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Distributed Systems

CA1

Rachel’s Shoe Shop

<https://github.com/rachelncirl/retail>

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# Project Proposal

**Option 4**. Retail (Personalized shopping recommendations, automated checkout,

inventory tracking)

## Rachel’s Shoe Shop

The application will provide an online shopping experience for shoes. It will be made up of a number of services to provide an end-to-end shopping experience:

### **ListShoes**

Returns details on all shoes currently stocked by Rachel’s Shoe shop.

### GetPrice

Returns the price of a specific shoe.

### ShoppingCart

Will add a specific shoe to the user’s shopping cart.

### ViewCart

Will return the list of shoes in the user’s shopping cart.

### Purchase

Will purchase the shoes in the user's shopping cart.

### Chat

Help facility if the user has any questions.

Each user of the application will need a unique identifier to keep track of items added to their personal shopping cart. When the user wishes to purchase a pair or multiple pairs of shoes, the add each pair to the shopping cart. The user can view the contents of their shopping cart. When the user chooses to Purchase, the items in their shopping cart are processed, and the shopping cart contents is reverted to empty.

# Initial Service Definition

## ListShoes

This is a server rpc service. No parameters are passed in the request. It will return a stream of ProductResponse objects, which will represent the shoes stocked by the shop. Each ProductResponse object will return the brand and the price of the shoe.

## GetPrice

This is a unary rpc service. The user will provide the brand of the shoe which will be passed as the only parameter in the ProductRequest. The service will return a single ProductResponse object which will contain the brand and the price of the shoe.

## ShoppingCart

This is a client rpc service which will pass in a stream of ShoppingCartRequest objects. The user will add one or more items to their shopping cart, and the content of the cart will be streamed to the server. Each ShoppingCartRequest object will contain the brand, size, color and quantity added to the cart. Once all items have been added to the cart, a message will be returned to indicate success, along with a total item count of objects added to the shopping cart.

## ViewCart

This is a server rpc call. The cartId will be passed in from the client in the ViewCartRequest, and the server will return a stream of all items in the cart in the ViewCartResponse.

## Purchase

This is unary rpc call. The cartId will be passed in from the client in the PurchaseRequest, and the server will return the PurchaseResponse which will contain a message with the purchase details. The user’s cart will also be cleared after the contents have been purchased.

## Chat

This is a bidirectional rpc call which will enable the user to engage with the customer service team if any issues are encountered while shopping.

# Initial Shop Proto Definition

syntax = "proto3";

package shop;

service ShoeShop{

//Unary Rpc

rpc GetPrice(ProductRequest) returns (ProductResponse);

rpc Purchase(PurchaseRequest) returns (PurchaseResponse);

//Server Rpc

rpc ListShoes(Empty) returns (stream ProductResponse);

rpc ViewCart(Empty) returns (stream ViewCartResponse);

//Client rpc

rpc ShoppingCart(stream ShoppingCartRequest) returns (ShoppingCartResponse);

//Bidirectional

rpc Chat(stream ChatMessage) returns (stream ChatMessage);

}

message ProductRequest{

string brand = 1;

}

message ProductResponse{

string brand = 1;

uint32 price = 2;

}

message ViewCartRequest {

string cartId = 1;

}

message ViewCartResponse {

string brand = 1;

uint32 size = 2;

string color = 3;

uint32 quantity = 4;

}

message PurchaseRequest {

string cartId = 1;

}

message PurchaseResponse {

string message = 1;

}

message Empty{}

message ShoppingCartRequest {

string brand = 1;

string color = 2;

string size = 3;

uint32 quantity = 4;

}

message ShoppingCartResponse {

string message = 1;

}

message ChatMessage{

string user = 1;

string message = 2;

}

# Initial User Interface

The user interface will be a single web page that will render all the services outlined in the initial proto definition.

BootStrap5 will be used to provide the look and feel of the website.

The top of the page will be a title banner for Rachel’s shoe shop.

Products will be listed on the left-hand side of the page, with the shopping cart and purchase capability to the right.

It is also proposed to have a chat button which will open a chat page, or a popup modal.

Also, if time permits, there will be a discount service, which will allow the user to apply a discount to their cart if they have a valid code.

A simple wireframe of the web page would be as follows:

A screenshot of a web page

Description automatically generated

The user should be able to scroll through the shoes offered, and click add to put them in the shopping cart.

The user should then be able to purchase the contents of the shopping cart

# Initial Server Side Services

The initial server-side services would be similar to the mobile shop example.

As a starting point, I created a server.js which contains all the services outlined in the proposal:

// Hard coded product list

const shoes = [

  { brand: "New Balance", price: 120},

  { brand: "Dr Martens", price: 150},

  { brand: "Adidas", price: 100},

  { brand: "Converse", price: 110},

  { brand: "Birkenstock", price: 90}

];

// Shopping cart contents

const cartItems = [];

// Unary

function GetPrice(call, callback){

  const shoe = shoes.find(s => s.brand === call.request.brand);

  if(shoe){

    callback(null, { brand: shoe.brand, price: shoe.price});

  }else{

      callback(null, { brand: shoe.brand, price: 0});

  }

}

// Server streaming

function ListShoes(call){

  shoes.forEach(shoe => call.write(shoe));

  call.end();

}

// Client rpc

function ShoppingCart(call, callback){

  let totalItems = 0;

  call.on("data", (order) => {

    totalItems += order.quantity;

    cartItems.push(order);

    console.log(`${cartItems.length} items in the Cart`)

    cartItems.forEach(item => console.log(item));

  })

  call.on("end", () => {

    callback(null, {message: `${totalItems} items added to Cart`});

  })

}

//server streaming

function ViewCart(call){

  cartItems.forEach(item => call.write(item));

  call.end();

}

//Unary

function Purchase(call, callback){

  let purchasedItems = cartItems.length;

  cartItems.length = 0;

  callback(null, {message: `${purchasedItems} items purchased`});

}

//Bidirectional

function Chat(call) {

  console.log("TODO");

  call.end();

}

const server = new grpc.Server();

server.addService(shopProto.ShoeShop.service, {

  GetPrice, ListShoes, ShoppingCart, ViewCart, Purchase, Chat

});

const PORT = '50051';

server.bindAsync(`0.0.0.0:${PORT}`, grpc.ServerCredentials.createInsecure(), (error, port)=>{

  if(error){

    console.error(error);

    return;

  }

  console.log(`Server running at localhost:${PORT}`);

});

# Initial Client Side Service

Similarly, the starting point for the client service was to use the example from our lectures.

After modification for Rachel’s Shoe shop it became:

// Unary

function getPrice() {

  const brand = readlineSync.question("Enter mobile brand: ");

  console.log(brand);

  client.GetPrice({ brand }, (error, response) => {

    if (error) {

      console.log(error);

    }

    else {

      console.log(`brand: ${response.brand}, Price: ${response.price}`);

    }

  });

}

// Unary

function purchase() {

  let cartId = 1;

  client.Purchase({ cartId }, (error, response) => {

    if (error) {

      console.log(error);

    }

    else {

      console.log(`${response.message}`);

    }

  });

}

// Server rpc

function listShoes() {

  const call = client.ListShoes({});

  call.on("data", (shop) => {

    console.log(`brand: ${shop.brand}, Price: ${shop.price}`)

  });

  call.on("end", () => console.log("End of shoe list"));

}

// Client rpc

function shoppingCart() {

  const call = client.ShoppingCart((error, respomse) => {

    if (error) console.error(error);

    else console.log(respomse.message);

  });

  let moreItems = true;

  while (moreItems) {

    const brand = readlineSync.question("Enter Shoe brand: ");

    const size = parseInt(readlineSync.question("Enter size: "));

    const color = readlineSync.question("Enter color: ");

    const quantity = parseInt(readlineSync.question("Enter quantity: "));

    call.write({ brand, size, color, quantity });

    moreItems = readlineSync.keyInYN("Add another item to the Shopping Cart?");

  }

  call.end();

}

// Server rpc

function viewCartContents() {

  const call = client.ViewCart({});

  call.on("data", (cart) => {

    console.log(`Brand: ${cart.brand}, Size: ${cart.size}, Color: ${cart.color}, Quantity: ${cart.quantity}`)

  });

  call.on("end", () => console.log("End of Cart Items list"));

}

// Bidirectional

function chat() {

  console.log("TODO");

}

function main() {

  console.log("\n1. Get Shoe Price");

  console.log("2. List Shoes");

  console.log("3. Add to Cart");

  console.log("4. Show Cart Contents");

  console.log("5. Purchase");

  console.log("6. Chat with support");

  const choice = parseInt(readlineSync.question("Choose an option: "))

  switch (choice) {

    case 1:

      getPrice();

      break;

    case 2:

      listShoes();

      break;

    case 3:

      shoppingCart();

      break;

    case 4:

      viewCartContents();

      break;

    case 5:

      purchase();

      break;

    case 6:

      chat();

      break;

    default:

      console.log("Invalid choice");

  }

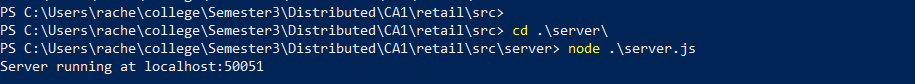
}

main();

# Initial Command Line Execution

With the basics of the services in place, it was now possible to run the services from the cli:

**Server**



**Client**

A screen shot of a computer program

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# Initial Static Webpage

With the basic services in place, I proceeded to develop the user interface as a static proof of concept.

Using simple bootstrap forms, buttons and layouts, the wiremock design from earlier was put in place.

A screenshot of a computer screen

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# Git Hub Integration

At this point, the github repository was created for the retail application

<https://github.com/rachelncirl/retail>

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Description automatically generated

All source code for the application was placed under the src folder, with general project documentation stored at the root level.

# Service Extraction

Following a meeting with my lecturer, the breakdown of the service became a lot clearer. The single shop proto file needed to be broken down into individual services – rather than a list of functions provided by one service.

## Refined Services

The following services were identified:

### ProductService

ListShoes - would return a list of all products offered by Rachel’s Shoe Shop.

GetPrice - would return the price of each individual product.

### ShoppingCartService

AddToCart – Produsts are added to the shopping cart.

ViewCartContents – Display the contents of the shopping cart.

Purchase – Checkout and clear the shopping cart contents.

### ChatService

Chat – Allows users to chat about products offered by the shop.

### DiscoveryService

Discovery – Allows the services offered by the shop to be discovered.

### DiscountService

Discount Service - Apply a code to the shopping cart that would reprice the total. This may be a standalone service, or it may be better suited to integration into the ShoppingCartService.

## Refined Protos

### Product Proto

syntax = "proto3";

package product;

service ProductService {

//Unary Rpc

rpc GetPrice(ProductRequest) returns (ProductResponse);

//Server Rpc

rpc ListShoes(Empty) returns (stream ProductResponse);

}

message ProductRequest{

string brand = 1;

}

message ProductResponse{

string brand = 1;

uint32 price = 2;

}

### Cart Proto

syntax = "proto3";

package cart;

service CartService {

//Unary Rpc

rpc Purchase(PurchaseRequest) returns (PurchaseResponse);

//Server Rpc

rpc ViewCart(Empty) returns (stream ViewCartResponse);

//Client rpc

rpc ShoppingCart(stream ShoppingCartRequest) returns (ShoppingCartResponse);

}

message ViewCartResponse {

string brand = 1;

uint32 size = 2;

string color = 3;

uint32 quantity = 4;

}

message PurchaseRequest {

string cartId = 1;

}

message PurchaseResponse {

string message = 1;

}

message Empty{}

message ShoppingCartRequest {

string brand = 1;

string color = 2;

string size = 3;

uint32 quantity = 4;

}

message ShoppingCartResponse {

string message = 1;

}

### Chat Proto

syntax = "proto3";

package chat;

service ChatService {

rpc sendMessage(stream ChatMessage) returns (stream ChatMessage) {}

}

message ChatMessage {

string name = 1;

string message = 2;

}

### Discovery Proto

// TODO

### Discount Proto

// TODO

# Integrating with Express

The next task was to start a web server and render the static purchase page.

The purchase.html file was moved to a public folder under src, which made it accessible to the express web server.

A simple express app.js was used to start the webserver

const express = require('express');

const http = require('http');

const path = require('path');

const app = express();

const server = http.createServer(app);

app.use(express.static(path.join(\_\_dirname, '../public')));

app.get('/', (req, res) => {

    res.sendFile(path.join(\_\_dirname, '../public', 'purchase.html'));

});

server.listen(50050, () => {

    console.log('Homepage is running');

});

This allowed the page to be rendered under localhost



A screenshot of a computer

Description automatically generated

# Creating Chat Service

The chat service from our lectures would again be the basis for the chat service for Rachels Shoe Shop.

The chat service would also use express, and display the chat.html content from the public folder when the /chat/ url is called.

Extracting the chat server code into its own server js file:

const express = require('express');

const socketIo = require('socket.io');

const http = require('http');

const path = require('path');

const app = express();

const server = http.createServer(app);

const io = socketIo(server);

let userCount = 1;

app.get('/chat/', (req, res) => {

    res.sendFile(path.join(\_\_dirname, '../public', 'chat.html'));

});

io.on('connection', (socket) => {

    console.log('A User is connected');

    const username = 'user' + userCount++;

    socket.emit('set username', username);

    console.log(username);

    socket.on('chat message', (msg) => {

        io.emit('chat message', {username, msg});

    });

    socket.on('disconnect', () => {

        console.log('user disconnected')

    });

});

server.listen(3000, () => {

    console.log('Server is running');

});

And the simple chat.html is as defined during class:

<!DOCTYPE html>

<html lang="en">

    <head>

        <meta charset="UTF-8"

        <meta name="viewport" content="width=device-width, initial-scale=1.0">

        <title> Chat </title>

        <style>

            body {

                font-family: Arial, Helvetica, sans-serif;

                margin: 0;

                padding: 0px;

                background-color: white;

            }

            #chat-container {

                width: 400px;

                margin: 0 auto;

                padding: 10px;

                background-color: white;

                border-radius: 5px;

                box-shadow: 0 0 10px rgba(0, 0, 0, 0.1);

            }

            #messages {

                height: 300px;

                overflow-y: scroll;

                border-bottom: 1px solid;

                padding: 10px;

                margin-bottom: 10px;

            }

            #message-input {

                width: calc(100% - 20px);

                padding: 10px;

                font-size: 16px;

                margin-top: 10px;

            }

            #send-button {

                padding: 10px, 15px;

                color: white;

                border: none;

                cursor: pointer;

                background-color: green;

            }

        </style>

    </head>

    <body>

        <div id="chat-container">

            <div id="messages"></div>

            <input type="text" id="messages-input" placeholder="Type your message..."/>

            <button id="send-button">Send</button>

        </div>

        <script src="/socket.io/socket.io.js"></script>

        <script>

            var socket = io();

            var username = '';

            var messages = document.getElementById('messages');

            var input = document.getElementById('messages-input');

            var sendButton = document.getElementById('send-button');

            socket.on('set username', function(name) {

                username = name;

                console.log('Your username is : ', username);

            });

            socket.on('chat message', function(data) {

                var messageElement = document.createElement('div');

                messageElement.textContent= data.username + ': ' + data.msg;

                messages.appendChild(messageElement);

                messages.scrollTop = messages.scrollHeight;

            });

            sendButton.addEventListener('click', function() {

                var message = input.value;

                if (message.trim()) {

                    socket.emit('chat message', message);

                    input.value = '';

                }

            });

        </script>

    </body>

</html>

To link the chat service into the purchase page, the chat button opens a modal that contains the chat.html in an embedded iFrame

<button type="button" class="btn btn-success w-100" data-bs-toggle="modal" data-bs-target="#chatModal">

    Chat

</button>

<!-- Chat Modal -->

<div class="modal fade" id="chatModal" tabindex="-1" aria-labelledby="chatModalLabel"

    aria-hidden="true">

    <div class="modal-dialog">

        <div class="modal-content">

            <!-- Modal Header -->

            <div class="modal-header">

                <h4 class="modal-title" id="chatModalLabel">Chat</h4>

                <button type="button" class="btn-close" data-bs-dismiss="modal"

                    aria-label="Close"></button>

            </div>

            <!-- Modal body -->

            <div class="modal-body">

                <div id="messages">

                    <div class="row">

                        <iframe id="responsive-iframe" src="http://localhost:3000/chat"></iframe>

                    </div>

                </div>

            </div>

        </div>

    </div>

</div>

Displaying the chat modals in the website:

A screenshot of a computer

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The structure of the project is also becoming more refined.

A screenshot of a computer

Description automatically generated

# Integrating Client and Server

At this point I needed to draw up the structure of the application to better understand the flow from the web page to the services and back.

A diagram of a website

Description automatically generated

Previously created purchase.html is now moved to index.html in the express web server.

Index.html will render static content, with the dynamic content rendered by the individual js files

The js files will call the client services defined in the app.js

App.js will call the server-side services.

The gRPC protos define the communication between the app.js and the server-side services.

# Integrating Product Service

Rather than presenting a static product list on the webpage, the product list will instead be loaded from the server-side product service as defined in the protos.

The static list was removed from the index.html, and replaced with a placeholder html object.

<!-- Products -->

<h4 class="text-center">Our Products</h4>

<div class="row">

<!-- Load the products from the server Node Js -->

      <table>

      <tbody id="productList"></tbody>

    </table>

</div>

<script src="/js/products.js"></script>

The placeholder productList object is overwritten on page load by the products.js content. When the page loads, the products.js will call the list api to fetch all the products:

// Retrieve Product List from Server on Page Load

document.addEventListener('DOMContentLoaded', function () {

    // Make an HTTP request to the Express server

    fetch(`/list`)

      .then(response => response.json())

      .then(data => {

        // Get the table body element where rows will be inserted

        const tableBody = document.getElementById("productList");

        // Loop through the JSON data and create rows

        data.forEach(shoe => {

          // HTML Code for each product will go here

        });

      })

      .catch(error => {

        console.error('Error:', error);

      });

  });

The list api is defined in the express server’s app.js

// Define an endpoint for listing shoes

app.get('/list', (req, res) => {

    // Create an array for gathering the shoe list

    let shoes = [];

    const call = products.ListShoes({});

    call.on("data", (shoe) => {

        // Add the shoe to the list

        shoes.push({

            id: shoe.id,

            brand: shoe.brand,

            price: shoe.price,

            description: shoe.description,

            image: shoe.image

        });

    });

    call.on("end", () => {

        // Return the list of shoes as a JSON response

        res.json(shoes);

    });

    call.on("error", (error) => {

        console.error(error);

        res.status(500).send('Error occurred while fetching shoes');

    });

});

Products.proto will define the contract for the ListShoes call

//Server Rpc

rpc ListShoes(Empty) returns (stream ProductResponse);

message ProductResponse{

string id = 1;

string brand = 2;

uint32 price = 3;

string description = 4;

string image = 5;

}

And the server-side products.js will implement the backend functionality

// Hardcoded product list

const shoes = [

  { id: "NB1", brand: "New Balance", price: 120, description: "530", image: "/images/newbalance.jpg" },

  { id: "DR1", brand: "Dr Martens", price: 200, description: "1460 Pascal", image: "/images/drmartens.jpg" },

  { id: "AD1", brand: "Adidas", price: 100, description: "VL Court 3.0", image: "/images/adidas.jpg" },

  { id: "CV1", brand: "Converse", price: 75, description: "All Star Hi", image: "/images/converse.jpg" },

  { id: "BK1", brand: "Birkenstock", price: 90, description: "Arizona", image: "/images/birkenstock.jpg" },

  { id: "CR1", brand: "Crocs", price: 90, description: "Classic Clog", image: "/images/crocs.jpg" }

];

// Server streaming - List all available shoes

function ListShoes(call) {

  shoes.forEach(shoe => call.write(shoe));

  call.end();

}

The Unary call to get the price of an individual product will be implemented using a similar flow, and will use the same ProductResponse object.

// Unary - Get the price of a shoe by its brand

function GetPrice(call, callback) {

  const shoe = shoes.find(s => s.brand === call.request.brand);

  if (shoe) {

    callback(null, { brand: shoe.brand, price: shoe.price });

  } else {

    callback(null, { brand: "", price: 0 });

  }

}

//Unary Rpc

rpc GetPrice(ProductRequest) returns (ProductResponse);

message ProductRequest{

string brand = 1;

}

# Integrating Cart Service

The Shopping Cart is designed to use Client RPC, with the stream of Products in the cart sent to the backed when the user makes a purchase

//Client rpc

rpc Purchase(stream PurchaseRequest) returns (PurchaseResponse);

message PurchaseRequest {

string id = 1;

string brand = 2;

uint32 price = 3;

string description = 4;

}

message PurchaseResponse {

string message = 1;

}

However, the cart needs to functional before it can be used to place an Order.

The shopping cart presents a further layer of complexity.

* The product service just presents a static list to the shopper. However, the shopping cart is dynamic. It will start out as empty, and change as person add, removes, clears or completes the purchase
* The cart contents is also specific to each person on the website, so a simple array to contain the cart contents will not work for multiple shoppers.

Similar to how a chat identifier was defined for each chat window, a unique user id will be assigned to each person shopping on the website.

When index.html is loaded, a script will run on the page to generate a unique user id for the shopper. This will be UI specific, so refreshing the page will result in a new user id and the contents of the cart will no longer be available to the shopper.

<script>

function generateUserId() {

// Random 9-character alphanumeric string

            return Math.random().toString(36).substr(2, 9);

    }

    window.userId = generateUserId();

    console.log("Generated User ID:", userId);

</script>

This userid can then be sent to server when adding items in the cart.

The cart will be stored on the server side using a Map, with the userId as the key, and an array of products as the value for each entry

// Map to hold user carts: key is userId, value is an array of cart items

const userCarts = new Map();

Five operations will be defined for the Cart Service

* AddToCart – Server Side Streaming as the request will send one item to the basket, but the server will return the updated cart contents for the UI to display
* RemoveFromCart – also Server Side Streaming as the request will send one item to be removed from the basket, and the server will return the updated cart contents for the UI to display with the item removed.
* GetCartConents – also Server Side Streming. The userId will be sent and the contents of the cart will be streamed back to the UI
* EmptyCart – Unary RPC – removes all the contents of the cart based on the userId.
* Purchase – Client RPC – the UI will stream the contents of the cart to complete the Order.

# Integrating Service Discovery

Todo

# Integrating Discount Service

Todo

# Integrating Inventory Service

Maybe it’s a Product item?