A Gather.town Clone in Links

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Abstract

This skeleton demonstrates how to use the `infthesis` style for undergraduate dissertations in the School of Informatics. It also emphasises the page limit, and that you must not deviate from the required style. The file `skeleton.tex` generates this document and should be used as a starting point for your thesis. Replace this abstract text with a concise summary of your report.

Research Ethics Approval

This project was planned in accordance with the Informatics Research Ethics policy. It did not involve any aspects that required approval from the Informatics Research Ethics committee.

Declaration

I declare that this thesis was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or professional qualification except as specified.

(*Caitlin McDougall*)

Acknowledgements

Any acknowledgements go here.

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Chapter 1

Introduction

The preliminary material of your report should contain:

- The title page.
- An abstract page.
- Declaration of ethics and own work.
- Optionally an acknowledgements page.
- The table of contents.

As in this example `skeleton.tex`, the above material should be included between:

```
\begin{preliminary}
    ...
\end{preliminary}
```

This style file uses roman numeral page numbers for the preliminary material.

The main content of the dissertation, starting with the first chapter, starts with page 1. ***The main content must not go beyond page 40.***

The report then contains a bibliography and any appendices, which may go beyond page 40. The appendices are only for any supporting material that's important to go on record. However, you cannot assume markers of dissertations will read them.

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1.1 Using Sections

Divide your chapters into sub-parts as appropriate.

1.2 Citations

Citations (such as [**?**] or [1]) can be generated using `BibTeX`. For more advanced usage, we recommend using the `natbib` package or the newer `biblatex` system.

These examples use a numerical citation style. You may use any consistent reference style that you prefer, including "(Author, Year)" citations.

Chapter 2

Background

2.1 Web Technologies

Since its inception, the internet has become integral to the way we live our lives as it allows us to find information instantly, share our interests with peers, buy groceries, and much more. In order to enable the internet to function as smoothly as it does, a variety of web technologies are utilised.

2.1.1 Classic Approaches

Commonly, the client-side consists of markup languages such as HTML and XML to specify the basic structure and content of the web-page, a styling language such as CSS to provide additional styling, and a language such a JavaScript to provide dynamic functionality. On the server-side, languages such as Python, Java and PHP can be used for performing more intensive computations and functionality. Finally, languages such as SQL and XQuery allow connections to databases which store the huge quantities of data which may be requested on a website. These different layers, or tiers, allow modulation of websites and allows for languages which are tailored to specific purposes.

Unfortunately, having this variety of programming languages to choose from at each level creates friction known as the impedance mismatch problem. Impedance mismatch problems are issues which arise as a result of combining technologies which use different archetypes [8].

2.1.2 Links

For this reason, the Links programming language has been created, offering a new approach to web technologies which replaces this three-tiered web model with a single language. Links is a strict, statically-typed, functional language which aims to replace the three-tiered web system with a single-source language [1]. It does so by providing a translator from the Links code to JavaScript and SQL, with the functional aspect of the language providing additional benefits such as database query optimisation, continuations for web interaction, and concurrency with message passing.

The pattern classically used when programming in Links to achieve concurrency is the Actor Model. In this model, an Actor is responsible for managing its own state and performing computations. In this way, there is no global state shared across actors or processes which allows for concurrency since computations are safe from attempting to modify the same memory location. Messages are sent between different actors and when an actor receives a message, it can perform any of 3 concurrent actions: send messages to other actors, create additional actors, or prepare for how subsequent messages will be handled [4]. The type and order of these messages are ensured by defining session types. However, the linear nature of session typing is not well-suited to the implementation of graphical user interfaces (GUI) which makes it more challenging to create webpages in Links.

For this reason, an adaptation of the Model-View-Update (MVU) architecture introduced by Elm has been added to Links [2]. Elm, like Links, is a functional language and, as such, the architecture it presents is particularly well-suited to functional programming. In this architecture, a model contains the state of the application, a view function renders the model, and an update function handles messages produced by these models and produces new models. The extension to the MVU architecture allows for session typing by adding commands (which enable side effects as seen in traditional web technologies), linearity, and model transitions.

Since the Links language is still in active development, it still lacks some functionality which is provided by JavaScript. Fortunately, Links offers a Foreign Functions Interface (FFI) which allows custom JavaScript functions to be written and called from a Links application such that any missing JavaScript functionality can still be included by the programmer. In particular, this paper will make use of FFI to make use of the WebRTC framework to achieve real-time communication between clients.

2.2 WebRTC

WebRTC is a set of standards making use of peer-to-peer connections to enable real-time applications such as text-based chat, audio sharing, and live video-conferencing [**?**]. This framework allows peers to send and receive information directly, without first sending the data through a server which can create delay.

2.2.1 Client-Server vs P2P

In the traditional Client-Server network architecture, devices in a network act as either a client or a server. Clients make requests for services and content which are received and actioned by the server, a higher-performance entity which is usually connected to a large number of clients [10]. In this way, clients are not connected directly to one another and in order to share content must instead send content first to the server which can in turn forward this to the destination client.

On the other hand, in the peer-to-peer (P2P) architecture, devices in the network can act as either a client or service provider at any point. In this way, devices in a P2P network share their combined resources in order to send content directly to one another without passing through a central entity [10]. WebRTC chooses to make use of the P2P network architecture due to the fact that these direct connections between clients give less delay for real-time applications while also giving more privacy to those communicating [**?**].

Although WebRTC uses P2P connections for file transfers during a session, it does make use of servers to properly manage each P2P connection. For example, when two clients access a video-conferencing website and want to communicate with one another, a signalling server will be set up to allow initial communication between the two clients.

2.2.2 ICE

In order for two clients to communicate with one another directly, they first need to know where within the network the other client is located, or in other words, their IP address. However, it is likely that both clients are connected to a router which performs Network Address Translation (NAT). This means that the local IP address of the client is hidden from the public network and replaced with a public IP address which is the address external hosts should use to communicate with the client. Since this translation happens at the router, the client does not know its own public IP address and so can't automatically tell other clients which address to use to connect to it.

Fortunately, Session Traversal Utilities for NAT (STUN) servers give clients the ability to ask for their own public IP address such that they can distribute this information to clients or servers they want to be able to connect to them. If, however, the router uses symmetric NAT, which means that the NAT mappings are dependent on both the source and the destination IP addresses, this no longer works as other servers would still be unable to connect since their IP address is not trusted. In this situation, Traversal Using Relays for NAT (TURN) servers are instead utilised to route messages to and from the clients, therefore creating a client-server connection rather than a P2P connection.

Interactive Connectivity Establishment (ICE) is used to describe the framework of collecting the different candidates which may be used to connect to the client such as their local IP address, public IP addresses given by STUN servers, or TURN server IP addresses.

2.2.3 Signalling

The ICE candidates are bundled up along with information about available media types and formats according to the Session Description Protocol (SDP). Clients can then exchange these SDP formatted messages as an offer to the other client and the other client responds with an answer until an agreement on how to communicate is achieved. This process is called Signalling and is facilitated by the Signalling server. Once the direct connection is agreed, the clients can then exchange media using a P2P connection.

2.3 Video Conferencing Systems

Technology has long been used to communicate with one another from afar, but mostly in the form of telephone calls or text-based messaging. However, the ability to send and receive video streams has revolutionised the way businesses, schools, and social circles function. The ability to share video with multiple users at the same time has become particularly relevant in the wake of the Covid-19 pandemic which saw the use of video-conferencing systems (VCS) boom as this became the closest to face-to-face meetings we could get.

A variety of VCS are available to use, with popular systems including Zoom, Microsoft Teams, and Cisco Webex all sharing a similar interface. The interface consists of live video feeds for a subset of participants, a larger area displaying the current speaker or currently shared screen, a small area showing the user's own live feed, and an area for text-based conversation. These systems also come with an increasing number of additional features to mimic the way we interact in real meetings such as raising hands, white-boarding and breakout rooms.

However, even with the inclusion of breakout rooms, these systems fail to adequately represent the spatiality of real meetings and social interactions. For example, a teacher may walk around the edge of a classroom to get a sense of who is struggling, while in these virtual environments they need to enter every breakout room, potentially interrupting the conversation. This limitation of traditional VCS has motivated new approaches to video conferencing which take into account this spatial awareness and enable more natural virtual interactions.

2.3.1 Gather.town

One such VCS offering proximity-based interactions is Gather.town [6], an online platform which allows companies or individuals to create a gamified virtual meeting space in which customised avatars can move around and interact with other avatars. When two avatars are within close proximity they will be connected and begin sharing video, whereas when they are far apart the connection stops and they are unable to see or hear one another. In addition to this, spaces can be set up for broadcasting to a large room of people as would be possible during a presentation and tables are available in which everyone can communicate with one another similarly to the traditional Zoom and Teams approaches.

Additionally, Gather.town is increasingly incorporating many of the features offered by traditional VCS such as white-boarding, screen-sharing and file-sharing. This ensures that users do not miss out on any functionality through switching to Gather.town. Gather.town also provides features not offered by static VCS as it has the unique ability to provide interactive games which users can play. This allows for a much more natural experience in environments such as classrooms or icebreaker sessions. Games offered include Chess, Codenames, Tetris, and more [7].

Some limitations of Gather.town which have been highlighted are its limit of 25 participants in the free version, and the performance of the software when multiple users are connected on a poor internet connection [11]. It has also been suggested that this visual interface could be inaccessible for those who find too much visual stimulus overwhelming or those with visual impairments who may struggle to interact easily with the virtual environment.

Overall, Gather.town provides a much more interactive experience for users and has been shown to reduce fatigue associated with virtual meetings. In addition, a study by [9] determined that both educators and students preferred using Gather.Town in comparison with using other static VCS such as Zoom and Teams. However, accessibility of Gather.Town may be an issue for those with visual impairments or sensitivity to visual stimuli. Therefore, there is a need for a Video Conferencing system which provides the benefits of Gather.Town's spatial and gamified interactions while maintaining an appropriate level of accessibility for those with visual impairments.

2.3.2 FluidMeet

Another alternative approach to live Video-Conferencing is proposed by FluidMeet [5]. In this system, the authors have focused on creating flexible boundaries between conversations (unlike the rigid break-out room boundaries offered by alternatives such as Teams). In doing so, they aim to offer more natural transitions between conversations and provide a more visual representation of different conversations.

FluidMeet achieves more natural transitions by offering the option for breakout rooms to be fully or partially open to others [5]. When fully open, users who are not in the group are able to hear and see what is going on in that group before joining. When partially open, non-group members instead have access to keywords being used in the conversation in the form of a word cloud and they can view audio visualisations in order to gain a sense of the atmosphere of a group.

Having access to all this information could be overwhelming for users, but FluidMeet offers the ability to choose which of these features are displayed, reducing the visual overload which may occur. This is an important feature to note as allowing users to customise how much information they receive enhances the accessibility of FluidMeet to those with visual impairments or those who just prefer a simpler interface.

2.3.3 Accessibility through Multiple Interfaces

A study by Gappa and Nordbrock (2004) explored ease of use in internet portals (search engines) which included individuals with hearing impairments, visual impairments, learning difficulties, and the elderly [3]. Their findings showed that all participants valued a clear and simple design. This shows that adding many layers of complexity which may be preferable for some, is not fit for purpose in all situations.

In the context of Video Conferencing, it is extremely important that disabled students, employees, and teachers have the same access to these systems and can communicate effectively with peers and colleagues. Therefore, if companies and schools want to use these interactive and spatial VCS, there need to be features included to allow disabled or elderly individuals to participate equally.

The ideal system is one which caters to both the needs of those who prefer simpler interfaces and those who prefer a more interactive experience. Therefore, this paper explores offering a choice between a simplified interface offered by static VCS and a gamified experience as offered by Gather.town. However, this produces a challenge in terms of allowing those using one interface to interact with those using the alternative interface.

Chapter 3

Conclusions

3.1 Final Reminder

The body of your dissertation, before the references and any appendices, *must* finish by page 40. The introduction, after preliminary material, should have started on page 1.

You may not change the dissertation format (e.g., reduce the font size, change the margins, or reduce the line spacing from the default single spacing). Be careful if you copy-paste packages into your document preamble from elsewhere. Some LaTeX packages, such as `fullpage` or `savetrees`, change the margins of your document. Do not include them!

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Appendix A

First appendix

A.1 First section

Any appendices, including any required ethics information, should be included after the references.

Markers do not have to consider appendices. Make sure that your contributions are made clear in the main body of the dissertation (within the page limit).

Appendix B

Participants' information sheet

If you had human participants, include key information that they were given in an appendix, and point to it from the ethics declaration.

Appendix C

Participants’ consent form

If you had human participants, include information about how consent was gathered in an appendix, and point to it from the ethics declaration. This information is often a copy of a consent form.