕРСИТЕТ «МИФИ»

Лабораторная работа на тему:
Программная реализация задачи раздела «Взаимодействие процессов, сигналы»

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Тема: Программная реализация задачи раздела «Взаимодействие процессов, сигналы»

Инструменты разработки: компилятор языка C (GCC) и универсальный отладчик GNU Debugger (GDB).

1. Задача

Реализовать веб-сервис, предоставляющий пользователям доступ к сетевой игре «Крестики-нолики». Клиент данной игры следует реализовать на языке JavaScript, используя возможности HTML5. Коммуникация между клиентом и сервером должна осуществляться через протокол HTTP и JSON. Сервер должен поддерживать неограниченное количество клиентских и игровых сессий.

2. Теоретическая часть

Для реализации веб-сервиса требуется параллельно обрабатывать несколько TCP соединений. Для этого можно использовать системный вызов `poll` ядра Linux.

Если отправлять от клиента на сервер данные в параметрах GET запроса, значительно упростится реализация сервера, так как, во-первых, нет необходимости в поддержке других методов HTTP, а во-вторых — чтение URL-параметров проще в реализации, чем чтение JSON. Для оптимизации и упрощения очистки памяти при чтении URL-параметров можно реализовать линейный аллокатор (арену).

Для отправки данных от сервера к клиенту следует использовать режим HTTP chunked transfer encoding, так как при его использовании не требуется знать заранее размер отправляемого сообщения. В таком случае мы можем использовать потоковую генерацию JSON. Чтобы минимизировать количество системных вызовов, можно использовать буферизацию.

С целью экономии памяти следует очищать сессии, которые были неактивны более пяти минут.

Для вывода на экран игрового поля в клиентской части можно воспользоваться Canvas API из спецификации HTML5.

3. Практическая часть

Было принято решение не использовать многопроцессность. В структуре `http_server_t` хранятся дескриптор сокета сервера, структуры `pollfd` для всех подключенных в данный момент клиентов и их количество, а также всё, что нужно для обработки текущего соединения (дескриптор сокета текущего клиента, буфер, арена, путь, связный список пар ключ-значение URL-параметров). Память под список URL-параметров выделяется на арене.

Для упрощения отладки проекта был реализован макрос `log_message(LOG_LEVEL_INFO | LOG_LEVEL_ERROR, "module_name", "text", ...)`.

Были реализованы структура `json_writer_t` и набор функций: `init_json_writer`, `json_start_dict`, `json_stop_dict`, `json_start_array` и др., позволяющие пользователю использовать потоковую генерацию JSON. Для буферизации была создана структура `buffered_writer_t` и набор функций: `init_buffered_writer`, `buffered_writer_flush`, `buffered_writer_write` и `buffered_writer_end`. Пример использования `json_writer_t` представлен в приложении А.

Информация о клиентских и игровых сессиях хранится в структуре `session_manager_t` в виде связных списков. Структура `session_t` содержит сессионный ключ, имя пользователя, ссылку на игровую сессию, время последней активности пользователя, флаг, указывающий, что сессию можно удалить, и ссылку на следующую в списке сессию. В структуре `game_session_t` содержатся ссылки на игроков, вид игры (архитектура приложения предусматривает возможность добавления нескольких игровых режимов), ссылку на состояние игры (`tictactoe_game_t`), флаги, описывающие состояние игровой сессии, и ссылку на следующую в списке игровую сессию. Изменения состояний структуры `game_session_t` показаны на диаграмме в приложении В.

Маршрутизация происходит в функции `main`, обрабатывают запросы функции из файла `http_handlers.c`. Для идентификации пользовательской сессии используется сессионный ключ, который передаётся как URL-параметр `id`. Для получения доступа к ресурсам, за исключением статических файлов и станицы авторизации, требуется наличие этого параметра. На диаграмме в приложении C показано, как обрабатываются запросы до момента подключения к игровой сессии.

Пример запроса клиента во время игры выглядит следующим образом: `GET /gameRequest?id=123&cell=2`, где `id` — это сессионный ключ, а опциональный параметр `cell` — клетка, на которую делает ход клиент-отправитель. Пример ответа сервера находится в приложении D.

Клиентская часть написана на JavaScript без использования сторонних библиотек. Вывод изображения на экран осуществляется с помощью Canvas API в режиме `CanvasRenderingContext2D`. Скриншоты интерфейса находятся в приложении E.

Весь код проекта находится в приложении F.

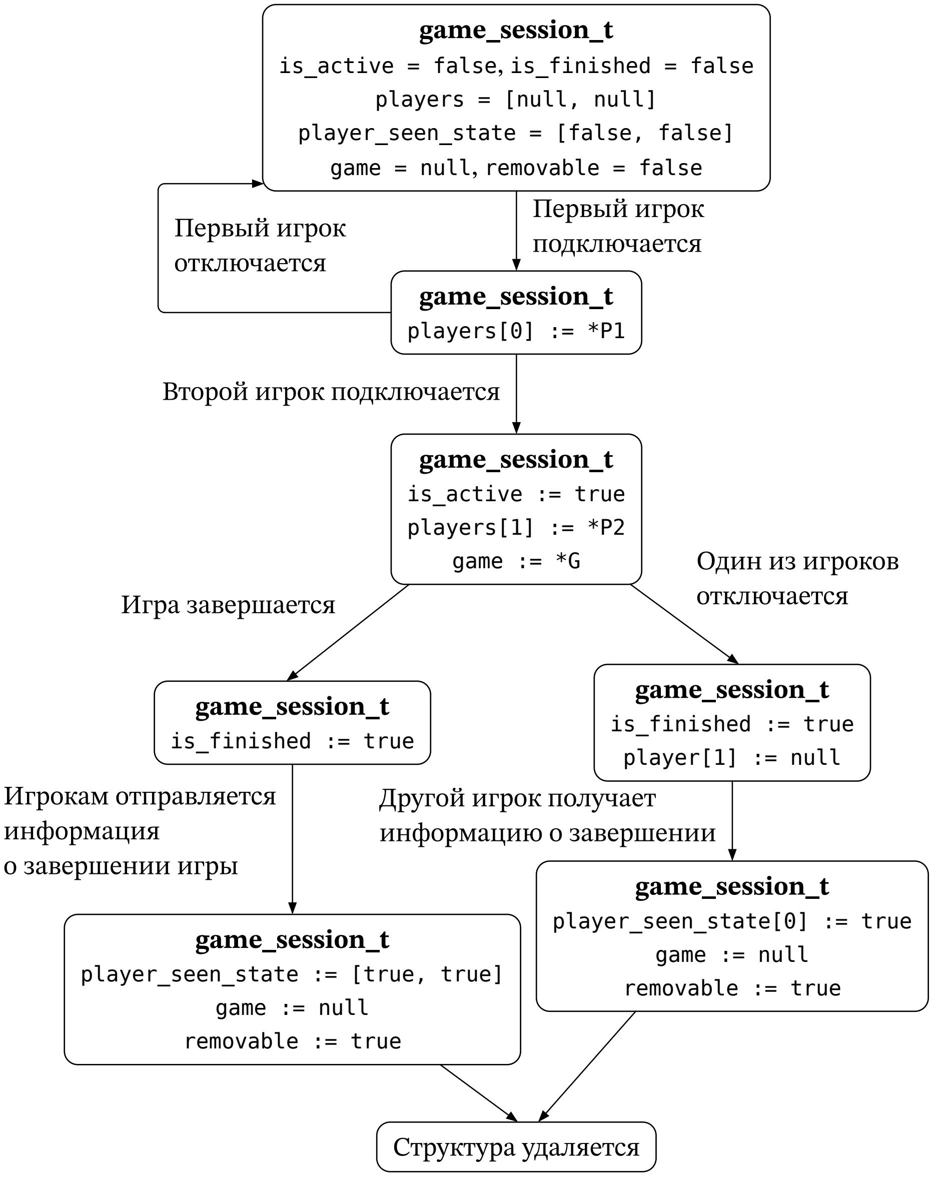
4. Содержание

5. Приложения

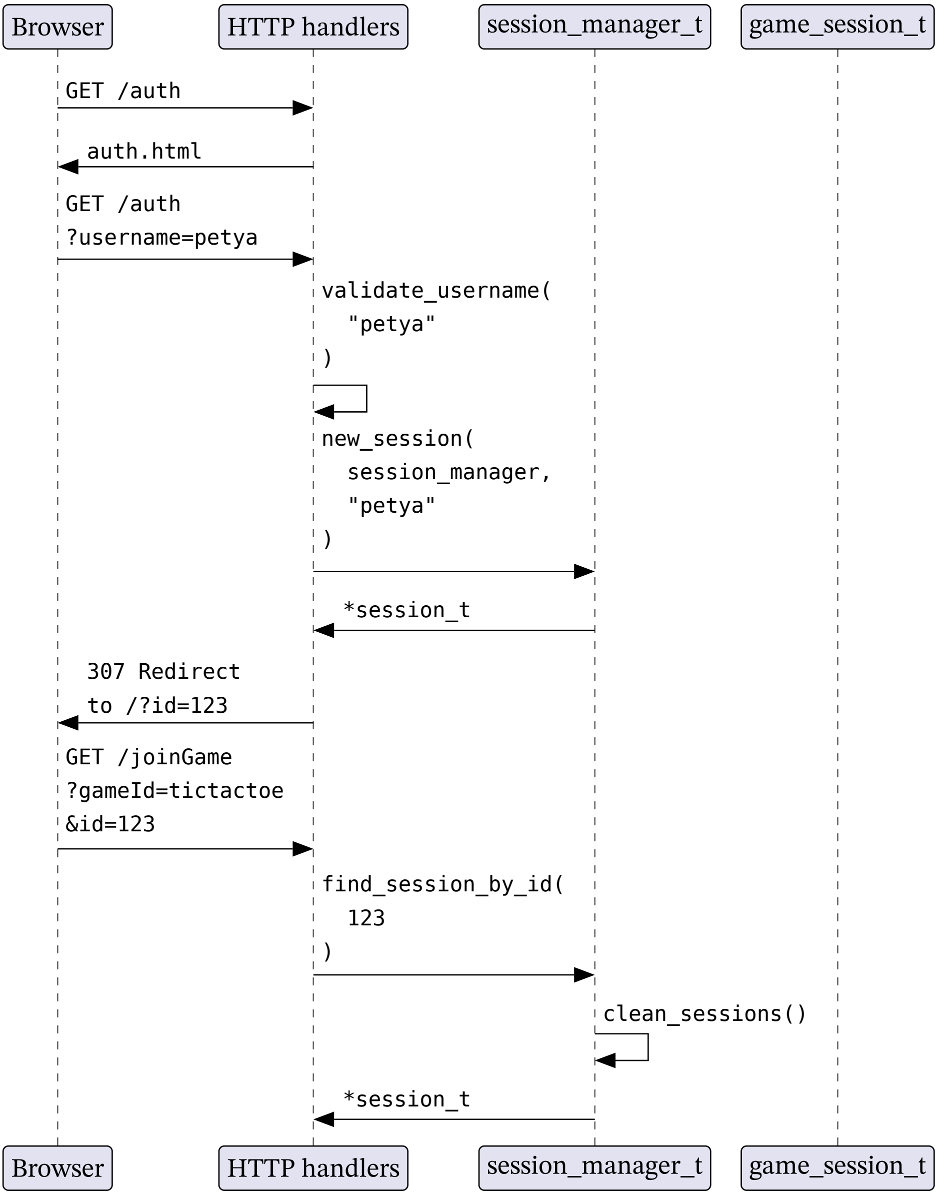
Приложение А

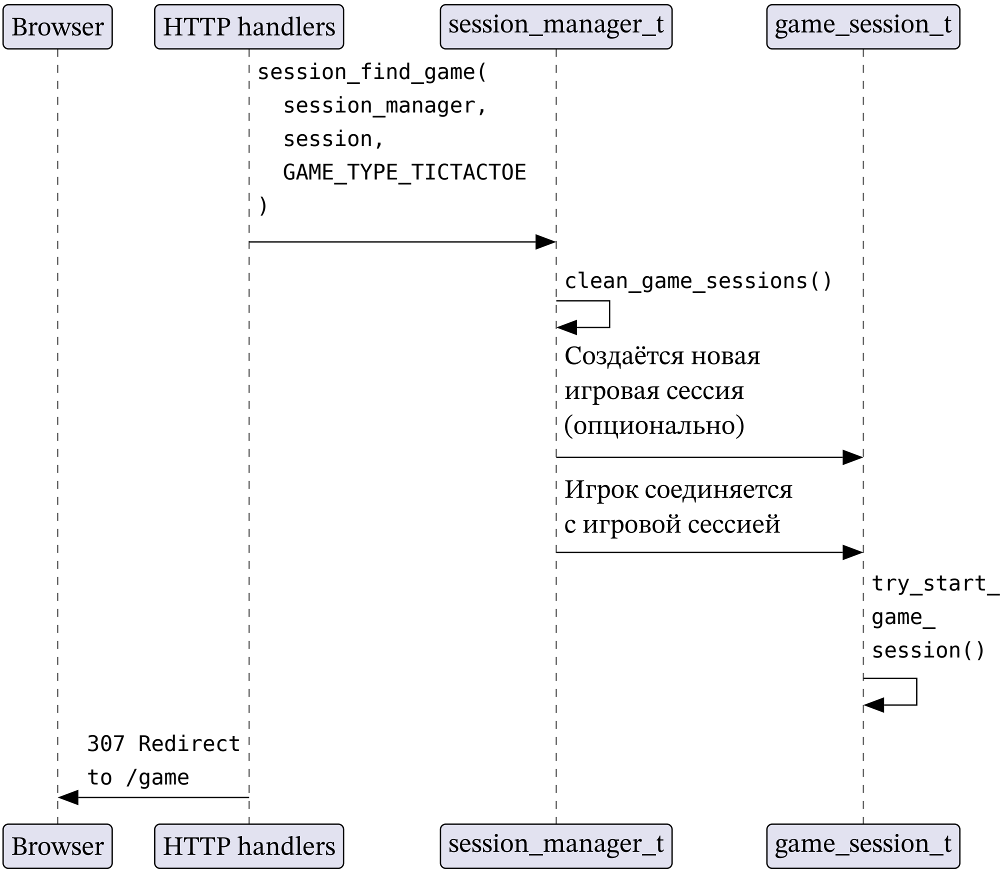
```c
void handle_session_list_request(
  session_manager_t *session_manager,
  json_writer_t *json_writer) {
  clean_sessions(session_manager);
  json_start(json_writer);
  json_start_array(json_writer);
  session_t *session = session_manager->sessions;
  while(session != NULL) {
    if (!session->is_active) {
      continue;
    }
    json_start_dict(json_writer);
    json_write_key(json_writer, "id");
    json_write_number(json_writer, session->id);
    json_write_key(json_writer, "name");
    json_write_string(json_writer, session->username);
    json_write_key(json_writer, "player_index");
    json_write_number(json_writer, session->player_index);
    json_write_key(json_writer, "game_session");
    if (session->game_session == NULL) {
      json_write_null(json_writer);
    } else {
      json_start_dict(json_writer);
      json_write_key(json_writer, "is_active");
      json_write_bool(
        json_writer, session->game_session->is_active
      );
      json_write_key(json_writer, "game_type");
      json_write_number(
        json_writer, session->game_session->game_type
      );
      json_stop_dict(json_writer);
    }
    json_stop_dict(json_writer);
    session = session->next_session;
  }
  json_stop_array(json_writer);
  json_end(json_writer);
}
```

Приложение В



Приложение С




Browser
HTTP handlers
session_manager_t
game_session_t
session_find_game(
  session_manager,
  session,
  GAME_TYPE_TICTACTOE
)
clean_game_sessions()
Создаётся новая игровая сессия (опционально)
Игрок соединяется с игровой сессией
try_start_game_session()
307 Redirect to /game
Browser
HTTP handlers
session_manager_t
game_session_t

Приложение D

```
{
  "status": "game_active",
  "your_index": 0.000000,
  "player_names": ["kirill", "fedya"],
  "state": {
    "active_player_index": 1.000000,
    "winner_index": -1.000000,
    "cells": ["X", " ", " ", " ", " ", " ", " ", " ", " "]
  }
}
```

Приложение E

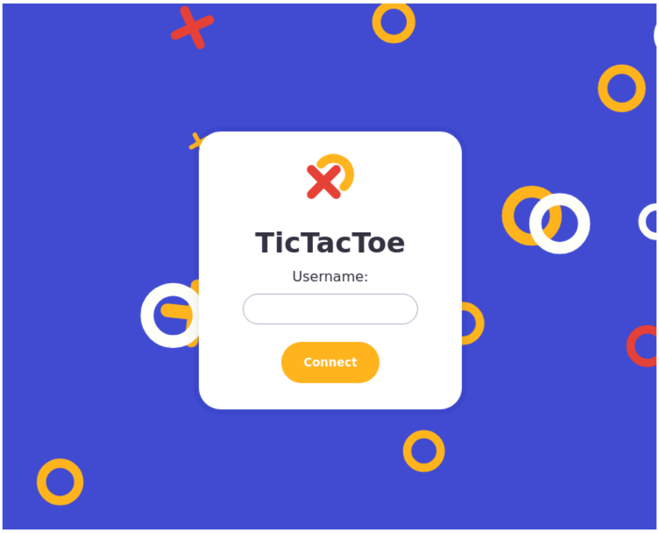


Рис. 1. Страница авторизации

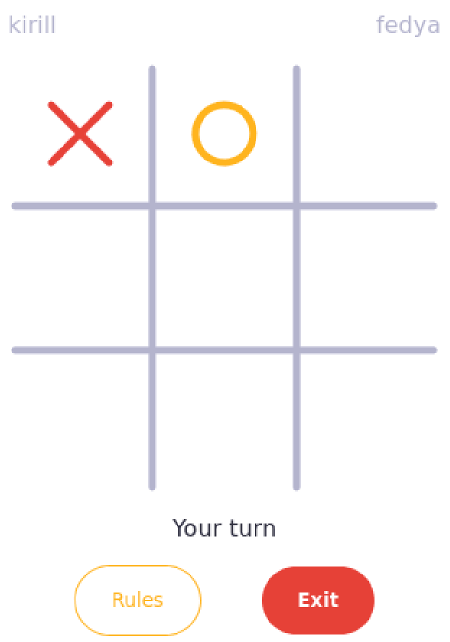


Рис. 2. Страница с игрой

Приложение F

```
// src/arena.c
#include <stdlib.h>
#include "arena.h"
#include "log.h"

void init_arena(arena_t *arena, int size) {
  arena->size = size;
  arena->position = 0;
  arena->buffer = (char *)malloc(size);
  if (arena->buffer == NULL) {
    log_message(LOG_LEVEL_ERROR, "arena", "Failed allocating %d bytes for
arena", size);
    exit(EXIT_FAILURE);
  }
  log_message(LOG_LEVEL_INFO, "arena", "Allocated %d bytes for arena", size);
}
void deinit_arena(arena_t *arena) {
  free(arena->buffer);
}

char *alloc_arena(arena_t *arena, int size) {
  if (arena->position + size > arena->size) {
    log_message(
      LOG_LEVEL_ERROR,
      "arena",
      "Failed allocating %d bytes on %d bytes arena",
      size,
      arena->size
    );
    return NULL;
  }
  char *res = arena->buffer + arena->position;
  arena->position += size + (8 - size % 8);
  return res;
}

void free_arena(arena_t *arena) {
  arena->position = 0;
}
// src/arena.h
#ifndef ARENA_H
#define ARENA_H

typedef struct {
  int size;
  int position;
  char *buffer;
} arena_t;

void init_arena(arena_t *arena, int size);

void deinit_arena(arena_t *arena);

char *alloc_arena(arena_t *arena, int size);

void free_arena(arena_t *arena);

#endif
// src/buffered_writer.c
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include "buffered_writer.h"
#include "http.h"
#include "log.h"

void init_buffered_writer(buffered_writer_t *buffered_writer, http_server_t
*http_server) {
  buffered_writer->position = 0;
  buffered_writer->http_server = http_server;
  buffered_writer->buffer = malloc(BUFFERED_WRITER_BUFFER_SIZE);
  if (buffered_writer->buffer == NULL) {
    log_message(
      LOG_LEVEL_ERROR,
      "buffered_writer",
      "Failed allocating %d bytes for buffered_writer",
      BUFFERED_WRITER_BUFFER_SIZE
    );
    exit(EXIT_FAILURE);
  }
  log_message(
    LOG_LEVEL_INFO,
    "buffered_writer",
    "Allocated %d bytes for buffered_writer",
    BUFFERED_WRITER_BUFFER_SIZE
  );
}

void buffered_writer_flush(buffered_writer_t *buffered_writer) {
  send_http_content(buffered_writer->http_server, buffered_writer->buffer,
buffered_writer->position);
  buffered_writer->position = 0;
}

void buffered_writer_write(buffered_writer_t *buffered_writer, char *buffer,
int size) {
  while (size > 0) {
    int available_space = BUFFERED_WRITER_BUFFER_SIZE - buffered_writer-
>position;
    if (available_space == 0) {
      buffered_writer_flush(buffered_writer);
      available_space = BUFFERED_WRITER_BUFFER_SIZE;
    }
    int segment_size = size < available_space ? size : available_space;
    memcpy(buffered_writer->buffer + buffered_writer->position, buffer,
segment_size);
    buffered_writer->position += segment_size;
    buffer += segment_size;
    size -= segment_size;
  }
}

void buffered_writer_end(buffered_writer_t *buffered_writer) {
  buffered_writer_flush(buffered_writer);
  close_http_connection(buffered_writer->http_server);
}
// src/buffered_writer.h
#ifndef BUFFERED_WRITER_H
#define BUFFERED_WRITER_H

#include "http.h"

#define BUFFERED_WRITER_BUFFER_SIZE 4096
```

```
typedef struct {
  http_server_t *http_server;
  char *buffer;
  int position;
} buffered_writer_t;

void init_buffered_writer(buffered_writer_t *buffered_writer, http_server_t
*http_server);

void buffered_writer_flush(buffered_writer_t *buffered_writer);

void buffered_writer_write(buffered_writer_t *buffered_writer, char *buffer,
int size);

void buffered_writer_end(buffered_writer_t *buffered_writer);

#endif
// src/http.c
#include <stdio.h>
#include <errno.h>
#include <stdlib.h>
#include <string.h>
#include <unistd.h>
#include <stdbool.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <arpa/inet.h>
#include "http.h"
#include "arena.h"
#include "log.h"

void init_http_server(http_server_t *http_server, int port) {
  init_arena(&http_server->arena, HTTP_ARENA_SIZE);
  http_server->connected_client_count = 0;
  http_server->pfds = calloc(HTTP_SERVER_MAX_CONNECTED + 1, sizeof(struct
pollfd));
  if (http_server->pfds == NULL) {
    log_message(LOG_LEVEL_ERROR, "http", "Failed allocating pfds");
    exit(EXIT_FAILURE);
  }
  http_server->buffer = (char *)malloc(HTTP_REQUEST_BUFFER_SIZE);
  if (http_server->buffer == NULL) {
    log_message(LOG_LEVEL_ERROR, "http", "Failed allocating request buffer");
    exit(EXIT_FAILURE);
  }
  int server_fd;
  struct sockaddr_in server_addr;
  server_fd = socket(AF_INET, SOCK_STREAM, 0);
  if (server_fd < 0) {
    log_message(LOG_LEVEL_ERROR, "http", "socket: %s", strerror(errno));
    exit(EXIT_FAILURE);
  }
  int opt = 1;
  if (setsockopt(server_fd, SOL_SOCKET, SO_REUSEADDR, &opt, sizeof(opt)) < 0) {
    log_message(LOG_LEVEL_ERROR, "http", "setsockopt: %s", strerror(errno));
    exit(EXIT_FAILURE);
  }
  server_addr.sin_family = AF_INET;
  server_addr.sin_addr.s_addr = INADDR_ANY;
  server_addr.sin_port = htons(port);
  if (bind(server_fd, (struct sockaddr*)&server_addr, sizeof(server_addr)) < 0)
{
    log_message(LOG_LEVEL_ERROR, "http", "bind: %s", strerror(errno));
    close(server_fd);
    exit(EXIT_FAILURE);
  }
  if (listen(server_fd, HTTP_SERVER_BACKLOG) < 0) {
    log_message(LOG_LEVEL_ERROR, "http", "listen: %s", strerror(errno));
    close(server_fd);
    exit(EXIT_FAILURE);
  }
  socklen_t len = sizeof(server_addr);
  if (getsockname(server_fd, (struct sockaddr *)&server_addr, &len) < 0) {
    log_message(LOG_LEVEL_ERROR, "http", "getsockname: %s", strerror(errno));
    close(server_fd);
    exit(EXIT_FAILURE);
  }
  port = ntohs(server_addr.sin_port);
  http_server->server_fd = server_fd;
  http_server->pfds[0].fd = server_fd;
  http_server->pfds[0].events = POLLIN;
  log_message(LOG_LEVEL_INFO, "http", "Server started on port %d", port);
}

void send_http_head(http_server_t *http_server, char *status) {
  char buffer[HTTP_SERVER_RESPONSE_LINE_SIZE];
  snprintf(buffer, HTTP_SERVER_RESPONSE_LINE_SIZE, "HTTP/1.1 %s\r\n", status);
  write(http_server->client_fd, buffer, strlen(buffer));
}

void send_http_header(http_server_t *http_server, char *key, char *value) {
  char buffer[HTTP_SERVER_RESPONSE_LINE_SIZE];
  snprintf(buffer, HTTP_SERVER_RESPONSE_LINE_SIZE, "%s: %s\r\n", key, value);
  write(http_server->client_fd, buffer, strlen(buffer));
}

void send_default_http_headers(http_server_t *http_server) {
  send_http_header(http_server, "Transfer-Encoding", "chunked");
}

void send_http_end_headers(http_server_t *http_server) {
  write(http_server->client_fd, "\r\n", 2);
}
```

```
void send_http_content(http_server_t *http_server, char *buffer, int size) {
  char size_buffer[64];
  snprintf(size_buffer, sizeof(size_buffer), "%X\r\n", size);
  write(http_server->client_fd, size_buffer, strlen(size_buffer));
  write(http_server->client_fd, buffer, size);
  write(http_server->client_fd, "\r\n", 2);
}

void close_http_connection(http_server_t *http_server) {
  for (int i = 0; i < http_server->connected_client_count; i++) {
    if (http_server->pfds[i + 1].fd == http_server->client_fd) {
      log_message(LOG_LEVEL_INFO, "http", "Removing FD %d", http_server-
>client_fd);
      http_server->connected_client_count--;
      http_server->pfds[i + 1].fd = http_server->pfds[http_server-
>connected_client_count + 1].fd;
      break;
    }
  }
  write(http_server->client_fd, "0\r\n\r\n", 5);
  close(http_server->client_fd);
}

void send_simple_http_error(http_server_t *http_server, char *status) {
  char buffer[HTTP_SERVER_RESPONSE_LINE_SIZE];
  snprintf(buffer, HTTP_SERVER_RESPONSE_LINE_SIZE, "<h1>%s</h1>", status);
  send_http_head(http_server, status);
  send_default_http_headers(http_server);
  send_http_header(http_server, "Content-Type", "text/html");
  send_http_end_headers(http_server);
  send_http_content(http_server, buffer, strlen(buffer));
  close_http_connection(http_server);
}

void send_http_redirect(http_server_t *http_server, char *path) {
  send_http_head(http_server, HTTP_STATUS_TEMPORARY_REDIRECT);
  send_http_header(http_server, "Location", path);
  send_http_end_headers(http_server);
  close_http_connection(http_server);
}

char read_url_hex(char *buffer) {
  char out = 0;
  for (int i = 1; i < 3; i++) {
    out *= 16;
    switch (buffer[i]) {
      case '0'...'9':
        out += buffer[i] - '0';
      break;
      case 'a'...'f':
        out += buffer[i] - 'a' + 10;
      break;
    }
  }
  return out;
}

char *read_url_segment(http_server_t *http_server, int *index) {
  char *delimiter = "\r\n?&= ";
  int end;
  int length = 0;
  for (int i = *index; i < HTTP_REQUEST_BUFFER_SIZE; i++) {
    bool end_found = false;
    for (int j = 0; delimiter[j] != '\0'; j++) {
      if (http_server->buffer[i] == delimiter[j]) {
        end_found = true;
        break;
      }
    }
    if (end_found || (http_server->buffer[i] == '\0')) {
      end = i;
      break;
    }
    if (http_server->buffer[i] == '%') {
      i += 2;
    }
    length++;
  }
  char *result = alloc_arena(&http_server->arena, length + 1);
  if (result == NULL) {
    return NULL;
  }
  result[length] = '\0';
  for (int i = *index, j = 0; j < length; i++, j++) {
    if (http_server->buffer[i] == '+') {
      result[j] = ' ';
    } else if (http_server->buffer[i] == '%') {
      result[j] = read_url_hex(&http_server->buffer[i]);
      i += 2;
    } else {
      result[j] = http_server->buffer[i];
    }
  }
  // log_message(LOG_LEVEL_INFO, "http", "Got url segment '%s'", result);
  *index = end;
  return result;
}

bool parse_query_entry(http_server_t *http_server, int *index) {
  char *key = read_url_segment(http_server, index);
  if (key == NULL) {
    return false;
  }
  if (http_server->buffer[*index] != '=') {
    return false;
  }
  (*index)++;
  char *value = read_url_segment(http_server, index);
  if (value == NULL) {
    return false;
  }
  parameter_list_entry_t **tail = &http_server->parameter_list;
  while (*tail != NULL) {
    tail = (parameter_list_entry_t **)&((**tail).next);
  }
  parameter_list_entry_t *new_entry = (parameter_list_entry_t *)alloc_arena(
    &http_server->arena,
    sizeof(parameter_list_entry_t)
  );
  if (new_entry == NULL) {
    return false;
  }
  new_entry->key = key;
  new_entry->value = value;
  new_entry->next = NULL;
  *tail = new_entry;
  log_message(LOG_LEVEL_INFO, "http", "Got parameter '%s' = '%s'", key, value);
  return true;
}

void parse_request(http_server_t *http_server) {
  free_arena(&http_server->arena);
  http_server->parameter_list = NULL;
  int i = 0;
  char *prefix = "GET ";
  while(prefix[i]) {
    if (http_server->buffer[i] != prefix[i]) {
      log_message(LOG_LEVEL_ERROR, "http", "Request doesn't start with 'GET
'");
      send_simple_http_error(http_server, HTTP_STATUS_NOT_IMPLEMENTED);
      return;
    }
    i++;
  }
  http_server->path = read_url_segment(http_server, &i);
  log_message(LOG_LEVEL_INFO, "http", "Got path = '%s'", http_server->path);
  if (http_server->buffer[i] == '?') {
    i++;
    if (!parse_query_entry(http_server, &i)) {
      log_message(LOG_LEVEL_ERROR, "http", "Error while reading request url");
      send_simple_http_error(http_server, HTTP_STATUS_BAD_REQUEST);
      return;
    }
    while (http_server->buffer[i] == '&') {
      i++;
      if (!parse_query_entry(http_server, &i)) {
        log_message(LOG_LEVEL_ERROR, "http", "Error while reading request
url");
        send_simple_http_error(http_server, HTTP_STATUS_BAD_REQUEST);
```

```
          return;
        }
      }
    }
    http_server->is_ok = true;
  }

  void accept_http_request(http_server_t *http_server) {
    http_server->is_ok = false;
    int ready = poll(http_server->pfds, http_server->connected_client_count + 1,
  -1);
    if (ready < 0) {
      log_message(LOG_LEVEL_ERROR, "http", "poll: %s", strerror(errno));
      exit(EXIT_FAILURE);
    }
    int count = http_server->connected_client_count;
    if (
      (http_server->connected_client_count < HTTP_SERVER_MAX_CONNECTED)
      && ((http_server->pfds[0].revents & POLLIN) != 0)
    ) {
      int client_fd;
      struct sockaddr_in client_addr;
      socklen_t client_len = sizeof(client_addr);
      client_fd = accept(http_server->server_fd, (struct sockaddr*)&client_addr,
  &client_len);
      if (client_fd < 0) {
        log_message(LOG_LEVEL_ERROR, "http", "accept: %s", strerror(errno));
        return;
      }
      char *host = inet_ntoa(client_addr.sin_addr);
      int port = ntohs(client_addr.sin_port);
      log_message(LOG_LEVEL_INFO, "http", "Connected client %s:%d", host, port);
      http_server->pfds[http_server->connected_client_count + 1].fd = client_fd;
      http_server->pfds[http_server->connected_client_count + 1].events = POLLIN;
      http_server->connected_client_count++;
      log_message(LOG_LEVEL_INFO, "http", "Connected clients count %d",
  http_server->connected_client_count);
    }
    for (int i = 0; i < count; i++) {
      if ((http_server->pfds[i + 1].revents & POLLIN) != 0) {
        int client_fd = http_server->pfds[i + 1].fd;
        int n = read(client_fd, http_server->buffer, HTTP_REQUEST_BUFFER_SIZE);
        if (n > 0) {
          http_server->buffer[n] = '\0';
        }
        http_server->client_fd = client_fd;
        parse_request(http_server);
        return;
      }
    }
  }

  char *get_http_parameter(http_server_t *http_server, char *key) {
```

```
  parameter_list_entry_t *parameter = http_server->parameter_list;
  while (parameter != NULL) {
    if (strcmp(parameter->key, key) == 0) {
      return parameter->value;
    }
    parameter = parameter->next;
  }
  return NULL;
}
// src/http.h
#ifndef HTTP_H
#define HTTP_H

#include <stdbool.h>
#include <poll.h>
#include "arena.h"

#define HTTP_SERVER_BACKLOG 16
#define HTTP_SERVER_MAX_CONNECTED 16
#define HTTP_ARENA_SIZE 4096
#define HTTP_REQUEST_BUFFER_SIZE 4096
#define HTTP_SERVER_RESPONSE_LINE_SIZE 512
#define HTTP_STATUS_OK "200 OK"
#define HTTP_STATUS_TEMPORARY_REDIRECT "307 Temporary Redirect"
#define HTTP_STATUS_BAD_REQUEST "400 Bad Request"
#define HTTP_STATUS_NOT_FOUND "404 Not Found"
#define HTTP_STATUS_INTERNAL_SERVER_ERROR "500 Internal Server Error"
#define HTTP_STATUS_NOT_IMPLEMENTED "501 Not Implemented"

typedef struct {
  char *key;
  char *value;
  void *next;
} parameter_list_entry_t;

typedef parameter_list_entry_t *parameter_list_t;

typedef struct {
  int server_fd;
  int client_fd;
  bool is_ok;
  char *buffer;
  arena_t arena;
  char *path;
  parameter_list_t parameter_list;
  int connected_client_count;
  struct pollfd *pfds;
} http_server_t;

void init_http_server(http_server_t *http_server, int port);

void send_http_head(http_server_t *http_server, char *status);
void send_http_header(http_server_t *http_server, char *key, char *value);

void send_default_http_headers(http_server_t *http_server);

void send_http_end_headers(http_server_t *http_server);

void send_http_content(http_server_t *http_server, char *buffer, int size);

void send_simple_http_error(http_server_t *http_server, char *status);

void send_http_redirect(http_server_t *http_server, char *path);

void close_http_connection(http_server_t *http_server);

void accept_http_request(http_server_t *http_server);

char *get_http_parameter(http_server_t *http_server, char *key);

#endif
// src/http_handlers.c
#include <stdio.h>
#include <stdlib.h>
#include <dirent.h>
#include <string.h>
#include "http_handlers.h"
#include "http.h"
#include "log.h"
#include "json_writer.h"
#include "sessions.h"
#include "tictactoe.h"

void init_static_handler(static_handler_t *static_handler) {
  DIR *d = opendir(STATIC_FILES_DIRECTORY);
  if (!d) {
    log_message(LOG_LEVEL_ERROR, "http_handlers", "Can't open %s directory",
STATIC_FILES_DIRECTORY);
    exit(EXIT_FAILURE);
  }
  struct dirent *dir;
  FILE *file;
  static_file_entry_t *entry;
  char path[256];
  while ((dir = readdir(d)) != NULL) {
    if (dir->d_type != DT_REG) {
      continue;
    }
    entry = (static_file_entry_t *)malloc(sizeof(static_file_entry_t));
    if (entry == NULL) {
      log_message(LOG_LEVEL_ERROR, "http_handlers", "Failed allocating
static_file_entry_t");
      exit(EXIT_FAILURE);
    }
    entry->name = strdup(dir->d_name);
    entry->next = NULL;
    if (entry->name == NULL) {
      log_message(LOG_LEVEL_ERROR, "http_handlers", "Failed allocating
static_file_entry_t name");
      exit(EXIT_FAILURE);
    }
    snprintf(path, sizeof(path), "%s/%s", STATIC_FILES_DIRECTORY, entry->name);
    file = fopen(path, "rb");
    if (file == NULL) {
      log_message(LOG_LEVEL_ERROR, "http_handlers", "Can't open file %s",
path);
      exit(EXIT_FAILURE);
    }
    fseek(file, 0, SEEK_END);
    entry->size = ftell(file);
    fseek(file, 0, SEEK_SET);
    entry->data = (char *)malloc(entry->size);
    if (entry->data == NULL) {
      log_message(LOG_LEVEL_ERROR, "http_handlers", "Can't allocate %d bytes
for %s", entry->size, entry->name);
      exit(EXIT_FAILURE);
    }
    fread(entry->data, 1, entry->size, file);
    fclose(file);
    *static_handler = entry;
    static_handler = (static_file_entry_t **)&entry->next;
    log_message(LOG_LEVEL_INFO, "http_handlers", "Loaded static file %s", dir-
>d_name);
  }
  closedir(d);
}

bool starts_with(char *string, char *prefix) {
  if (string == NULL || prefix == NULL) {
    return false;
  }
  int len_string = strlen(string);
  int len_prefix = strlen(prefix);
  if (len_prefix > len_string) {
    return false;
  }
  return strncmp(string, prefix, len_prefix) == 0;
}

bool ends_with(char *string, char *suffix) {
  if (string == NULL || suffix == NULL) {
    return false;
  }
  int len_string = strlen(string);
  int len_suffix = strlen(suffix);
  if (len_suffix > len_string) {
    return false;
  }
  return strncmp(string + (len_string - len_suffix), suffix, len_suffix) == 0;
}

bool match_static_path(http_server_t *http_server) {
  return starts_with(http_server->path, STATIC_PATH_PREFIX);
}

char *get_mime(char *path) {
  if (ends_with(path, ".html")) {
    return "text/html";
  }
  if (ends_with(path, ".js")) {
    return "text/javascript";
  }
  if (ends_with(path, ".css")) {
    return "text/css";
  }
  if (ends_with(path, ".svg")) {
    return "image/svg+xml";
  }
  return "text/plain";
}

void send_static_file(static_handler_t *static_handler, http_server_t
*http_server, char *name) {
  static_file_entry_t *entry = *static_handler;
  while (true) {
    if (entry == NULL) {
      send_simple_http_error(http_server, HTTP_STATUS_NOT_FOUND);
      return;
    }
    if (strcmp(entry->name, name) == 0) {
      break;
    }
    entry = entry->next;
  }
  send_http_head(http_server, HTTP_STATUS_OK);
  send_default_http_headers(http_server);
  send_http_header(http_server, "Content-Type", get_mime(name));
  send_http_end_headers(http_server);
  send_http_content(http_server, entry->data, entry->size);
  close_http_connection(http_server);
}

void handle_static_request(static_handler_t *static_handler, http_server_t
*http_server) {
  char *name = http_server->path + strlen(STATIC_PATH_PREFIX);
  send_static_file(static_handler, http_server, name);
}

void handle_session_list_request(session_manager_t *session_manager,
json_writer_t *json_writer) {
  clean_sessions(session_manager);
  json_start(json_writer);
  json_start_array(json_writer);
  session_t *session = session_manager->sessions;
  while(session != NULL) {
    if (!session->is_active) {
      continue;
    }
    json_start_dict(json_writer);
    json_write_key(json_writer, "id");
    json_write_number(json_writer, session->id);
    json_write_key(json_writer, "name");
    json_write_string(json_writer, session->username);
    json_write_key(json_writer, "player_index");
    json_write_number(json_writer, session->player_index);
    json_write_key(json_writer, "game_session");
    if (session->game_session == NULL) {
      json_write_null(json_writer);
    } else {
      json_start_dict(json_writer);
      json_write_key(json_writer, "is_active");
      json_write_bool(json_writer, session->game_session->is_active);
      json_write_key(json_writer, "game_type");
      json_write_number(json_writer, session->game_session->game_type);
      json_stop_dict(json_writer);
    }
    json_stop_dict(json_writer);
    session = session->next_session;
  }
  json_stop_array(json_writer);
  json_end(json_writer);
}

void handle_auth_request(
  http_server_t *http_server,
  session_manager_t *session_manager,
  static_handler_t *static_handler
) {
  char *username = get_http_parameter(http_server, "username");
  if (username == NULL) {
    send_static_file(static_handler, http_server, "auth.html");
    return;
  }
  if (!validate_username(username)) {
    send_http_redirect(http_server, "/auth?msg=Invalid%20username");
    return;
  }
  session_t *session = new_session(session_manager, username);
  if (session == NULL) {
    send_simple_http_error(http_server, HTTP_STATUS_INTERNAL_SERVER_ERROR);
    return;
  }
  char path[256];
  snprintf(path, sizeof(path), "/?id=%d", session->id);
  send_http_redirect(http_server, path);
  log_message(LOG_LEVEL_INFO, "http_handlers", "Created new session #%d '%s'",
session->id, session->username);
}

session_t *get_session_from_parameter(http_server_t *http_server,
session_manager_t *session_manager) {
  char *session_id_str = get_http_parameter(http_server, "id");
  if (session_id_str == NULL) {
    return NULL;
  }
  int session_id = atoi(session_id_str);
  return find_session_by_id(session_manager, session_id);
}

void handle_join_game(http_server_t *http_server, session_manager_t
*session_manager, session_t *session) {
  char *game_id_str = get_http_parameter(http_server, "gameId");
  if (game_id_str == NULL) {
    send_simple_http_error(http_server, HTTP_STATUS_BAD_REQUEST);
    return;
  }
  game_type_t game_type = str_to_game_type(game_id_str);
  if (game_type == GAME_TYPE_EMPTY) {
    send_simple_http_error(http_server, HTTP_STATUS_BAD_REQUEST);
    return;
  }
  session_find_game(session_manager, session, game_type);
  char path[256];
  snprintf(path, sizeof(path), "/game?id=%d&gameType=%s", session->id,
game_type_to_str(game_type));
  send_http_redirect(http_server, path);
}

void handle_game_request(http_server_t *http_server, session_t *session,
json_writer_t *json_writer) {
  update_session(session);
  char *status;
  if (session->game_session == NULL) {
    log_message(LOG_LEVEL_INFO, "http_handlers", "Trying to handle_game_request
without game_session");
    status = "no_game_session";
  } else if (!session->game_session->is_active) {
    status = "game_not_started";
  } else if (session->game_session->is_finished) {
    status = "game_finished";
  } else {
    status = "game_active";
  }
  json_start(json_writer);
  json_start_dict(json_writer);
  json_write_key(json_writer, "status");
  json_write_string(json_writer, status);
  json_write_key(json_writer, "your_index");
  json_write_number(json_writer, session->player_index);
  json_write_key(json_writer, "player_names");
  json_start_array(json_writer);
  if (session->game_session != NULL) {
    for (int i = 0; i < MAX_PLAYERS_PER_GAME; i++) {
      session_t *isession = session->game_session->players[i];
      if (isession == NULL) {
        json_write_null(json_writer);
      } else {
        json_write_string(json_writer, isession->username);
      }
    }
  }
  json_stop_array(json_writer);
  if (session->game_session != NULL && session->game_session->game != NULL) {
    json_write_key(json_writer, "state");
    switch (session->game_session->game_type) {
      case GAME_TYPE_EMPTY:
        json_write_null(json_writer);
        break;
      case GAME_TYPE_TICTACTOE:
        tictactoe_handle_request(session->game_session, session, http_server);
        tictactoe_write_json(session->game_session, json_writer);
        break;
    }
    if (session->game_session->is_finished) {
      end_game_session(session->game_session);
    }
  }
  json_stop_dict(json_writer);
  json_end(json_writer);
  if (session->game_session != NULL) {
    session->game_session->player_seen_state[session->player_index] = true;
  }
}

void handle_disconnect_from_game_session(http_server_t *http_server, session_t
*session) {
  disconnect_from_game_session(session);
  char path[256];
  snprintf(path, sizeof(path), "/?id=%d", session->id);
  send_http_redirect(http_server, path);
}
// src/http_handlers.h
#ifndef HTTP_HANDLERS_H
#define HTTP_HANDLERS_H

#include <stdbool.h>
#include "http.h"
#include "json_writer.h"
#include "sessions.h"
```

```
#define STATIC_PATH_PREFIX "/static/"
#define STATIC_FILES_DIRECTORY "./static/"

typedef struct {
  char *name;
  int size;
  char *data;
  void *next;
} static_file_entry_t;

typedef static_file_entry_t *static_handler_t;

void init_static_handler(static_handler_t *static_handler);

bool starts_with(char *string, char *prefix);

bool ends_with(char *string, char *suffix);

bool match_static_path(http_server_t *http_server);

char *get_mime(char *path);

void send_static_file(static_handler_t *static_handler, http_server_t
*http_server, char *name);

void handle_static_request(static_handler_t *static_handler, http_server_t
*http_server);

void handle_session_list_request(session_manager_t *session_manager,
json_writer_t *json_writer);

void handle_auth_request(
  http_server_t *http_server,
  session_manager_t *session_manager,
  static_handler_t *static_handler
);

session_t *get_session_from_parameter(http_server_t *http_server,
session_manager_t *session_manager);

void handle_join_game(http_server_t *http_server, session_manager_t
*session_manager, session_t *session);

void handle_game_request(http_server_t *http_server, session_t *session,
json_writer_t *json_writer);

void handle_disconnect_from_game_session(http_server_t *http_server, session_t
*session);

#endif
// src/json_writer.c
#include <stdio.h>
#include <string.h>
```

```
#include "json_writer.h"
#include "buffered_writer.h"

void init_json_writer(
  json_writer_t *json_writer, http_server_t *http_server, buffered_writer_t
*buffered_writer
) {
  json_writer->http_server = http_server;
  json_writer->buffered_writer = buffered_writer;
}

void json_start_dict(json_writer_t *json_writer) {
  if (!json_writer->is_first) {
    buffered_writer_write(json_writer->buffered_writer, ",", 1);
  }
  json_writer->is_first = true;
  buffered_writer_write(json_writer->buffered_writer, "{", 1);
}

void json_stop_dict(json_writer_t *json_writer) {
  buffered_writer_write(json_writer->buffered_writer, "}", 1);
  json_writer->is_first = false;
}

void json_start_array(json_writer_t *json_writer) {
  if (!json_writer->is_first) {
    buffered_writer_write(json_writer->buffered_writer, ",", 1);
  }
  json_writer->is_first = true;
  buffered_writer_write(json_writer->buffered_writer, "[", 1);
}

void json_stop_array(json_writer_t *json_writer) {
  json_writer->is_first = false;
  buffered_writer_write(json_writer->buffered_writer, "]", 1);
}

void json_write_number(json_writer_t *json_writer, double number) {
  if (!json_writer->is_first) {
    buffered_writer_write(json_writer->buffered_writer, ",", 1);
  }
  json_writer->is_first = false;
  char buffer[256];
  snprintf(buffer, sizeof(buffer), "%f", number);
  buffered_writer_write(json_writer->buffered_writer, buffer, strlen(buffer));
}

void json_write_bool(json_writer_t *json_writer, bool value) {
  if (!json_writer->is_first) {
    buffered_writer_write(json_writer->buffered_writer, ",", 1);
  }
  json_writer->is_first = false;
  char *buffer = value ? "true" : "false";
  buffered_writer_write(json_writer->buffered_writer, buffer, strlen(buffer));
}

bool is_printable(char c) {
  switch (c) {
    case '\0':
    case '\r':
    case '\n':
    case '"':
    case '\t':
      return false;
  }
  return true;
}

char *escape(char c) {
  switch (c) {
    case '\r':
      return "\\r";
    case '\n':
      return "\\n";
    case '"':
      return "\\\"";
    case '\t':
      return "\\t";
  }
  return NULL;
}

void json_write_string(json_writer_t *json_writer, char *string) {
  if (!json_writer->is_first) {
    buffered_writer_write(json_writer->buffered_writer, ",", 1);
  }
  buffered_writer_write(json_writer->buffered_writer, "\"", 1);
  json_writer->is_first = false;
  int start = 0, end = 0;
  while (string[start] != '\0') {
    while (is_printable(string[end])) {
      end++;
    }
    buffered_writer_write(json_writer->buffered_writer, string + start, end -
start);
    char *escaped = escape(string[end]);
    if (escaped == NULL) {
      break;
    }
    buffered_writer_write(json_writer->buffered_writer, escaped, 2);
    start = ++end;
  }
  buffered_writer_write(json_writer->buffered_writer, "\"", 1);
}

void json_write_key(json_writer_t *json_writer, char *key) {
  json_write_string(json_writer, key);
  json_writer->is_first = true;
  buffered_writer_write(json_writer->buffered_writer, ":", 1);
}

void json_write_null(json_writer_t *json_writer) {
  if (!json_writer->is_first) {
    buffered_writer_write(json_writer->buffered_writer, ",", 1);
  }
  json_writer->is_first = false;
  char *buffer = "null";
  buffered_writer_write(json_writer->buffered_writer, buffer, strlen(buffer));
}

void json_start(json_writer_t *json_writer) {
  json_writer->is_first = true;
  send_http_head(json_writer->http_server, HTTP_STATUS_OK);
  send_default_http_headers(json_writer->http_server);
  send_http_header(json_writer->http_server, "Content-Type", "application/
json");
  send_http_end_headers(json_writer->http_server);
}

void json_end(json_writer_t *json_writer) {
  json_writer->is_first = true;
  buffered_writer_end(json_writer->buffered_writer);
}
// src/json_writer.h
#ifndef JSON_WRITER_H
#define JSON_WRITER_H

#include <stdbool.h>
#include "http.h"
#include "buffered_writer.h"

typedef struct {
  http_server_t *http_server;
  buffered_writer_t *buffered_writer;
  bool is_first;
} json_writer_t;

void init_json_writer(
  json_writer_t *json_writer, http_server_t *http_server, buffered_writer_t
*buffered_writer
);

void json_start_dict(json_writer_t *json_writer);

void json_stop_dict(json_writer_t *json_writer);

void json_start_array(json_writer_t *json_writer);

void json_stop_array(json_writer_t *json_writer);
void json_write_number(json_writer_t *json_writer, double number);

void json_write_bool(json_writer_t *json_writer, bool value);

void json_write_string(json_writer_t *json_writer, char *string);

void json_write_key(json_writer_t *json_writer, char *key);

void json_write_null(json_writer_t *json_writer);

void json_start(json_writer_t *json_writer);

void json_end(json_writer_t *json_writer);

#endif
// src/log.c
#include <stdio.h>
#include <time.h>
#include "log.h"

void log_header(log_level_t level, char *module) {
  time_t rawtime;
  struct tm * timeinfo;
  char timestamp_buffer[80];
  time(&rawtime);
  timeinfo = localtime(&rawtime);
  strftime(timestamp_buffer, sizeof(timestamp_buffer), "%Y-%m-%d %H:%M:%S",
timeinfo);
  char *level_str;
  switch (level) {
    case LOG_LEVEL_INFO:
      level_str = "\033[34mINFO";
      break;
    case LOG_LEVEL_ERROR:
      level_str = "\033[31mERROR";
      break;
  }
  fprintf(stderr, "\033[90m[%s] %s\033[90m %s: \033[0m", timestamp_buffer,
level_str, module);
}
// src/log.h
#ifndef LOG_H
#define LOG_H

#include <stdio.h>

typedef enum {
  LOG_LEVEL_INFO,
  LOG_LEVEL_ERROR,
} log_level_t;

void log_header(log_level_t level, char *module);
```

```
#define log_message(level, module, fmt, ...) if (1) { \
  log_header(level, module); fprintf(stderr, fmt "\n", ##__VA_ARGS__); \
}

#endif
// src/main.c
#include <time.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <signal.h>
#include <stdbool.h>
#include "log.h"
#include "http.h"
#include "buffered_writer.h"
#include "json_writer.h"
#include "http_handlers.h"
#include "sessions.h"

#define DEFAULT_HTTP_SERVER_PORT 8080

void print_usage(char *name) {
  printf(
    "Usage: %s [port]\n"
    "\n"
    "Options:\n"
    "  -h, --help\tPrint this message\n",
    name
  );
}

int main(int argc, char **argv) {
  signal(SIGPIPE, SIG_IGN);
  srand(time(NULL));
  http_server_t http_server;
  buffered_writer_t buffered_writer;
  json_writer_t json_writer;
  static_handler_t static_handler;
  session_manager_t session_manager;
  int port;
  if (argc == 1) {
    port = DEFAULT_HTTP_SERVER_PORT;
  } else if (argc == 2) {
    if (strcmp(argv[1], "--help") == 0 || strcmp(argv[1], "-h") == 0) {
      print_usage(argv[0]);
      exit(EXIT_SUCCESS);
    }
    port = atoi(argv[1]);
  } else {
    print_usage(argv[0]);
    exit(EXIT_FAILURE);
  }
  log_message(LOG_LEVEL_INFO, "main", "Starting...");
  init_http_server(&http_server, port);
  init_buffered_writer(&buffered_writer, &http_server);
  init_json_writer(&json_writer, &http_server, &buffered_writer);
  init_static_handler(&static_handler);
  init_session_manager(&session_manager);
  while (true) {
    accept_http_request(&http_server);
    if (!http_server.is_ok) {
      continue;
    }
    if (match_static_path(&http_server)) {
      handle_static_request(&static_handler, &http_server);
      continue;
    }
    if (strcmp(http_server.path, "/sessions") == 0) {
      handle_session_list_request(&session_manager, &json_writer);
      continue;
    }
    if (strcmp(http_server.path, "/auth") == 0) {
      handle_auth_request(&http_server, &session_manager, &static_handler);
      continue;
    }
    session_t *session = get_session_from_parameter(&http_server,
&session_manager);
    if (session == NULL) {
      send_http_redirect(&http_server, "/auth");
      continue;
    }
    if (strcmp(http_server.path, "/") == 0) {
      send_static_file(&static_handler, &http_server, "index.html");
      continue;
    }
    if (strcmp(http_server.path, "/joinGame") == 0) {
      handle_join_game(&http_server, &session_manager, session);
      continue;
    }
    if (strcmp(http_server.path, "/game") == 0) {
      send_static_file(&static_handler, &http_server, "game.html");
      continue;
    }
    if (strcmp(http_server.path, "/gameRequest") == 0) {
      handle_game_request(&http_server, session, &json_writer);
      continue;
    }
    if (strcmp(http_server.path, "/disconnect") == 0) {
      handle_disconnect_from_game_session(&http_server, session);
      continue;
    }
    send_simple_http_error(&http_server, HTTP_STATUS_NOT_FOUND);
  }
  return 0;
}
```

```
// src/sessions.c
#include <time.h>
#include <string.h>
#include <stdlib.h>
#include <stdbool.h>
#include "sessions.h"
#include "log.h"
#include "tictactoe.h"

char *game_type_to_str(game_type_t game_type) {
  switch (game_type) {
    case GAME_TYPE_EMPTY:
      return NULL;
    case GAME_TYPE_TICTACTOE:
      return "tictactoe";
  }
  return NULL;
}

game_type_t str_to_game_type(char *string) {
  if (strcmp(string, "tictactoe") == 0) {
    return GAME_TYPE_TICTACTOE;
  }
  return GAME_TYPE_EMPTY;
}

void reset_session(session_t *session) {
  disconnect_from_game_session(session);
  session->is_active = false;
}

void init_session_manager(session_manager_t *session_manager) {
  session_manager->game_sessions = NULL;
  session_manager->sessions = NULL;
}

bool validate_username(char *username) {
  if (username == NULL) {
    log_message(LOG_LEVEL_ERROR, "sessions", "Expected username got NULL");
    return false;
  }
  if (strlen(username) == 0) {
    log_message(LOG_LEVEL_ERROR, "sessions", "Empty username");
    return false;
  }
  if (strlen(username) > USERNAME_MAX_LENGTH) {
    log_message(LOG_LEVEL_ERROR, "sessions", "Username is too long");
    return false;
  }
  char *c = username;
  while (*c != '\0') {
    switch (*c) {
      case 'A'...'Z':
```

```
      case 'a'...'z':
      case '0'...'9':
      case '_':
        c++;
        continue;
      default:
        log_message(LOG_LEVEL_ERROR, "sessions", "Invalid character in
username");
        return false;
    }
  }
  return true;
}

void update_session(session_t *session) {
  session->last_active = time(NULL);
}

session_t *new_session(session_manager_t *session_manager, char *username) {
  if (!validate_username(username)) {
    return NULL;
  }
  session_t *session = malloc(sizeof(session_t));
  if (session == NULL) {
    log_message(LOG_LEVEL_ERROR, "sessions", "Can't allocate new session");
    exit(1);
  }
  session->next_session = session_manager->sessions;
  session_manager->sessions = session;
  session->is_active = true;
  session->id = rand();
  session->game_session = NULL;
  update_session(session);
  strcpy(session->username, username);
  log_message(LOG_LEVEL_INFO, "sessions", "New session #%d '%s'", session->id,
session->username);
  return session;
}

session_t *find_session_by_id(session_manager_t *session_manager, int id) {
  clean_sessions(session_manager);
  session_t *session = session_manager->sessions;
  while (session != NULL) {
    if (!session->is_active) {
      session = session->next_session;
      continue;
    }
    if (session->id == id) {
      return session;
    }
    session = session->next_session;
  }
  return NULL;
```

```
}

void clean_game_sessions(session_manager_t *session_manager) {
  game_session_t **last_ref = &session_manager->game_sessions;
  game_session_t *session = session_manager->game_sessions;
  while (session != NULL) {
    if (!session->removable) {
      *last_ref = session;
      last_ref = (game_session_t **)(&session->next_game_session);
      session = session->next_game_session;
    } else {
      game_session_t *next_session = session->next_game_session;
      free(session);
      session = next_session;
    }
  }
  *last_ref = NULL;
}

void session_find_game(session_manager_t *session_manager, session_t *session,
game_type_t game_type) {
  clean_game_sessions(session_manager);
  update_session(session);
  disconnect_from_game_session(session);
  game_session_t *game_session = session_manager->game_sessions;
  while (game_session != NULL) {
    if (
      game_session->is_active ||
      (game_session->game_type != game_type && game_session->game_type !=
GAME_TYPE_EMPTY)
    ) {
      game_session = game_session->next_game_session;
      continue;
    }
    for (int j = 0; j < MAX_PLAYERS_PER_GAME; j++) {
      if (game_session->players[j] == NULL) {
        session->game_session = game_session;
        session->player_index = j;
        game_session->players[j] = session;
        game_session->game_type = game_type;
        try_start_game_session(game_session);
        return;
      }
    }
    game_session = game_session->next_game_session;
  }
  game_session = malloc(sizeof(game_session_t));
  if (game_session == NULL) {
    log_message(LOG_LEVEL_ERROR, "sessions", "Can't allocate new game
session");
    exit(1);
  }
  session->game_session = game_session;
  session->player_index = 0;
  game_session->is_active = false;
  game_session->is_finished = false;
  for (int i = 0; i < MAX_PLAYERS_PER_GAME; i++) {
    game_session->player_seen_state[i] = false;
    game_session->players[i] = NULL;
  }
  game_session->players[0] = session;
  game_session->game_type = game_type;
  game_session->game = NULL;
  game_session->removable = false;
  game_session->next_game_session = session_manager->game_sessions;
  session_manager->game_sessions = game_session;
}

void clean_sessions(session_manager_t *session_manager) {
  session_t *session = session_manager->sessions;
  time_t now = time(NULL);
  while (session != NULL) {
    if (!session->is_active) {
      session = session->next_session;
      continue;
    }
    if (now - session->last_active > MAX_SESSION_INACTIVE_TIME) {
      log_message(LOG_LEVEL_INFO, "sessions", "Cleaning session #%d", session-
>id);
      reset_session(session);
    }
    session = session->next_session;
  }
  session_t **last_ref = &session_manager->sessions;
  session = session_manager->sessions;
  while (session != NULL) {
    if (session->is_active) {
      *last_ref = session;
      last_ref = (session_t **)(&session->next_session);
      session = session->next_session;
    } else {
      session_t *next_session = session->next_session;
      free(session);
      session = next_session;
    }
  }
  *last_ref = NULL;
}

void disconnect_from_game_session(session_t *session) {
  if (session->game_session == NULL) {
    return;
  }
  session->game_session->players[session->player_index] = NULL;
  switch (session->game_session->game_type) {
    case GAME_TYPE_EMPTY:
      break;
    case GAME_TYPE_TICTACTOE:
      tictactoe_handle_disconnect(session->game_session, session);
      break;
  }
  end_game_session(session->game_session);
  session->game_session = NULL;
}

void end_game_session(game_session_t *game_session) {
  if (!game_session->is_active) {
    return;
  }
  if (!game_session->is_finished) {
    for (int i = 0; i < MAX_PLAYERS_PER_GAME; i++) {
      game_session->player_seen_state[i] = false;
    }
  }
  game_session->is_finished = true;
  for (int i = 0; i < MAX_PLAYERS_PER_GAME; i++) {
    if (game_session->players[i] == NULL) {
      continue;
    }
    if (!game_session->player_seen_state[i]) {
      return;
    }
  }
  for (int i = 0; i < MAX_PLAYERS_PER_GAME; i++) {
    session_t *session = game_session->players[i];
    if (session == NULL) {
      continue;
    }
    session->game_session = NULL;
  }
  if (game_session->game != NULL) {
    switch (game_session->game_type) {
      case GAME_TYPE_EMPTY:
        break;
      case GAME_TYPE_TICTACTOE:
        tictactoe_deinit(game_session);
        break;
    }
  }
  game_session->removable = true;
}

void try_start_game_session(game_session_t *game_session) {
  for (int i = 0; i < MAX_PLAYERS_PER_GAME; i++) {
    if (game_session->players[i] == NULL) {
      return;
    }
  }
  game_session->is_active = true;
```

```c
  switch (game_session->game_type) {
    case GAME_TYPE_EMPTY:
      log_message(LOG_LEVEL_ERROR, "sessions", "Attempting to start
GAME_TYPE_EMPTY");
      break;
    case GAME_TYPE_TICTACTOE:
      tictactoe_init(game_session);
      break;
  }
}
// src/sessions.h
#ifndef SESSIONS_H
#define SESSIONS_H

#include <time.h>
#include <stdbool.h>

#define USERNAME_MAX_LENGTH 256
#define MAX_PLAYERS_PER_GAME 2
#define MAX_SESSION_INACTIVE_TIME 300

typedef enum {
  GAME_TYPE_EMPTY,
  GAME_TYPE_TICTACTOE,
} game_type_t;

typedef struct {
  bool is_active;
  bool is_finished;
  void *players[MAX_PLAYERS_PER_GAME];
  bool player_seen_state[MAX_PLAYERS_PER_GAME];
  game_type_t game_type;
  void *game;
  bool removable;
  void *next_game_session;
} game_session_t;

typedef struct {
  bool is_active;
  int id;
  char username[USERNAME_MAX_LENGTH + 1];
  game_session_t *game_session;
  int player_index;
  time_t last_active;
  void *next_session;
} session_t;

typedef struct {
  game_session_t *game_sessions;
  session_t *sessions;
} session_manager_t;

char *game_type_to_str(game_type_t game_type);
```

```
game_type_t str_to_game_type(char *string);

void init_session_manager(session_manager_t *session_manager);

bool validate_username(char *username);

void update_session(session_t *session);

session_t *new_session(session_manager_t *session_manager, char *username);

session_t *find_session_by_id(session_manager_t *session_manager, int id);

void session_find_game(session_manager_t *session_manager, session_t *session,
game_type_t game_type);

void clean_sessions(session_manager_t *session_manager);

void disconnect_from_game_session(session_t *session);

void end_game_session(game_session_t *game_session);

void try_start_game_session(game_session_t *game_session);

#endif
// src/tictactoe.c
#include <stdio.h>
#include <stdlib.h>
#include "tictactoe.h"
#include "log.h"
#include "http.h"

void tictactoe_init(game_session_t *game_session) {
  log_message(LOG_LEVEL_INFO, "tictactoe", "Creating new game");
  tictactoe_game_t *game = malloc(sizeof(tictactoe_game_t));
  if (game == NULL) {
    log_message(LOG_LEVEL_ERROR, "tictactoe", "Failed allocating
tictactoe_game_t");
    return;
  }
  game->active_player_index = 0;
  game->winner = -1;
  for (int i = 0; i < 9; i++) {
    game->cells[i] = TICTACTOE_CELL_EMPTY;
  }
  game_session->game = game;
}

void tictactoe_deinit(game_session_t *game_session) {
  log_message(LOG_LEVEL_INFO, "tictactoe", "Deinitializing game");
  if (game_session->game == NULL) {
    return;
  }
  free(game_session->game);
}

void tictactoe_write_json(game_session_t *game_session, json_writer_t
*json_writer) {
  tictactoe_game_t *game = game_session->game;
  json_start_dict(json_writer);
  json_write_key(json_writer, "active_player_index");
  json_write_number(json_writer, game->active_player_index);
  json_write_key(json_writer, "winner_index");
  json_write_number(json_writer, game->winner);
  json_write_key(json_writer, "cells");
  json_start_array(json_writer);
  for (int i = 0; i < 9; i++) {
    char *value;
    switch (game->cells[i]) {
      case TICTACTOE_CELL_EMPTY:
        value = " ";
        break;
      case TICTACTOE_CELL_X:
        value = "X";
        break;
      case TICTACTOE_CELL_O:
        value = "O";
        break;
    }
    json_write_string(json_writer, value);
  }
  json_stop_array(json_writer);
  json_stop_dict(json_writer);
}

tictactoe_cell_t tictactoe_check_line(tictactoe_game_t *game, int start, int
step) {
  tictactoe_cell_t first_cell = game->cells[start];
  if (first_cell == TICTACTOE_CELL_EMPTY) {
    return TICTACTOE_CELL_EMPTY;
  }
  for (int i = 1; i < 3; i++) {
    tictactoe_cell_t cell = game->cells[start + i * step];
    if (cell != first_cell) {
      return TICTACTOE_CELL_EMPTY;
    }
  }
  return first_cell;
}

tictactoe_cell_t tictactoe_check_all_lines(tictactoe_game_t *game) {
  tictactoe_cell_t result = tictactoe_check_line(game, 0, 4);
  if (result != TICTACTOE_CELL_EMPTY) {
    return result;
  }
  result = tictactoe_check_line(game, 2, 2);
  if (result != TICTACTOE_CELL_EMPTY) {
    return result;
  }
  for (int i = 0; i < 3; i++) {
    result = tictactoe_check_line(game, i * 3, 1);
    if (result != TICTACTOE_CELL_EMPTY) {
      return result;
    }
    result = tictactoe_check_line(game, i, 3);
    if (result != TICTACTOE_CELL_EMPTY) {
      return result;
    }
  }
  return TICTACTOE_CELL_EMPTY;
}

void tictactoe_try_finish(game_session_t *game_session) {
  tictactoe_game_t *game = game_session->game;
  tictactoe_cell_t winner_cell = tictactoe_check_all_lines(game);
  if (winner_cell == TICTACTOE_CELL_X) {
    game->winner = 0;
  } else if (winner_cell == TICTACTOE_CELL_O) {
    game->winner = 1;
  }
  if (winner_cell != TICTACTOE_CELL_EMPTY) {
    end_game_session(game_session);
    return;
  }
  for (int i = 0; i < 9; i++) {
    if (game->cells[i] == TICTACTOE_CELL_EMPTY) {
      return;
    }
  }
  end_game_session(game_session);
}

void tictactoe_handle_request(game_session_t *game_session, session_t *session,
http_server_t *http_server) {
  char *cell_str = get_http_parameter(http_server, "cell");
  if (cell_str == NULL) {
    return;
  }
  int cell = atoi(cell_str);
  if (cell < 0 || cell >= 9) {
    log_message(LOG_LEVEL_INFO, "tictactoe", "Invalid move cell=%d", cell);
  }
  tictactoe_game_t *game = game_session->game;
  if (game->active_player_index != session->player_index) {
    return;
  }
  if (game->cells[cell] != TICTACTOE_CELL_EMPTY) {
    return;
  }
  game->cells[cell] = session->player_index == 1 ? TICTACTOE_CELL_O :
TICTACTOE_CELL_X;
  game->active_player_index = (game->active_player_index + 1) % 2;
  tictactoe_try_finish(game_session);
}

void tictactoe_handle_disconnect(game_session_t *game_session, session_t
*session) {
  if (game_session == NULL || game_session->game == NULL || session == NULL) {
    return;
  }
  tictactoe_game_t *game = game_session->game;
  game->winner = 1 - session->player_index;
}
```

```
// src/tictactoe.h
#ifndef TICTACTOE_H
#define TICTACTOE_H

#include "sessions.h"
#include "json_writer.h"

typedef enum {
  TICTACTOE_CELL_EMPTY,
  TICTACTOE_CELL_X,
  TICTACTOE_CELL_O,
} tictactoe_cell_t;

typedef struct {
  int active_player_index;
  int winner;
  tictactoe_cell_t cells[9];
} tictactoe_game_t;

void tictactoe_init(game_session_t *game_session);

void tictactoe_deinit(game_session_t *game_session);

void tictactoe_write_json(game_session_t *game_session, json_writer_t
*json_writer);

void tictactoe_handle_request(game_session_t *game_session, session_t *session,
http_server_t *http_server);

void tictactoe_handle_disconnect(game_session_t *game_session, session_t
*session);

#endif
```

```
// static/auth-background.js
const canvas = document.getElementById("background-canv");
const ctx = canvas.getContext("2d");

const CONFIG = {
  particleCount: 50,
  minSize: 8,
  maxSize: 32,
  minSpeed: 0.01,
  maxSpeed: 0.15,
  colors: [
    "#E94138", "#FFB520", "#FFFFFB"
  ],
  lineWidth: 4,
  background: "#424CD4",
};

function rand(min, max) {
  return Math.random() * (max - min) + min;
}
function randInt(min, max) {
  return Math.floor(Math.random() * (max - min + 1)) + min;
}
class Particle {
  constructor(width, height) {
    this.reset(width, height, true);
  }
  reset(width, height, init = false) {
    this.type = Math.random() < 0.5 ? "cross" : "circle";
    this.radius = rand(CONFIG.minSize, CONFIG.maxSize);
    this.x = rand(0, width);
    this.y = rand(0, height);
    const speed = rand(CONFIG.minSpeed, CONFIG.maxSpeed);
    const angle = rand(0, Math.PI * 2);
    this.vx = Math.cos(angle) * speed;
    this.vy = Math.sin(angle) * speed;
    this.color = CONFIG.colors[randInt(0, CONFIG.colors.length - 1)];
    this.rotation = rand(0, Math.PI * 2);
    this.rotationSpeed = rand(-0.003, 0.003);
  }
  update(width, height) {
    this.x += this.vx;
    this.y += this.vy;
    this.rotation += this.rotationSpeed;
    if (this.x < -2 * this.radius) {
      this.x = width + 2 * this.radius;
    }
    if (this.x > width + 2 * this.radius) {
      this.x = -2 * this.radius;
    }
    if (this.y < -2 * this.radius) {
      this.y = height + 2 * this.radius;
    }
    if (this.y > height + 2 * this.radius) {
      this.y = -2 * this.radius;
    }
  }
  draw(ctx) {
    ctx.save();
    ctx.lineWidth = Math.max(1, CONFIG.lineWidth * (this.radius / 8));
    if (this.type === "circle") {
      ctx.beginPath();
      ctx.strokeStyle = this.color;
      ctx.arc(this.x, this.y, this.radius, 0, Math.PI * 2);
      ctx.stroke();
    } else {
      ctx.translate(this.x, this.y);
      ctx.rotate(this.rotation);
      ctx.lineCap = "round";
      ctx.strokeStyle = this.color;
      const r = this.radius;
      ctx.beginPath();
      ctx.moveTo(-r, 0);
      ctx.lineTo(r, 0);
      ctx.moveTo(0, -r);
      ctx.lineTo(0, r);
      ctx.stroke();
    }
    ctx.restore();
  }
}
class ParticleSystem {
  constructor(canvas, ctx, count) {
    this.canvas = canvas;
    this.ctx = ctx;
    this.width = window.innerWidth;
    this.height = window.innerHeight;
    this.particles = [];
    this.count = count;
    this._createParticles();
  }
  _createParticles() {
    this.particles.length = 0;
    for (let i = 0; i < this.count; i++) {
      this.particles.push(new Particle(this.width, this.height));
    }
  }
  resize(width, height) {
    this.width = width;
    this.height = height;
    for (const p of this.particles) {
      p.x = Math.min(Math.max(p.x, -p.radius), width + p.radius);
      p.y = Math.min(Math.max(p.y, -p.radius), height + p.radius);
    }
  }
  updateAndDraw() {
    this.ctx.fillStyle = CONFIG.background;
    this.ctx.fillRect(0, 0, this.width, this.height);
    for (const p of this.particles) {
      p.update(this.width, this.height);
      p.draw(this.ctx);
    }
  }
}
const system = new ParticleSystem(canvas, ctx, CONFIG.particleCount);
function animate() {
  system.updateAndDraw();
  requestAnimationFrame(animate);
}
function setCanvasSizeToDisplaySize() {
  const w = window.innerWidth;
  const h = window.innerHeight;
  if (canvas.width !== w || canvas.height !== h) {
    canvas.width = w;
    canvas.height = h;
    system.resize(w, h);
  }
}
window.addEventListener("resize", setCanvasSizeToDisplaySize);
setCanvasSizeToDisplaySize();
animate();
// static/game.js
const COLORS = {
  cross: "#E94138",
  circle: "#FFB520",
  outline: "#B8B8D1",
};
const ANIMATION_STEP = 0.003;
const canv = document.getElementById("canv");
const ctx = canv.getContext("2d");
const statusDiv = document.getElementById("status");
const modalExit = document.getElementById("modal-exit");
const exitButton = document.getElementById("exit-button");
const splashElem = document.getElementById("splash");
const playersElem = document.getElementById("players");
const spinner = document.getElementById("spinner");
const params = new URLSearchParams(window.location.search);
const id = params.get("id");
const gameType = params.get("gameType");
let state = { active_player_index: 0, cells: Array.from({ length: 9 }).map((_)
=> " ") };

function showThisGuide() {
  showModalGuide("/static/" + gameType + "-guide.html");
}

async function disconnectFollowLink(url) {
  if (url == undefined) {
    url = "/"
  }
  modalBg.classList.remove("hidden");
  modalExit.classList.remove("hidden");
  setTimeout(
    () => {
      modalBg.classList.remove("modal-hidden");
      modalExit.classList.remove("modal-hidden");
    },
    20
  );
  exitButton.onclick = () => {
    fetch("/disconnect?id=" + id).then(() =>
      window.open(url + "?id=" + id, "_self")
    )
  };
}

function easingFunction(x) {
  if (x > 1) {
    return 1;
  }
  if (x < 0) {
    return 0;
  }
  return (1 - Math.cos(Math.PI * x)) / 2;
}

class Sprite {
  constructor(type) {
    this.type = type;
    this.progress = 0;
  }

  update(deltaTime) {
    this.progress += ANIMATION_STEP * deltaTime;
  }
}

class Drawer {
  constructor(canv, ctx, statusDiv, splashElem, playersElem, spinner) {
    this.canv = canv;
    this.ctx = ctx;
    this.statusDiv = statusDiv;
    this.splashElem = splashElem;
    this.playersElem = playersElem;
    this.spinner = spinner;
    this.playerIndex = -1;
    this.cells = Array.from({ length: 9 }).map((_) => " ");
    this.sprites = Array.from({ length: 9 }).map((_) => null);
    this.lastTime = null;
    this.finished = false;
  }

  splash(text) {
    this.splashElem.innerText = text;
    this.splashElem.classList.remove("hidden");
    const keyframes = [
      { transform: 'scale(0)' },
      { transform: 'scale(1)' },
    ];
    const options = {
      duration: 300,
      easing: "cubic-bezier(0.68, -0.55, 0.265, 1.55)",
      iterations: 1,
    };
    this.splashElem.animate(keyframes, options);
  }

  update(response) {
    if (this.finished) {
      return;
    }
    this.playersElem.innerHTML = response.player_names.map((x) => {
      if (x == null) {
        return "<div class='unknown'>???</div>";
      }
      return "<div>" + x + "</div>";
    }).join("");
    const state = response.state;
    this.playerIndex = response.your_index;
    if (response.status == "game_active") {
      this.spinner.classList.add("hidden");
      this.statusDiv.innerText = state.active_player_index ==
this.playerIndex ? "Your turn" : "";
    }
    if (response.status == "game_finished") {
      this.finished = true;
      setTimeout(() => {
        window.open("/?id=" + id, "_self")
      }, 2000);
      if (state.winner_index == this.playerIndex) {
        this.splash("You win!");
      } else if (state.winner_index == 1 - this.playerIndex) {
        this.splash("You lost!");
      } else {
        this.splash("Draw!");
      }
    }
    const cells = state.cells;
    for (let i = 0; i < 9; i++) {
      if (cells[i] != this.cells[i]) {
        this.sprites[i] = new Sprite(cells[i]);
        this.cells[i] = cells[i];
      }
    }
  }

  drawGrid(n) {
    const cellWidth = this.canv.width / n;
    this.ctx.strokeStyle = COLORS.outline;
    this.ctx.lineCap = "round";
    this.ctx.lineWidth = 5.0;
    for (let i = 1; i < n; i++) {
      this.ctx.beginPath();
      this.ctx.moveTo(i * cellWidth, 5);
      this.ctx.lineTo(i * cellWidth, n * cellWidth - 5);
      this.ctx.stroke();
      this.ctx.beginPath();
      this.ctx.moveTo(5, i * cellWidth);
      this.ctx.lineTo(n * cellWidth - 5, i * cellWidth);
      this.ctx.stroke();
    }
  }

  drawSprite(sprite, x, y, size) {
    if (sprite == null) {
      return;
    }
    size *= 0.2;
    this.ctx.save();
    this.ctx.translate(x, y);
    this.ctx.lineCap = "round";
    this.ctx.lineWidth = 5.0;
    if (sprite.type == "X") {
      const p1 = easingFunction(sprite.progress / 0.8);
      if (p1 > 0) {
        this.ctx.strokeStyle = COLORS.cross;
        this.ctx.beginPath();
        this.ctx.moveTo(-size, -size);
        this.ctx.lineTo(-size + 2 * p1 * size, -size + 2 * p1 * size);
        this.ctx.stroke();
      }
      const p2 = easingFunction((sprite.progress - 0.2) / 0.8);
      if (p2 > 0) {
        this.ctx.beginPath();
        this.ctx.moveTo(size, -size);
        this.ctx.lineTo(size - 2 * p2 * size, -size + 2 * p2 * size);
        this.ctx.stroke();
      }
    } else if (sprite.type == "O") {
      this.ctx.strokeStyle = COLORS.circle;
      this.ctx.rotate(-1);
      this.ctx.beginPath();
      ctx.arc(0, 0, size, 0, easingFunction(sprite.progress) * Math.PI * 2);
      this.ctx.stroke();
    }
    this.ctx.restore();
  }

  draw(time) {
    let deltaTime = null;
    if (this.lastTime == null) {
      deltaTime = 0;
    } else {
      deltaTime = time - this.lastTime;
    }
    this.lastTime = time;
    this.ctx.clearRect(0, 0, this.canv.width, this.canv.height);
    this.drawGrid(3);
    const cellWidth = this.canv.width / 3;
    for (let i = 0; i < 9; i++) {
      const x = (i % 3);
      const y = Math.floor(i / 3);
      this.drawSprite(this.sprites[i], (x + 0.5) * cellWidth, (y + 0.5) *
cellWidth, cellWidth);
      if (this.sprites[i] != null) {
        this.sprites[i].update(deltaTime);
      }
    }
  }
}

const drawer = new Drawer(canv, ctx, statusDiv, splashElem, playersElem,
spinner);

function draw(time) {
  drawer.draw(time);
  requestAnimationFrame(draw);
}

draw(0);

async function update(cell) {
  console.log(cell);
  let path = "/gameRequest?id=" + id;
  if (cell != null) {
    path += "&cell=" + cell
  }
  const response = await fetch(path);
  if (!response.ok) {
    return;
  }
  const result = await response.json();
  console.log(result);
  if (result.state) {
    state = result.state;
  }
  // statusDiv.innerText = result.status;
  drawer.update(result);
}

update();
setInterval(() => update(), 500);

canv.addEventListener("click", (e) => {
  const x = Math.floor(3 * (e.clientX - canv.getBoundingClientRect().left) /
canv.width);
  const y = Math.floor(3 * (e.clientY - canv.getBoundingClientRect().top) /
canv.height);
  const cell = x + 3 * y;
  update(cell);
});
// static/pages-general.js
const modalBg = document.getElementById("modal-bg");
const modalGuide = document.getElementById("modal-guide");
const iframe = document.getElementById("iframe");
function showModalGuide(url) {
  modalBg.classList.remove("hidden");
  modalGuide.classList.remove("hidden");
  setTimeout(
    () => {
      modalBg.classList.remove("modal-hidden");
      modalGuide.classList.remove("modal-hidden");
    },
    20
  );
  iframe.src = url;
}
function hideModal() {
  modalBg.classList.add("modal-hidden");
  Array.from(document.getElementsByClassName("modal")).map((x) =>
x.classList.add("modal-hidden"));
  setTimeout(
    () => {
      modalBg.classList.add("hidden");
      modalGuide.classList.add("hidden");
    },
    400
  );
}
function followLink(link) {
  window.open(link + window.location.search, "_self");
}
function joinGame(gameId) {
  const params = new URLSearchParams(window.location.search);
  params.set("gameId", gameId);
  const newUrl = "/joinGame?" + params.toString();
  window.open(newUrl, "_self");
}
```