Computer Science Department

CCP6427: Cloud Engineering

Spring 2022

Design and development of a microservices-based application

Submission Deadline: 22/5/2022

Actual Submission Date: 22/5/2022

Student Registration Number/s
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Declaration: *I have completed and submitted this work by myself without assistance from or communication with another person either external or fellow student. I understand that not working on my own will be considered grounds for unfair means and will result in fail mark for this work and might invoke disciplinary actions. It is at the instructor's discretion to conduct an oral examination, if necessary, which will result in the award of the final grade for that particular piece of work.*

Report

File Conversion Microservices with Eureka

Abstract

Through the creation of a minimal file conversion service a microservices based system will be developed and thoroughly explained in documentation. The aim is to apply industry popular architectures and design patterns at a smaller scale. MVC and IoC will allow for the creation of flexible software that can meet current and adapt to future requirements. The Eureka service registry will coordinate communication between the client and conversion microservices. Due to the microservice architecture, HTTP communication becomes an essential stepping stone for de-coupling and adding scalability to the devised solution.

Keywords: Microservices, Springboot, Eureka Netflix, Model View Controller (MVC), Representational State Transfer (REST), Service Discovery Protocol (SDP), Hypertext Transfer Protocol (HTTP).

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1. Introduction

In this project the microservices software engineering architecture will be put in practice by using as an example a simple file conversion system. The system will be responsible for receiving plain text data, converting it to a pdf file and sending it back to the client application. By enforcing strict architectural and design requirements a future-proof solution aims to be constructed. This will be performed by using a Eureka service as a base which will then orchestrate communication across two microservices, one for client interaction and the other for the file conversion process. By operating under these conditions HTTP will be liberally used for communicational purposes and in order to use the REST API architecture. In this report, the system's specification, design, implementation, testing and project evaluation will all be discussed.

2. System Specification

The purpose of the developed system can be further elaborated upon by acknowledging its requirements in detail. The system has minimal business logic, but several architectural constraints require consideration. System requirements will be presented organised by type below.

Architectural system requirements:

- Microservices are designed independently of each other's implementation, communicating strictly through HTTP requests.
- The use of Model View Controller (MVC) software design pattern.
- Registration of microservices to Netflix Eureka service registry.

Functional system requirements:

- Users expect a pdf file to be generated containing user provided plain text.

3. Design

Harbouring understanding of the system specification allows for the creation of the software design. An appropriate representation to demonstrate the system's design is through the use of a software architecture diagram with service-to-service communication.

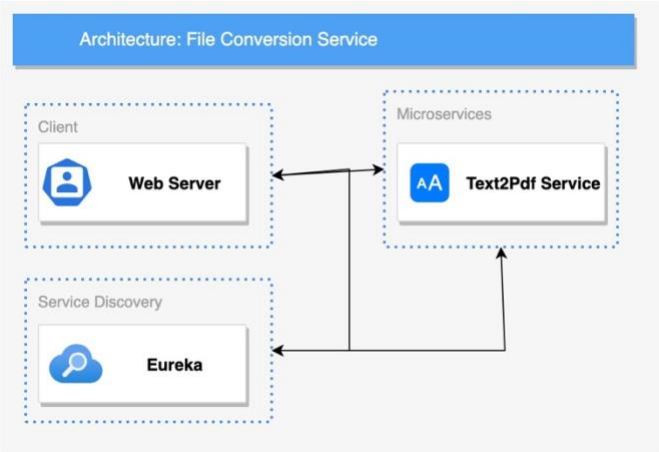


Figure 3.1 Architectural Design Diagram

Elaborating on the figure, clients and microservices have to register to the Eureka service discovery. Eureka will map services using the service discovery protocol to allow for communication between registered systems through the lookup operation. Lookup only requires the provision of the service name from the requestor. Eureka also monitors the state of each registered service in order to react to system failures during runtime.

The web server is responsible for providing to users a UI through which they can initiate the conversion process. The user sends a request containing the text that needs to be transformed and the relevant microservice (as routed by Eureka) is expected to serve the request. The text to pdf conversion service then receives a request for a conversion and performs the operation. Independent of a successful or erroneous outcome, a request is sent back to the web server with the file or exceptions that led to operation failure. Lastly, the web server reacts to the microservice response by serving the file or informing the user of errors that may have occurred.

By addressing the communication between the services and their purpose, an effort will be placed in explaining each service's design individually. This will be performed with a diagram depicting each service's package. Eureka will be excluded from the process due to its minimal setup and package footprint.

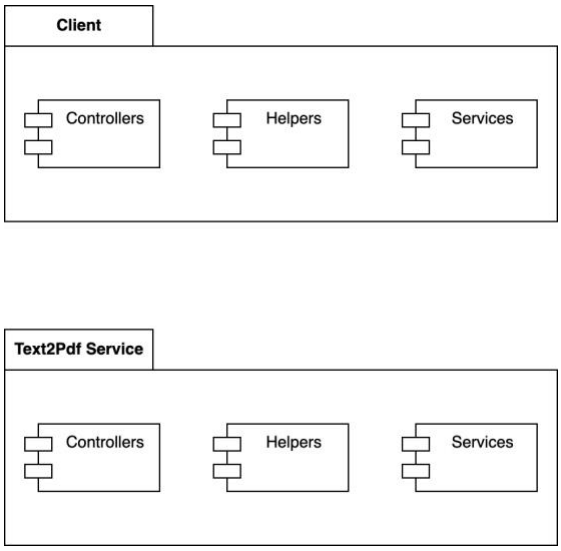


Figure 3.2 High-Level Design Diagram

There are three common elements amongst the client and the service. Controllers in both applications will be used to provide external access to the service using REST API's. These will contain minimal logic and delegate tasks retrieved from requests to other components. Services which will contain business logic are responsible of resolving requests. A notable exception is the client's services which are only responsible with contacting other microservices to solve requests. In this case, the text to pdf microservice receives a request at its controller from the client. The text to pdf application will then ask its services to handle the requested operation with business logic and return a response. The response is then received by the client's service which forwards it to the requestor through the controller. The text to pdf microservice may be accessed individually with requests, mainly intended for developers. In the case of an error, helpers will construct an exception stack trace that tracks exceptions across applications.

4. Implementation

The design of the software is further analysed at a lower level during implementation.

4.1 Sequential Analysis of Developed Classes

Following the sequence of events that lead to the generation of a pdf that is downloaded by a user, the process and relevant classes will be analysed in this section.

Controllers are present in both applications and the home controller is the same in both solutions. It leads to the index page of each application.

```
@Controller
public class HomeController {
```

Figure 4.1 Home Controller Code

```
    // Provide access to the index page.
    @RequestMapping("/")
    public String home() {
        return "index";
    }
}
```

In the client application, the user controller is responsible for receiving file conversion requests using the HTTP GET method. The appropriate service then handles this request. It also builds an appropriate error response if exceptions occur by issuing an operation to the exception response builder.

```
// Endpoints
// Expect a GET request.
@RequestMapping(method = RequestMethod.GET, value = "/txt2pdf")
public ResponseEntity<?> requestTextToPdf(String input) {
    // Send request through the service to the text to pdf microservice.
    try {
        return userResponderService.sendTextToPDFRequest(input);
    }
    // Catch exceptions from the user responder service and send a context-
full response.
    catch (Exception exception) {
        Map<String, String> body =
ExceptionResponseBuilder.buildExceptionResponse(exception.toString(),
UserController.class.getSimpleName());
        return
ResponseEntity.internalServerError().contentType(MediaType.APPLICATION_JSON).b
ody(body);
    }
}
```

Figure 4.2 User Controller Code

The exception response builder which is available in both applications shares the same logic. As a parameter any existing stack trace and the class name of the caller class are added to the response. A timestamp is also generated for this stack trace. Then as a whole a JSON structure is returned back to the controller in order to be sent as a response to the user.

```
public class ExceptionResponseBuilder {
    // Creates an exception response by assembling the body.
    public static Map<String, String> buildExceptionResponse(String content,
String creator){
        // Create JSON structure and add provided data
        Map<String, String> body = new HashMap<>();
        body.put("message", content);
        body.put("failed_at", creator);
        // Add Timestamp
        SimpleDateFormat dateFormat = new SimpleDateFormat("HH:mm:ss dd-MM-
yyyy");
        String timeStamp = dateFormat.format(new Date());
        body.put("timestamp", timeStamp);
        return body;
```

Figure 4.3 Exception Response Builder Code

```
    }
}
```

When the user responder service receives a conversion request, it will prepare a request to be sent to the text to pdf microservice. A specified response type is added as a header which is then assembled in the request using rest template. The exchange method is used to explicitly select the HTTP method to be used. If the request fails to be sent, an exception is forwarded to the user controller.

```
// Sends a request for a txt2pdf conversion to an external microservice with
the user input.
public ResponseEntity<?> sendTextToPDFRequest(String input) {
    try {
        // Setup Headers & URL
        String url = serviceUrl + "/txt2pdf?input={input}";
        HttpHeaders headers = new HttpHeaders();
        // Accept PDF media types responses

headers.setAccept(Collections.singletonList(MediaType.APPLICATION_PDF));
        HttpEntity<String> entity = new HttpEntity<>("body", headers);
        // Send a GET request to the text to pdf microservice's controller
with the user input.
        // Expect a byte[] format response.
        return restTemplate.exchange(url, HttpMethod.GET, entity,
byte[].class, input);
    } catch (Exception e) {
        throw new RuntimeException("Failed to send request to microservice,
cause: " + e);
    }
}
```

Figure 4.4 User Responder Service Code

On the text to pdf microservice once a request is received, it will instruct the text to pdf service to initiate the conversion. If the conversion succeeds, the controller will prepare the response headers and the pdf file name. Otherwise, the operation stops and an exception stack trace is attached to a new HTTP response (generated using exception response builder).

```
@RequestMapping(method = RequestMethod.GET, value = "/txt2pdf")
public ResponseEntity<?> serveTextToPdf(String input) {
    try {
        // Create pdf name based on the date and time (flexible for frequent
users, no duplicate names)
        DateFormat dateFormatter = new SimpleDateFormat("dd-MM-
yyyy:hh:mm:ss");
        String currentDateTime = dateFormatter.format(new Date());
        // Prepare Headers to open PDF on the client and allow downloading.
        String headerKey = "Content-Disposition";
        String headerValue = "inline; filename=pdf_" + currentDateTime +
".pdf";
        // Get converted result
        byte[] res;
        res = this.textToPDFService.convertTextToPdf(input);
        // Send a successful response
```

```
        return ResponseEntity.ok()
                .header(headerKey, headerValue)
                .contentType(MediaType.APPLICATION_PDF)
                .body(res);
    }
    // Catch exceptions from the text to pdf service and send a context-full
response.
    catch (Exception exception) {
        Map<String, String> body =
ExceptionResponseBuilder.buildExceptionResponse(exception.toString(),
```

Figure 4.5 Text to PDF Controller Code

```
TextToPdfController.class.getSimpleName());
        return
ResponseEntity.internalServerError().contentType(MediaType.APPLICATION_JSON).b
ody(body);
    }
}
```

The text to pdf service receives the request for conversion with the user input and performs the conversion. A byte array output stream and a document are required. The document comprises of a pdf writer and pdf document. In the case input was not provided in the request, sample text is used. A minimal format method is responsible for providing the necessary structure to the document. In case an exception occurs during the creation or writing of the pdf file, the operation stops and an exception is sent to the controller.

```
public byte[] convertTextToPdf(String input) {
    try {
        // Create Pdf
        final ByteArrayOutputStream output = new ByteArrayOutputStream();
        var writer = new PdfWriter(output);
        var pdf = new PdfDocument(writer);
        var document = new Document(pdf);
        // Provide some text if the input was null
        if (input == null)
            input = "Seems like no input was provided, here is some text for
you!";
        // Format
        format(document, input);
        // Finalize Operation
        document.close();
        return output.toByteArray();
    } catch (Exception e) {
        throw new RuntimeException("Exception thrown when converting text to
pdf at: " + e);
    }
}
// All pdf formatting should occur within. The document is preserved without a
return.
```

Figure 4.6 Text to PDF Conversion Code

The pdf format method at the moment only creates a paragraph using the user input, but the de-coupling allows for easier addition of new formatting requirements in the future.

```
private void format(Document document, String input) {
    document.add(new Paragraph(input));
}
```

Figure 4.7 PDF Formatting Code

4.2 Commitment to Richardson's Maturity Model

An evaluation of the REST API endpoints and HTTP requests will highlight the level of commitment to Richardson's maturity model.

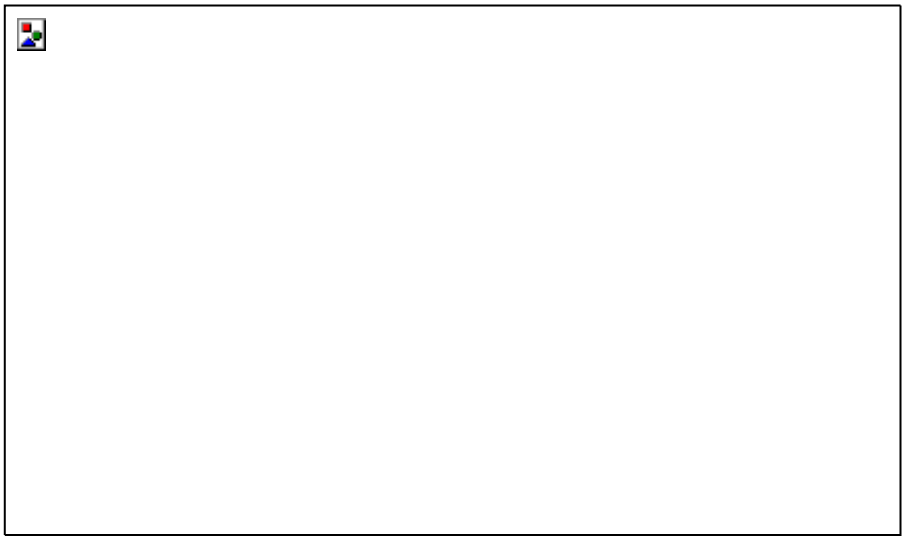


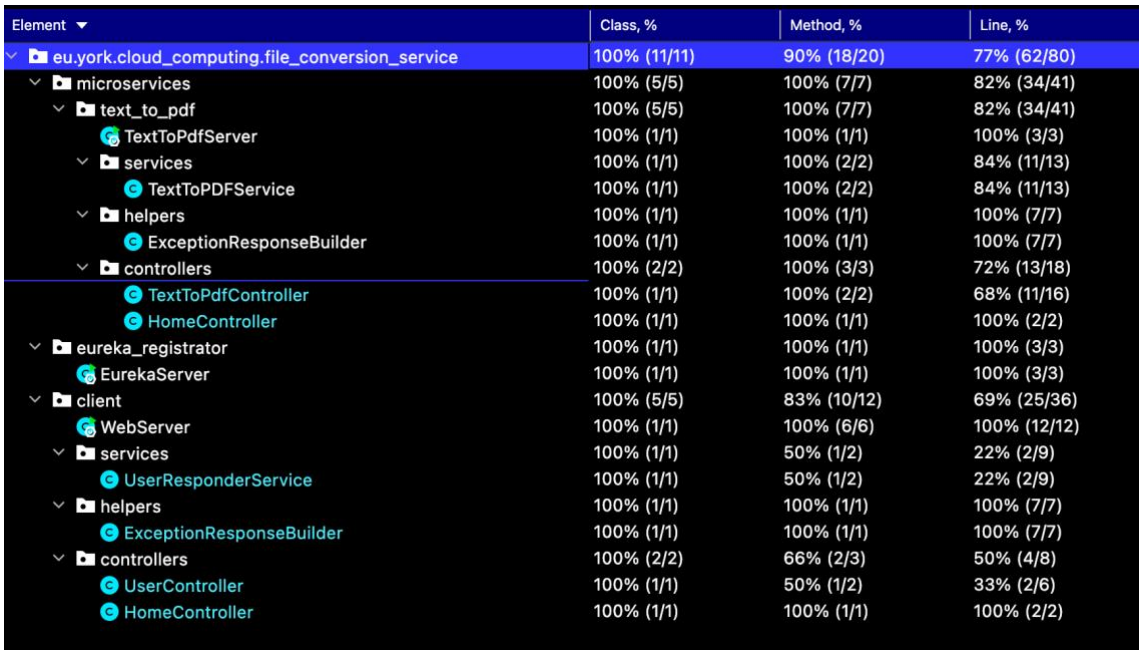
Figure 4.8 Excerpted from Martin Fowler's Article on Richardson's Maturity Levels [1]

In order to assure Level 0 is reached, we need to use HTTP methods for external communication. This is reached in the software as proven in the previous section. Level 1 requires the use of resources. In this system since there is no persistence endpoints do not utilise the REST resource system. In Level 2 it is required that HTTP verbs are used appropriately following their semantic definition. In this project the GET request is used explicitly since all operations are reproducible (idempotence) and do not alter resources. Level 3 requires HATEOAS Hypermedia implementation not present in this version of the system.

5. Testing

The software was tested to ensure that during development errors introduced can be more easily identified. Also, testing enabled the discovery of unknown bugs during

development. Overall, 77% of all line of codes and 90% of methods were tested although the type of testing possessed varied aims.



Element	Class, %	Method, %	Line, %
eu.york.cloud_computing.file_conversion_service	100% (11/11)	90% (18/20)	77% (62/80)
microservices	100% (5/5)	100% (7/7)	82% (34/41)
text_to_pdf	100% (5/5)	100% (7/7)	82% (34/41)
TextToPdfServer	100% (1/1)	100% (1/1)	100% (3/3)
services	100% (1/1)	100% (2/2)	84% (11/13)
TextToPDFService	100% (1/1)	100% (2/2)	84% (11/13)
helpers	100% (1/1)	100% (1/1)	100% (7/7)
ExceptionResponseBuilder	100% (1/1)	100% (1/1)	100% (7/7)
controllers	100% (2/2)	100% (3/3)	72% (13/18)
TextToPdfController	100% (1/1)	100% (2/2)	68% (11/16)
HomeController	100% (1/1)	100% (1/1)	100% (2/2)
eureka_registrator	100% (1/1)	100% (1/1)	100% (3/3)
EurekaServer	100% (1/1)	100% (1/1)	100% (3/3)
client	100% (5/5)	83% (10/12)	69% (25/36)
WebServer	100% (1/1)	100% (6/6)	100% (12/12)
services	100% (1/1)	50% (1/2)	22% (2/9)
UserResponderService	100% (1/1)	50% (1/2)	22% (2/9)
helpers	100% (1/1)	100% (1/1)	100% (7/7)
ExceptionResponseBuilder	100% (1/1)	100% (1/1)	100% (7/7)
controllers	100% (2/2)	66% (2/3)	50% (4/8)
UserController	100% (1/1)	50% (1/2)	33% (2/6)
HomeController	100% (1/1)	100% (1/1)	100% (2/2)

Figure 5.1 Testing Coverage

Both home controllers had identical tests. A unit test ensured that during and after creation the controller never had a null state. An integration test which run a mocked HTTP request to make sure the system would redirect to the appropriate page and return the expected HTTP code.

```
@SpringBootTest(classes = HomeController.class)
@AutoConfigureMockMvc
class HomeControllerTest {
    @Autowired
    MockMvc mockMvc;
```

Figure 5.2 Home Controller Test

```
    HomeController homeController = new HomeController();

    // Unit Test
    @Test
    void controllerNotNull() {
        assertNotNull(homeController);
    }

    // Integration Test
    @Test
    void controllerRedirectSuccess() throws Exception {

mockMvc.perform(get("/").content("index")).andExpect(status().isOk()).andExpec
t(forwardedUrl("index"));
    }
}
```

The exception response builder constituted of a single test that checked if the return was not null and contained the input values in the JSON response.

```
class ExceptionResponseBuilderTest {

    @Test
    void buildExceptionResponse() {
        Map<String, String> res =
ExceptionResponseBuilder.buildExceptionResponse("test", "someone");
        String expectedInString = "someone";
        String expectedInString2 = "test";
        // Make sure it's not null
        assertNotNull(res);
        // Check if result contains the given parameters
        assertTrue(res.toString().contains(expectedInString) &&
res.toString().contains(expectedInString2));
    }
}
```

Figure 5.3 Exception Response Builder Test

The Eureka server had an integration test which asserted that the main method should run successfully.

```
class EurekaServerTest {

    // Integration Test
    @Test
    void eurekaServerLoadsMainMethod() {
        EurekaServer.main(new String[] {});
    }
}
```

Figure 5.4 Eureka Server Test

The user controller was tested for integration with the rest of the system just to ensure that it never reaches a null state.

```
@SpringBootTest(classes = {UserController.class, UserResponderService.class})
class UserControllerTest {
```

Figure 5.5 User Controller Test

```
    @MockBean
    UserResponderService userResponderService;
    UserController userController = new UserController(userResponderService);

    // Integration Test
    @Test
    void controllerNotNull() {
        assertNotNull(userController);
    }
}
```

The web server was tested to make sure its main method runs successfully in integration tests and the application context never reached a null state during that process.

```
class WebServerTest {
    // Integration Tests
    @Test
    void webServerLoadsMainMethodContextNotNull() {
        WebServer.main(new String[] {});
        // Context not null
        assertNotNull(WebServer.applicationContext);
    }
}
```

Figure 5.6 Web Server Test

The text to pdf controller was tested for status code, data type of return and other header data conformance.

```
@SpringBootTest(classes = {TextToPdfController.class, TextToPDFService.class})
class TextToPdfControllerTest {
    TextToPDFService textToPDFService = new TextToPDFService();
    TextToPdfController textToPdfController = new
TextToPdfController(textToPDFService);

    @Test
    void serveTextToPdfReturnsPDFStatusSuccess() throws Exception {
        ResponseEntity<?> res = textToPdfController.serveTextToPdf("hello");
        // Appropriate status code received
        assertEquals(res.getStatusCode(), HttpStatus.OK);
        // Appropriate content disposition received
        String expectedContentDis =
ContentDisposition.builder("inline").build().toString();
        String resContentDis =
res.getHeaders().getContentDisposition().toString();
        assertTrue(resContentDis.contains(expectedContentDis));
        // Appropriate media type
        String expectedMediaType = MediaType.APPLICATION_PDF.toString();
        String resMediaType = res.getHeaders().getContentType().toString();
        assertEquals(resMediaType, expectedMediaType);
    }

    @Test
    void serveTextToPdfGivenNullReturnsNonNullStatusSuccess() throws Exception
{
        ResponseEntity<?> res = textToPdfController.serveTextToPdf(null);
        // Not Null
        assertNotNull(res);
        // Appropriate status code received
        assertEquals(res.getStatusCode(), HttpStatus.OK);
    }
}
```

Figure 5.7 Text to PDF Controller Test

Lastly, the text to pdf server was tested for integration with the rest of the system for a successful main method operation.

```
class TextToPdfServerTest {
```

Figure 5.8 Text to PDF Server Test

```
    // Integration Tests
    @Test
    void textToPdfServerLoads() {
        TextToPdfServer.main(new String[] {});
    }
}
```

Overall, due to time constraints the testing effort was minimized to improve other elements of the software, but still applied to a level which can help current and future development efforts.

6. Evaluation

In any project evaluation from the developer is a critical component which can improve their skill, the continuation of the project and reveal further insight into development.

There were some improvements to be made that were not actually integrated to the final product:

- A more sophisticated system of exception handling which would read on the client side if an error has occurred by expecting an exception builder response JSON. This would allow then the redirection of the user to a page where a user-friendly error message would be shown instead.
- Traditionally a Continuous Integration (CI) solution would be used to automate test runs, but due to the small size of the project this was omitted. Usually, the tool the developer is familiar with for such use cases is GitHub Actions.

7. Conclusion

Overall, the project offered an opportunity for the developer to get involved in and west of techniques and technologies which resulted in a functional system that conforms to the predefined goals. Although some aspects could have been further polished of the software as explored in the evaluation there is quality to the work as presented mainly in the implementation, design and testing of this document.

References

[1] F. Martin, “Richardson Maturity Model,” *steps toward the glory of REST*, 2010. [Online]. Available: https://www.martinfowler.com/articles/richardsonMaturityModel.html. [Accessed: 22-May-2022].