Information Processing Report

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1 Overview

The system is a game called *glutton.io*, in which the goal of the player is to dominate the arena as the supreme blob. To achieve this, the player must navigate the environment, growing their blobs by consuming smaller ones. This process is encapsulated in the flow diagram in Figure 1.

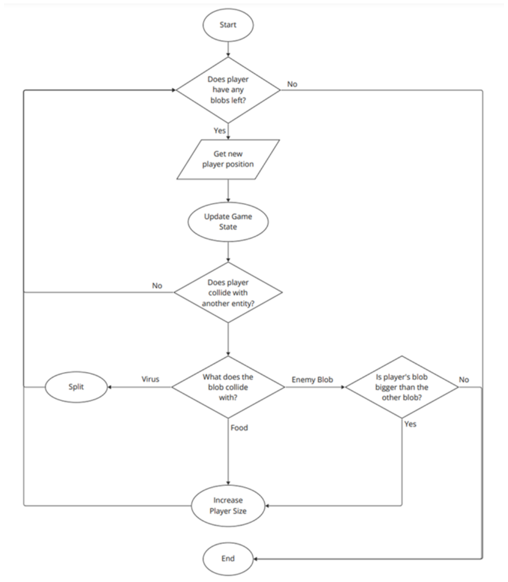

Start
Does player have any blobs left?
No
Yes
Get new player position
Update Game State
Does player collide with another entity?
No
What does the blob collide with?
Virus
Split
Enemy Blob
Is player's blob bigger than the other blob?
No
Yes
Food
Increase Player Size
End

Figure 1: Game flow diagram

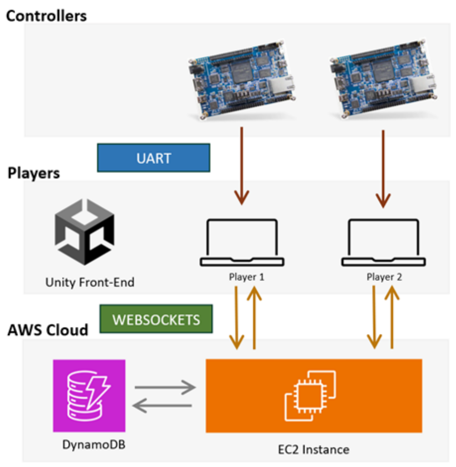


Figure 2: Overall System Architecture

2 FPGA

The main requirements for the FPGA were to create a seamless user experience by creating a responsive controller with low latency. Figure 3 shows the architecture used to achieve the goals.

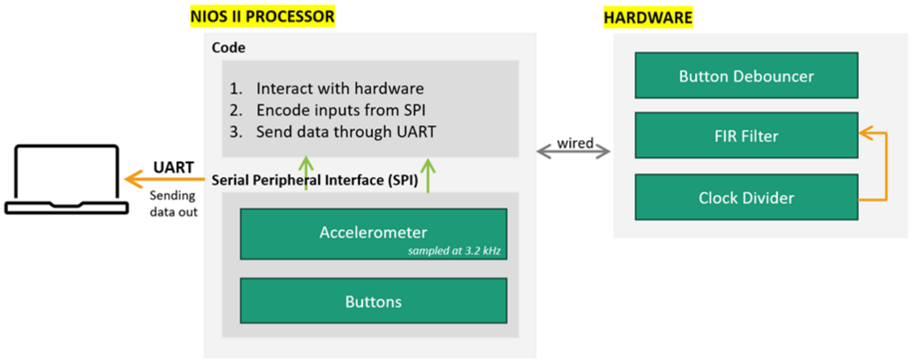


Figure 3: FPGA Architecture

35	25	15	5	4	0
Accelerometer X	Accelerometer Y	Switch	K1	K0	\n

Figure 4: Bit field encoding for UART communication

2.1 Communication between the FPGA and the PC

UART communication was used, using the JTAG interface provided. To minimise latency, 2 major design decisions were made:

1. The bits were to be encoded before sending them over JTAG, as seen in Figure 4.
2. The driver interface was rewritten in C#, to avoid the usage of the NIOS II terminal.

By only sending the necessary data, we managed to receive data at 3.2kHz [refer to next section], allowing us to receive the latest data from the FPGA.

To check the user experience, a simple Python game was written to roll around a ball.

By using the NIOS II terminal, our ball was unresponsive and our debounced button signals were missed half of the times. This prompted testing of the latency τ_{UART}, with the results shown below:

Using the NIOS II terminal	Using the rewritten *intel_jtag_uart* library
324 ms	55 ms

We chose C# as the new driver interface language as it is the default on Unity, further simplifying the interfacing of the FPGA and the game. As a result, the translated library significantly reduced controller latency. This also allowed any player with NIOS II drivers installed to connect to the FPGA automatically anytime during the game.

2.2 FPGA hardware

This section revolves around the FPGA virtual machine, an accurate behavioural model that allows code to be testing in software before flashing to the NIOS II. It also allows data analysis, enabling these design decisions to be objectively measured.

2.2.1 Creating a responsive FIR filter

As most wired controls have a latency of no more than 10ms, that was the goal. FIR filters are discrete time filters, and have an associated group delay of:

$$\frac{N-1}{2T_s} = -\frac{d\phi}{d\omega}$$

To minimise the delay, we can:

1. Reduce the sampling time (T_s).
2. Reduce N (the number of coefficients)

Our testing environment showed that although the data was coming in at 5300 Hz, the accelerometer only updated every 100 Hz. To reduce the sampling time, the datasheet (pg. 13), allows us to raise the sampling rate from 100 Hz to 3.2 kHz. This allowed the use of a 64-tap filter (for a 10ms group delay), but due to hardware limitations, only use 45 taps could be used.

Figure 5 shows an FFT of real accelerometer data, indicating that noise started at 8Hz, therefore the FIR filter in Figure 6 was designed using MATLAB to attenuate all frequencies above 10 Hz, with a stopband frequency of 100 Hz and stopband attenuation of -20 dB.

Figure 7 verifies the behaviour, clearly showing the group delay under 10 ms.

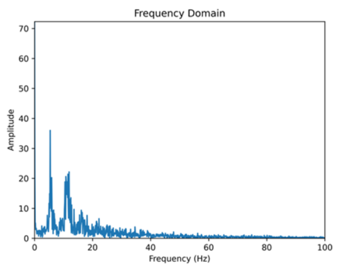


Figure 5: FFT of real accelerometer data

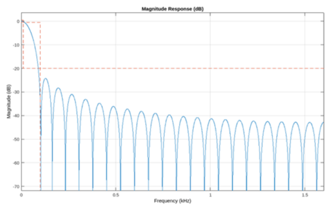


Figure 6: FIR filter

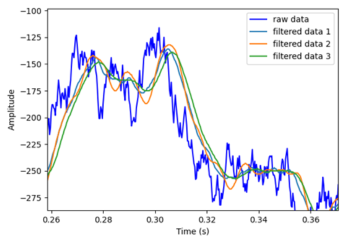


Figure 7: Filter time response

2.2.2 Creating responsive buttons

A button debouncer was implemented in hardware with a time of 10 ms. This was simulated in the Python demo game before being ported to Unity.

2.2.3 Overall latency

The overall latency was measured to be $\tau = \tau_{UART} + \tau_{FIR} + \tau_p = 55 + 10 + 10 = 75$ ms in which τ_p is the processing delay.

3 Game

The game was designed in Unity, as seen in Figure 8, since it provides a wide range of tools for implementing the idea we had for the game. Additionally, it is more convenient to design a 2D game in Unity, than in other game engines. The game's functionality is written in C#, the default language in Unity.

The gameplay consists of 3 key parts. A player can:

1. Eat small masses to increase in size
2. Shoot mass from themselves to decrease their size
3. Absorb other players who are smaller.

The speed of the player decreases proportionally to their size increase, so that smaller players can outmaneuver bigger ones. However, by shooting mass the opposite way, a bigger player can gain a small boost in speed, which can allow them to catch up to a smaller one and absorb them.

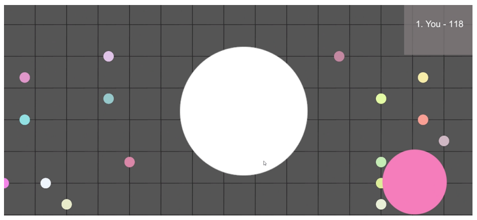


Figure 8: A screenshot of the game

4 Server

The main requirements of the the server were to act as the central authority of the global game state and to provide a smooth experience by minimising latency.

4.1 Communication between the clients and the server

4.1.1 Client/Server dichotomy

Figure 9 shows the persistent duplex communication between the server and the different clients.

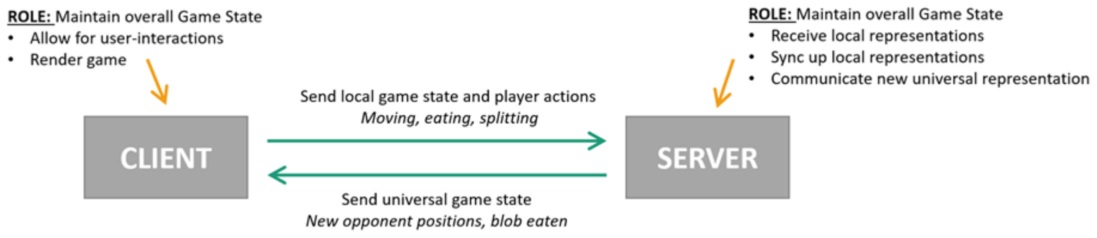

ROLE: Maintain overall Game State
• Allow for user-interactions
• Render game
CLIENT
Send local game state and player actions
Moving, eating, splitting
Send universal game state
New opponent positions, blob eaten
SERVER
ROLE: Maintain overall Game State
• Receive local representations
• Sync up local representations
• Communicate new universal representation

Figure 9: Server/Client roles

4.1.2 Client/Server interaction

The client informs the server of local events. The server then verifies the integrity of the message it received through the universal game state. If no cheating concerns are raised, the server updates the universal game state and broadcasts an update message to all clients, including the client who initiated the trigger.

A player eats a food blob as soon as it collides with it. This interaction was made possible through a close server-client dynamic, with the full details shown in Figure 10.

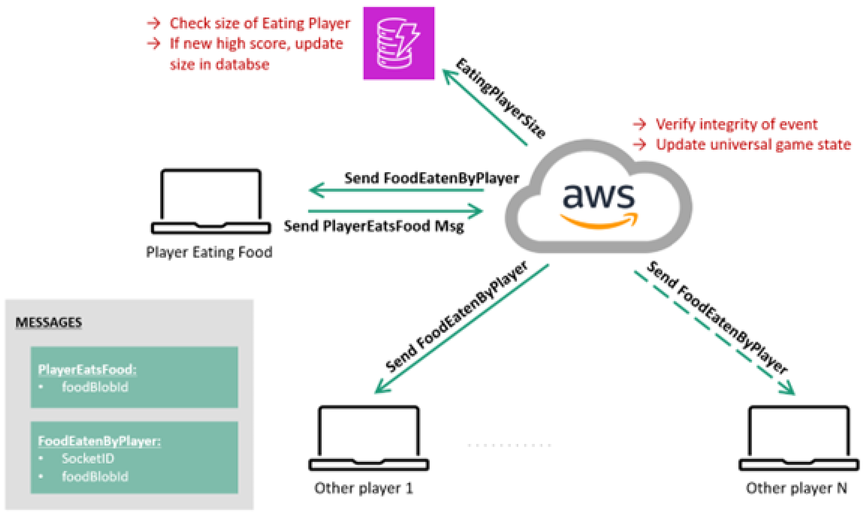


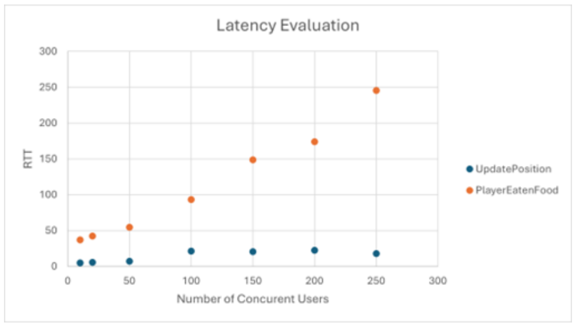
Figure 10: Full interaction of a player eating a mass object

4.1.3 Factoring in latency

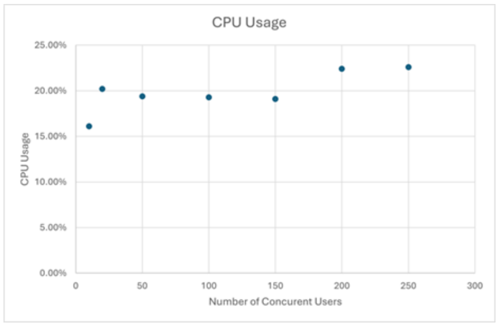
Server-Client interactions were designed with latency at the forefront. Multiple strategies were adopted to keep this delay small.

One first concern was raised when deciding whether event detection would take place on client or server side. It was ultimately decided that the client would be sending trigger to the server, as that would significantly improve the time complexity of detections from $O(mn)$ for naïve server checks to $O(m)$ for client-side detections. Here, m and n respectively represent the number of food blobs and the number of players.

A second concern was raised when considering the UpdatePosition event. Each client sends a position update every 0.01 seconds. If the server were to broadcast the updated game state for every position change it receives, it would be doing n^2 broadcasts roughly every 0.01 seconds. To mitigate this issue, we resorted to only sending clients position updates when every player has already sent their updated position, reducing the number of broadcasts to n every cycle.



(a) Latency



(b) CPU usage

Figure 11: Server load testing

4.1.4 Load testing

Server load testing was conducted through the Artillery framework. Virtual users were created to emulate real user interacting with the game. These virtual users would:

1. Send a Join message to the server.
2. Send an UpdatePosition message to the server every 10 ms.
3. Send PlayerEatsFood message every 500 ms.
4. Record the time it takes to receive a response to each message sent.

Testing was conducted on arenas of different size. The results are shown in Figure 11.

4.2 Server infrastructure

4.2.1 Specifications

Latency had to be kept low to ensure a smooth game flow. The consensus was that the message RTT should approach the human visual processing threshold of 200ms.

Scalability was also taken into consideration. A game should be able to handle 150-250 players concurrently without crashing.

An AWS EC2 instance was chosen to meet those requirements all the while considering cost. Its specifications are shown in the table below:

Component	Specification	Purpose
Instance Type	t2.micro	Determines available computational resources, adapted for small to medium-sized workloads
vCPU	1	Chose single-threaded processing capability to execute events sequentially
Memory	1GB	Used to store temporary game data, player information, and support the execution of the server's software

4.2.2 Communications and Database

As seen in Figure 2, WebSockets were used for its concurrency handling and duplex communications.

A MongoDB database was maintained to save individual players high scores.