T-111.5360 Report: Remote Mouse

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December 29, 2015

Abstract

With the emergence of WebSockets, web application developers have a new, versatile standard technology in their toolbox for developing new kinds of web applications. We explore the possibilities it provides for implementing a demanding real time communications channel between browsers. Our implementation is a virtual mouse pointer on a web page, controlled from another web page. We found that WebSockets together with a few other modern web technologies provide means for meeting and exceeding the requirements for developing an application in this area, with relatively modest development effort. The principal findings and to a certain extent software developed have potential for applicability not only in our chosen primary application area of remote web page control, but also in user assistance and usability evaluation.

1 Introduction

WebSockets is a technology providing an efficient full-duplex bidirectional communications channel between clients and servers. Due to its low latency characteristics, it is well suited for real time applications. The WebSocket protocol is standardized by IETF (Fette and Melnikov, 2011) and W3C (Hickson, 2012) develops an API to enable its use in web pages.

In this report we introduce Remote Mouse, a virtual mouse pointer on an arbitrary web page, controlled from another web device. WebSockets is used as the communications technology between the devices, through an intermediate server.

A public live instance of our implementation is available at `https://remote-mouse.herokuapp.com/`.

2 Related work

Bassbouss et al. (2013) address multi-screen web application development and the transformation of traditional web applications to multi-screen capabilities. Both the current and proposed multi-screen application models utilize WebSocket in communications between clients (screens) and servers.

Agar.io[1] is a massively multiplayer online game. Players control cells in a petri dish, attempting to grow larger by consuming pellets and other cells, and avoiding being consumed by other cells. The game is available for web browsers on its website, and Android and iOS versions are available for mobile devices. The web version uses an HTML canvas and its 2D context for rendering, as well as HTML animation frames. Communication between the browser and the server is implemented using WebSockets. Data is transferred using WebSocket binary frames (WebSocket opcode 2), which are constructed using the ECMAScript 6 ArrayBuffer and DataView objects. Due to the binary nature of the data, the exact semantics of it are not available. During gameplay, the traffic consists of on the order of 50 WebSocket frames per second, with their sizes ranging approximately from a few to 200 bytes.

YouTube has a feature with which it is possible to control another YouTube window's video controls from another screen, such as a computer or a mobile device. It is primarily intended for controlling YouTube on smart TVs, but can also be used in a browser. The controlled screen[2] is operated by its paired remote[3]. The remote works by sending POST requests to the server that forwards them to the controlled window. It also uses polling every 10 seconds to check that the controlled device is still available. The controlled window uses long polling to check if any information is updated. YouTube is using LocalStorage for storing information about the playback device and different identifiers. MediaSource is used to attach sources to their video elements.

Remot.io[4] is a service that controls HTML presentations such as reveal.js[5] from touch based devices. The controlling device sends POST requests to the server that forwards them to the controlled device using long polling by the controlled device. Remot.io is using touch events for their remote. Swipe gestures translate to the directions the user wants to navigate in the slides.

3 Results

Using Remote Mouse starts with going to its front page. Devices that are going to be controlled install a bookmarklet that enables control by a connected controller. Typically this is carried out by dragging the bookmarklet into the browser's bookmarks toolbar or equivalent. The bookmarklet needs to be installed only once; after that it can be invoked directly from where it was installed to.

There are three versions of the bookmarklet available. The first two, heroku and localhost, load the controlling

[1]`http://agar.io/`

[2]`http://www.youtube.com/tv`

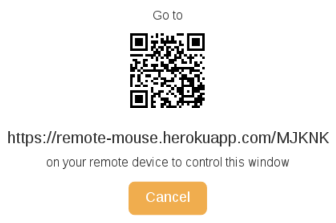
[3]`http://www.youtube.com/pair`

[4]`http://remot.io/`

[5]`http://lab.hakim.se/reveal-js`

JavaScript code from and communicate using WebSockets with the respective server, one hosted at Heroku, or one running locally. The third one, heroku inline, is the same as the normal Heroku one with the exception that it contains the entire JavaScript code in the bookmarklet instead of causing it to be loaded from the server on demand. The inlined code has been minified using the Google Closure Compiler[6].

When the bookmarklet is invoked, a URL for the controller is presented. By loading this URL, a session between the controller and controllee is established and the remote control can start. The URL is presented also as a QR code to make it easy to access with mobile devices.


Go to

https://remote-mouse.herokuapp.com/MJKNK

on your remote device to control this window

Figure 1: Controller prompt

When a controller joins the session by loading the session URL, the popup on the controllee closes and the session starts. A virtual mouse pointer image is displayed on the controllee, and the controller UI is shown on the controlling device. Most of the controller window is empty and serves as the area for mouse and touch movements.

For non-touch devices, the controller document has `mousemove` and `click` event handlers. Each mousemove event results in the pointer position being sent to the server in a WebSocket message. For touch devices, the document contains event listeners for `touchstart`, `touchmove`, and `touchend`.

Positions are sent as pairs of floating point numbers between 0 and 1, representing the relative left and top position offsets of the event in percents, proportional to the dimensions of the controller window. The controllee moves the virtual pointer according to these values, by converting them to percentages for the virtual pointer's `left` and `top` CSS properties.

WebSocket messages for click events contain only the information that the controller requests a click; there is no position information included with it. The controllee locates the element which is the target of the click based on its own virtual pointer position, using the Document.elementFromPoint CSSOM View Module method[7].

Scrolling is implemented in two ways. For touch devices, a two-finger touch move event translates to scrolling the controllee's view. The second scroll implementation is done using the DeviceOrientation API[8]. Tilting the controller up and downwards results in scrolling the controllee's document accordingly. Tilt-scrolling can be toggled on and off with a three finger touch event.

[6]`http://closure-compiler.appspot.com/`
[7]`http://www.w3.org/TR/cssom-view/`
[8]`http://www.w3.org/TR/orientation-event/`

Event	Example message
Session request	`create:KJK4B`
Session response	`roomcode:KJK4B`
Position change	`pos:0.7245,0.6241`
Click	`click:left`
Scroll	`scroll:-0.004555`
Latency adjustment	`setLatency:10`
Latency request	`ping:null`
Latency response	`pong`
Controllee not present	`error:noClient`

Table 1: WebSocket message payloads

To aid in analysis and development, the controller contains a debug bar at the top of the controller window. Display of the debug bar is toggled from the bottom right corner of the controller UI. It contains controls for artificially increasing the latency at the server side, interval how often to send events to the server, how many events to pack in a single WebSocket payload, sending only every n'th event, as well as indicator displaying the current measured latency.

The server between the controller and controllee is implemented with Node.js, using the Express[9] and ws[10] modules. The server is mostly just a relay that forwards messages from controller to controllee, keeps track of sessions between them and notifies them about other parties' presence, responds to latency requests, and implements artificial latency throttling. Express is included only in order to be able to easily serve static files from the same server as the WebSockets implementation, otherwise the built-in http module of Node.js along with ws would suffice.

The application's development is hosted in a GitHub repository located at `https://github.com/valterkraemer/Remote-Mouse`. The server can be run locally with the command `node app.js` in the project's top level directory. By default, it listens on port 3000 and can be accessed at `http://localhost:3000/`. Pushes to the GitHub repository are automatically deployed in the public Heroku instance at `https://remote-mouse.herokuapp.com/`. The Heroku instance uses the secure `https` and `wss` protocols in order to make it possible to control web applications served over both `http` and `https` protocols with it.

The controllee implementation consists of roughly 5 kB of non-minified JavaScript code (3 kB minified, embeddable to a bookmarklet) which includes the virtual pointer image as a data URL, and a few hundred bytes of CSS. The controller side is about 6 kB of non-minified JavaScript, and 3 kB of HTML and CSS. The server implementation is about 4 kB JavaScript.

4 Analysis

Technology stack

The most important technology for both controller and controllee sides of the Remote Mouse implementation is

[9]`http://expressjs.com/`
[10]`https://github.com/websockets/ws`

	WebSockets	Device-Orientation
IE	10 (2012)	(11) (2013)
Edge	12 (2015)	(12) (2015)
Firefox	11 (2012)	(6) (2011)
Chrome	16 (2011)	(7) (2010)
Safari	7 (2013)	-
iOS Safari	6.1 (2013)	(4.3) (2011)
Android Browser	4.4 (2013)	(3) (2011)
Chrome for Android	47 (2015)	(47) (2015)

Table 2: caniuse.com: WebSockets and DeviceOrientation support in selected browsers

WebSockets. According to caniuse.com, it is fully supported in all current major browsers since 2013[11]. The Node.js ws library used on the server side has had releases available from GitHub since 2011[12].

The DeviceOrientation API used to implement scrolling based on controller orientation is also well supported in current browsers to the extent required by Remote Mouse. According to caniuse.com[13], only Microsoft Edge has full support for it, most other browsers have partial support, and the desktop version of Safari has none. Safari's non-support is not a major problem, because controller devices are expected to be mobile ones, and the iOS Safari supports the API.

Table 2 summarizes support for WebSockets and DeviceOrientation in major browsers. The versions listed are the first ones in which full support for the technology appeared, followed by the release year in parenthesis. If full support is not yet available, the version number in parenthesis indicates the first version with partial support.

Other browser side technologies besides these two used in Remote Mouse are basic ones that can nowadays be assumed to be present in practically all browsers.

User experience

To test the subjective effect of latency on user experience, a test with three users was conducted. The users were first asked to use an Apple Magic Trackpad[14] to get a feeling of a local, low latency user experience. Then, they were asked to use Remote Mouse with the latency throttle set to varying settings. The latency settings were shuffled, i.e. not presented in increasing or decreasing order in order to avoid users' expectations affecting the results. Users were tasked to grade the quality of the pointer control experience in scale from 0 to 10, with grade 0 being the lowest one, equal to unusable, and 10 being equally good as the Magic Trackpad.

All three users rated the experience to belong in the middle of the scale at approximately 250 ms latency. 500 ms was classified as barely usable, and 0 to 100 ms quite acceptable. User test data is included in table 3 and visualized in figure 2.

[11]`http://caniuse.com/#feat=websockets`

[12]`https://github.com/websockets/ws/releases`

[13]`http://caniuse.com/#feat=deviceorientation`

[14]`https://en.wikipedia.org/wiki/Magic_Trackpad`

User 1		User 2		User 3	
Latency	Grade	Latency	Grade	Latency	Grade
500 ms	2	400 ms	2	0 ms	8
200 ms	4	100 ms	5	500 ms	1
100 ms	5	300 ms	4	300 ms	4
0 ms	6	0 ms	8	100 ms	8
100 ms	6	100 ms	8	0 ms	9
0 ms	8	0 ms	8	200 ms	7

Table 3: Subjective user test results

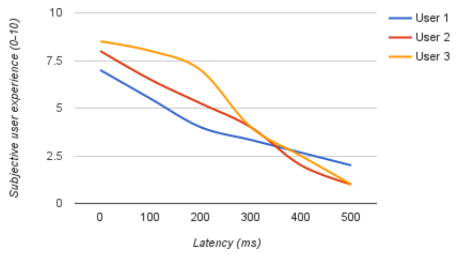


Figure 2: Latency effect on user experience

Performance characteristics

To aid in estimating how these estimates translate to use of Remote Mouse in different network setups, table 4 lists the typical latencies when the service is running in Heroku and locally, and when it is being used over different network connections.

Using Google Chrome, running both the controller and controllee in the same instance of the browser on a Intel Core i7-3610QM 2.30GHz quad core laptop running Fedora 23 Linux, and with a local Remote Mouse server, results in roughly 9% CPU usage evenly distributed across cores under rapid pointer movements.

When the pointer is being moved at normal speeds in this laptop setup, the Remote Mouse controller sends roughly 80 to 90 WebSocket messages per second. Moving the pointer faster increases it up to 120 messages per second. Each pointer position message is about 40 bytes with batch size 1, translating to roughly 5 kB/s bandwidth requirement. This requirement would however only be achieved if the WebSocket message size was optimally fitted with the network MTU size which is rarely if ever the case. Submitting the small message in much larger frames results in suboptimal use of network

Network	Server	Latency
2G	Heroku	500 ms
3G	Heroku	70 ms
LTE	Heroku	70 ms
Wi-Fi	Heroku	70 ms
Wi-Fi	local	5 ms

Table 4: Typical setup latencies

bandwidth.

The debug bar's controls allow examination of how various environmental and optimization aspects affect the user experience. Decreasing the frequency of sent events decreases network bandwidth usage but results in choppier pointer movements observed on the controllee. Bundling several position events into one WebSocket payload has beneficial networking implications, but without specific implementation on the controllee, has the same effect as if only the last of the message's position events was sent. This is because the controllee browser does not keep up with all CSS positioning events resulting from the rapid stream of them coming while the payload is being parsed, but just renders the last of them.

Implementation

The bookmarklet script approach works without any additional extensions or plugins installed and thus is very easy to deploy and invoke. However, the script injection approach has two significant drawbacks.

First, because the script is injected to the controlled document, it does not survive page transitions. Remote control has to be re-established for each new web page separately. To ease this, the last used room code is stored on the controllee's local web storage and the bookmarklet automatically uses it and reconnects to the same session when invoked in a window or tab where control was previously enabled.

The second drawback is that some sites, such as Facebook and GitHub, enable Content Security Policies[15] that prevent the controller script from working. Inlining the whole code in the bookmarklet – such as is done in the heroku inline version of it – works around some of these restrictions but is not a universal solution. For example, the script in the bookmarklet might load and execute, but not be allowed to contact the Remote Mouse server.

5 Conclusions and future work

Latency of a network connection is much more important for satisfactory user experience with Remote Mouse than its bandwidth. Bandwidth needs of the application are already quite modest with the current implementation, and could be further reduced, for example by using a more efficient binary WebSocket message payloads, and compression. However, given the already low requirements and possibility of getting negative effects on latency from optimizing for bandwidth usage, these possibilities were not pursued as they are not likely to result in significant overall user experience improvements, if any.

Based on the test conducted as well as the authors' own experiences, the latency goal for acceptable Remote Mouse user experience should be set to the 0 to 100 ms range. According to our test results, these kinds of latencies can be achieved with 3G and better mobile network connections; 2G connectivity is not sufficient.

[15] http://www.w3.org/TR/CSP/

The technology stack related to WebSockets is stable and ready for production use in both browser and server side. We did not run into any issues on either browser or server side during the Remote Mouse development process that would have been related to WebSockets implementations. On the contrary, we found the APIs and implementations very easy to use, and their performance matches or exceeds the requirements for Remote Mouse. We were able to implement more functionality than our initial plan included while spending only roughly 80% of the time allotted for implementation in our research plan, while not taking advantage of any browser side third party libraries and only very minimal ones at server side.

We have identified two significant areas for future work on Remote Mouse. First, creating a browser extension to replace the bookmarklet script injection approach could be a way to overcome its single page and content security policy drawbacks. However, that would make it browser specific and require deployment and installation of the extension, thus weakening its universal usability. Second, further work on processing several batched position events on the controllee in a way that the browser would also render all the position movements could result in even better performing overall implementation and user experience.

A prominent use case for Remote Mouse is remote control of web based presentations and applications, using for example a laptop computer to host the presentation or web application and displaying its screen to viewers, while controlling it remotely from a mobile device. Because the contents of the controllee screen are not visible in the controller, this use case is in our implementation limited to setups where the user operating the controller can see the controllee screen. If the controllee screen would be available for remote viewing, use cases like for example remote assistance of web application use would be quite relevant. The technology and principle of tracking the pointer or touch movements could also be used for recording user actions on a web site, for example for usability evaluation, user interface research, and trials.

References

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