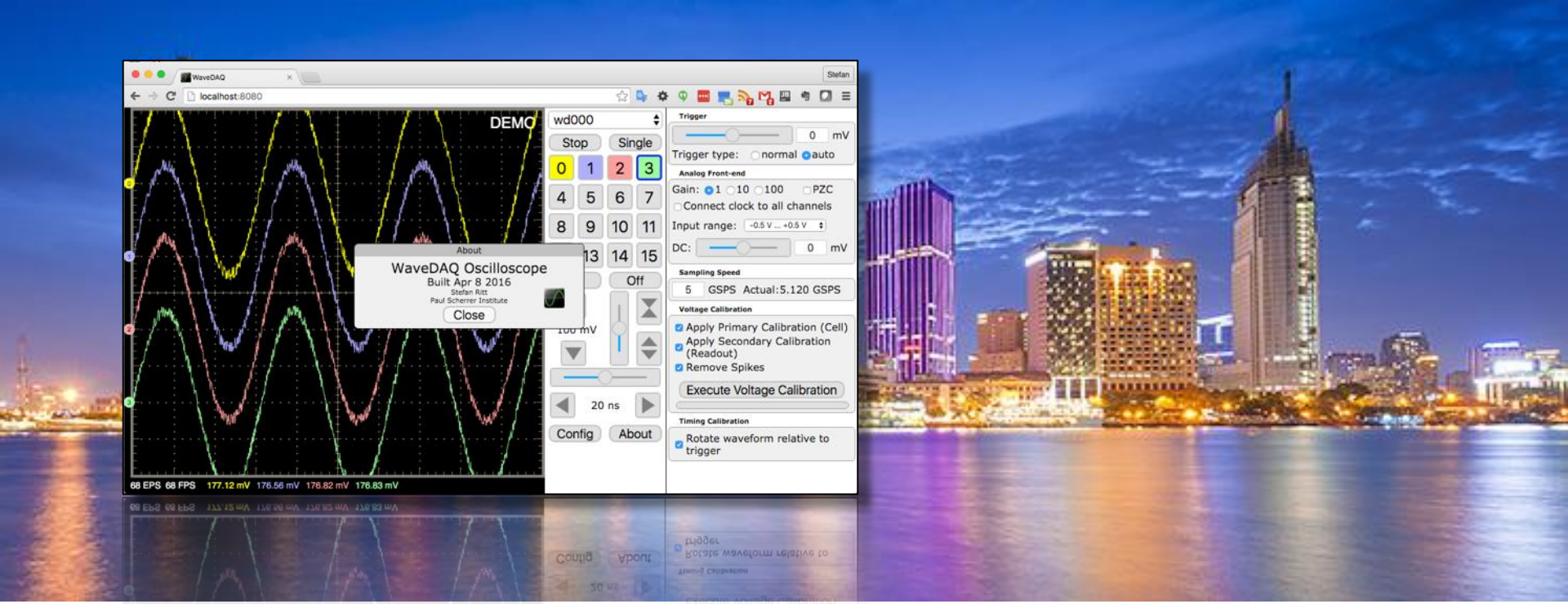


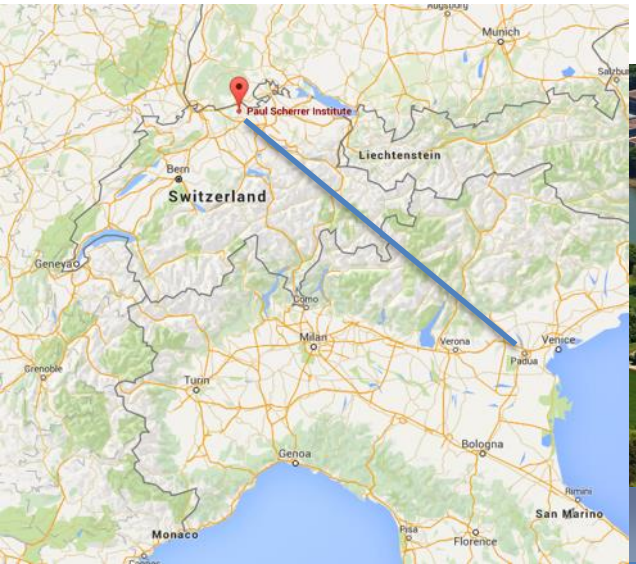
Stefan Ritt, Paul Scherrer Institute, Switzerland

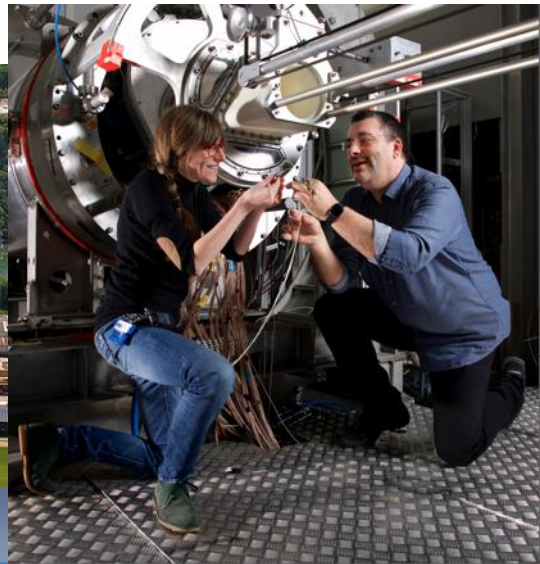
REAL-TIME DATA VISUALIZATION AND CONTROL USING MODERN WEB TECHNOLOGIES

2ND REAL TIME SCHOOL, HO CHI MINH CITY, VIETNAM, 2016

Something about myself

- Studied at University of Karlsruhe, Germany
- Head of muon physics group at the Paul Scherrer Institute, Switzerland
- Developer of
  ELOG electronic logbook (midas.psi.ch/elog)
  MIDAS DAQ system (midas.triumf.ca)
  DRS chip (www.psi.ch/drs)



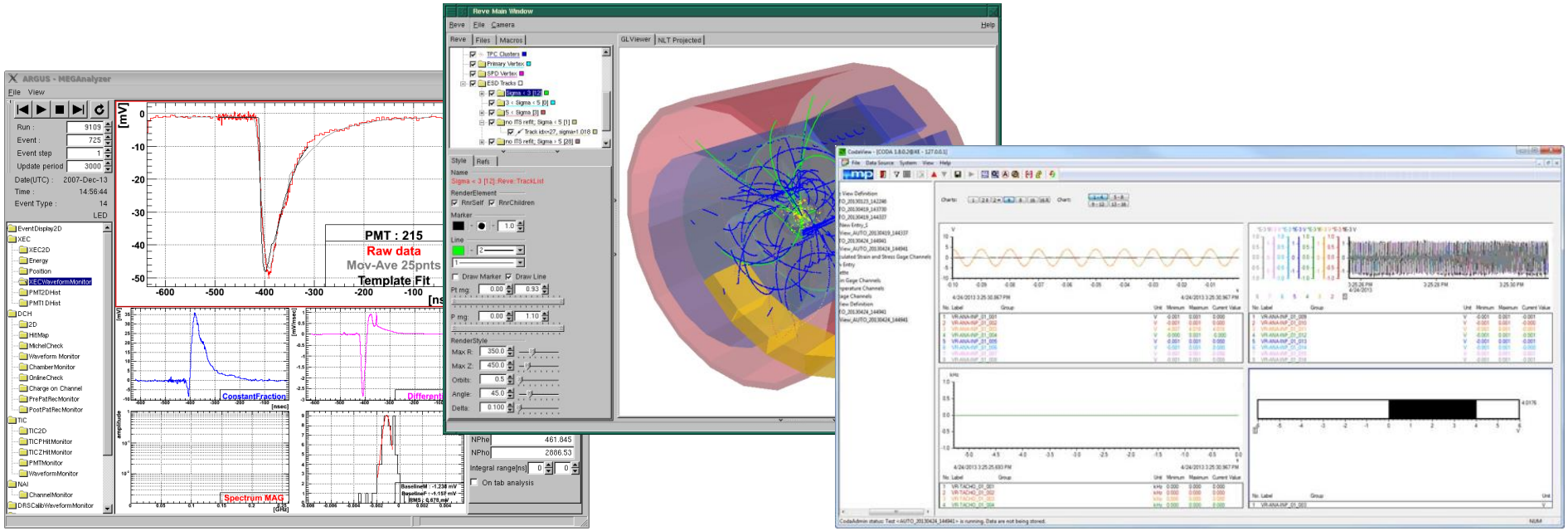


About this Lecture

- Web technologies from a user's point of view (will cover ~5% of HTML) – mainly examples driven
- Slow start with basics, advanced topics at the end
- Log in to wireless network:
  SSID **XXX** Password **XXX**
- Please follow all practical examples with your own laptop:
  jsfiddle.net/user/stefanritt
- Slides, programs, … on Dropbox:
  db.tt/WWkBEhMQ
- Please ask questions any time

Experimental Data Visualization and Control

- The traditional way
  - Dedicated programs (ROOT, Qt, TCL/TK, …)
  - Must be compiled for different OS
  - Require certain libraries to be installed
  - Limited smartphone support



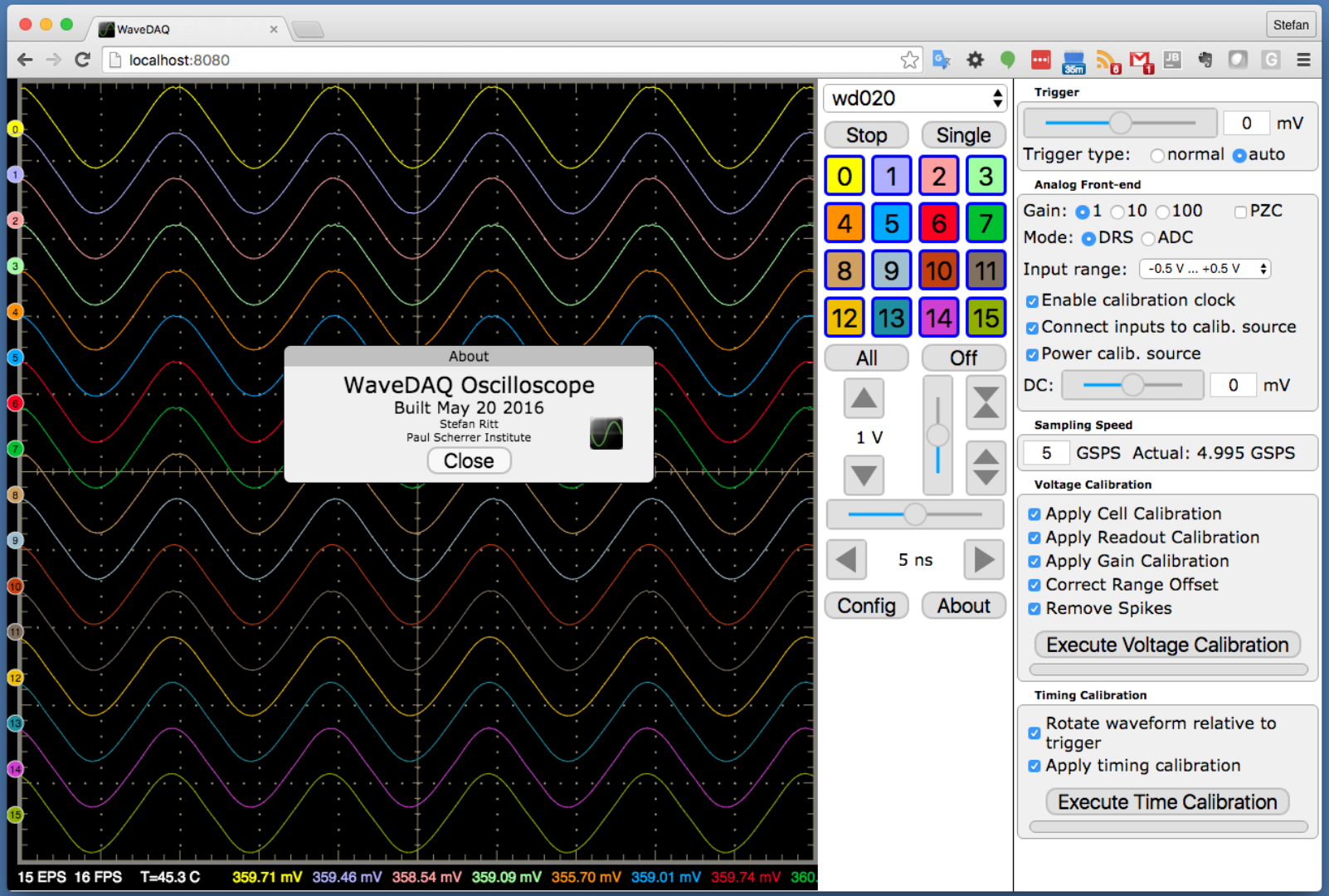
A new opportunity

HTML5 – CSS3 – JavaScript – JSON

Advantages of Web Control

- You only need a browser to access your experiment (from home, public terminal, smartphone)
- Software updates get deployed automatically
- Easy creation of web pages showing several experiments
- Modern browsers run JavaScript at the speed of native programs some years ago
- Debugging of code inside the browser

What you will learn – a little teaser



Agenda

- Basic Web technologies
  - HTML
  - CSS
  - Forms
  - JavaScript
  - DOM
- Advanced Web technologies
  - AJAX
  - JSON
  - Canvas

Agenda

- Server side implementation
  - Mongoose server
  - JSON-RPC
  - Implementation on Raspberry Pi
- Advanced web concepts
  - Push technology with Websockets
  - Floating dialog boxes
  - Dialog widgets

Agenda

- Applications
  - Temperature display
  - Turning LEDs on and off on server
  - Pushing information to browsers
  - Oscilloscope application
  - Other Applications

HTML + CSS

Hypertext Markup Language

```
<div>
Hello Real Time Conference
</div>
```

Cascading Style Sheets

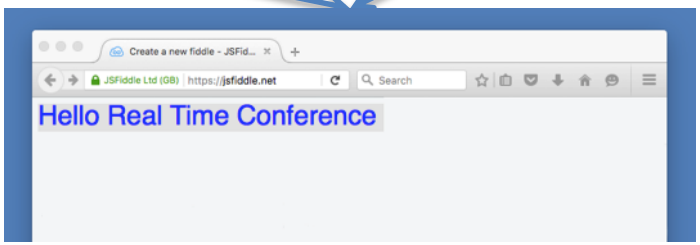
Selector
Declaration
Declaration
Declaration
Declaration

```
div {
  font-family:sans-serif;
  font-size:200%;
  color:blue;
  background-color:#E0E0E0;
}
```

Property
Value

Browser

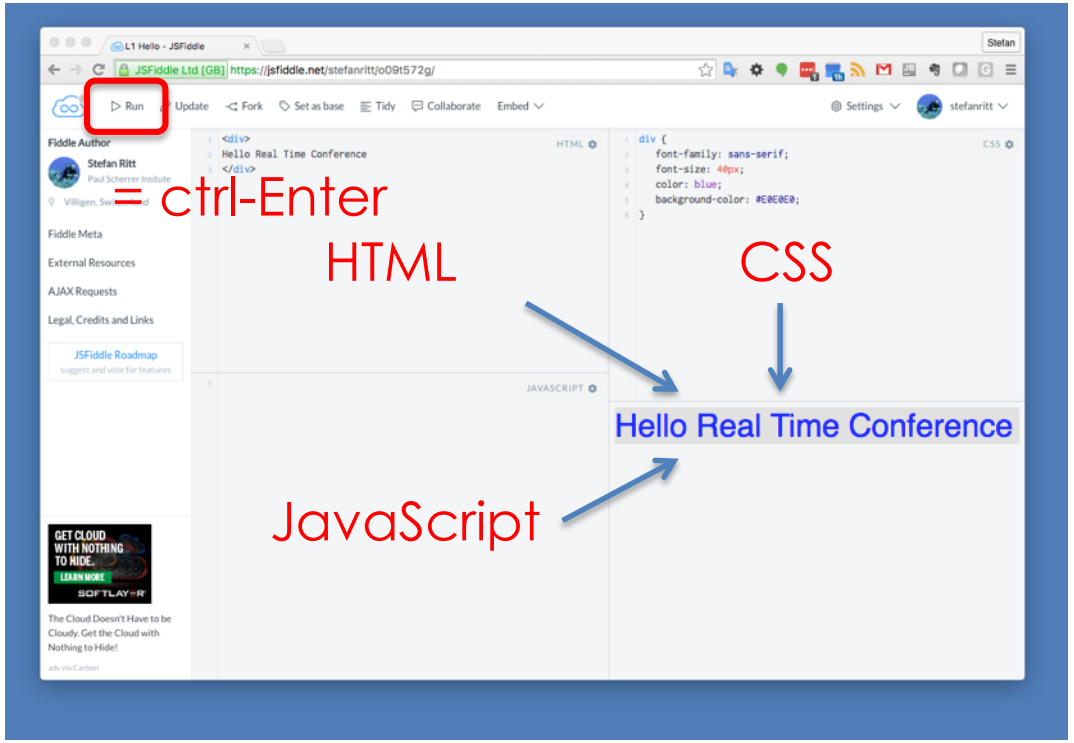
```
<style>
  div {
    color:blue;
    font-size:200%;
  }
</style>
```



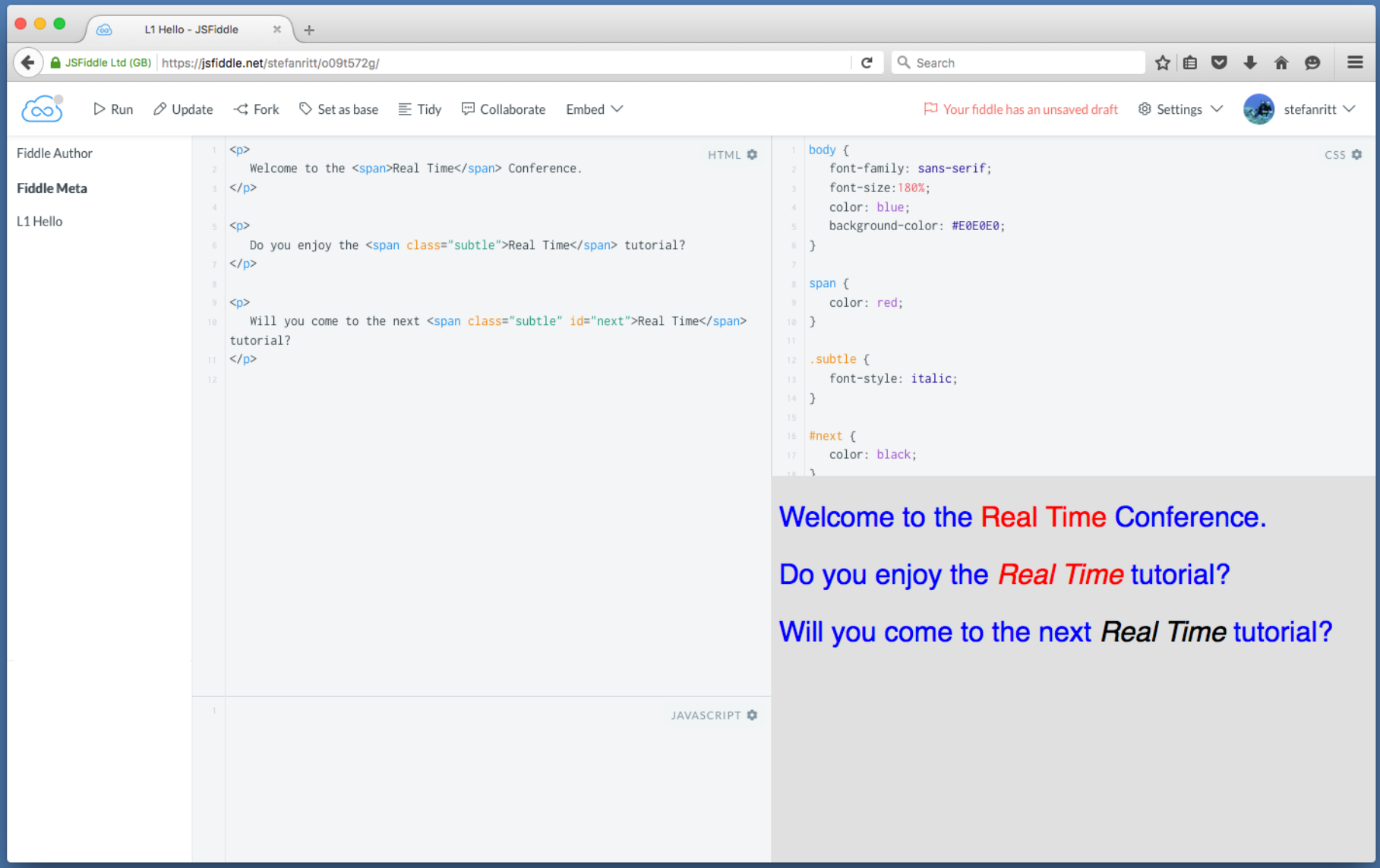

```
<head>
  <link rel="stylesheet" type="text/css" href="mystyle.css">
</head>
```

jsfiddle.net

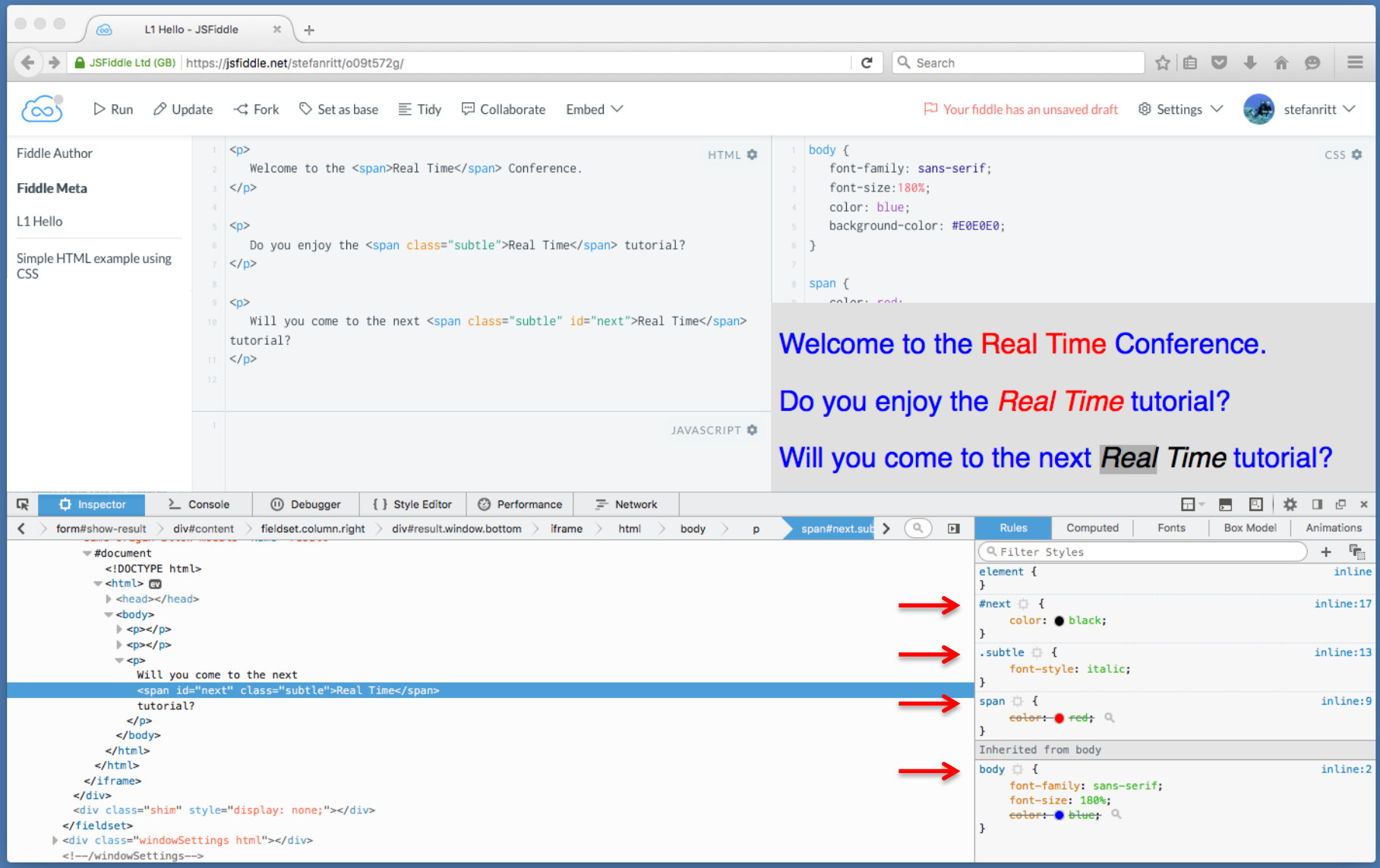
- Online tool to test HTML, CSS & JavaScript
- Documentation: doc.jsfiddle.net
- Alternatives:
  cssdeck.com
  jsbin.com
  dabblet.com



First Example



Debugging CSS



CSS Selectors

Selector	Example	Description
.	.subtle	Selects all elements with class="subtle"
#	#next	Selects all elements with id="next"
element	p	Selects all elements
element > element	div > p	Selects all <p> elements where the parent is a element
element[attribute]	input[type="text"]	Select all <input type="text"> elements
element:nth-child(i)	p:nth-child(2)	Select all <p> elements which are the second child of their parent

```
p:nth-child(odd) {
  background: #F0F0F0;
}
p:nth-child(even) {
  background: #C0C0C0;
}
```

http://www.w3schools.com/cssref/css_selectors.asp

HTML - CSS

- Do make use of separated HTML and CSS `Hello <font color="red">Conference</font>` is bad practice!
- Overview of CSS options: http://www.w3schools.com/css/
- Debug CSS e.g. with Chrome Develop Tools or Firefox Inspector
- Google Search is your friend: "CSS text size" → { font-size: 200%; }
- www.w3schools.com, wiki.selfhtml.org (only German)

Full minimal HTML5

```
<!doctype html>
<html lang="en">
  <head>
    <meta http-equiv="content-type" content="text/html; charset=utf-8">
    <title>Minimal Page</title>
    <link rel="stylesheet" type="text/css" href="style.css">
    <script type="text/javascript" src="script.js"></script>
  </head>
  <body>
    Hello World
  </body>
</html>
```

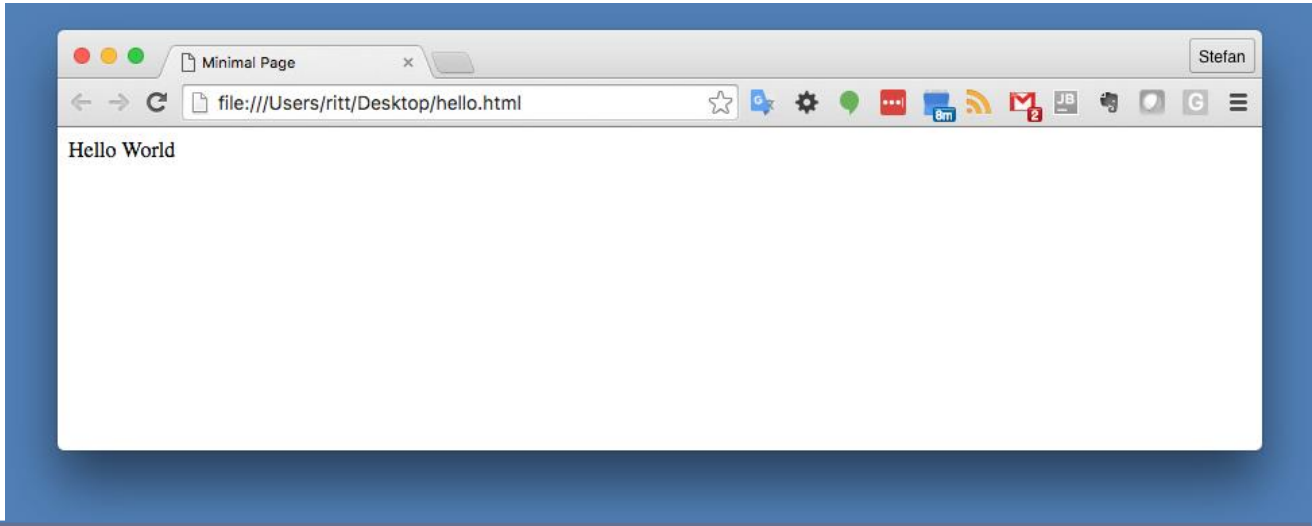
Tells the browser that this is an HTML5 file

Primary language

Encoding

Optional

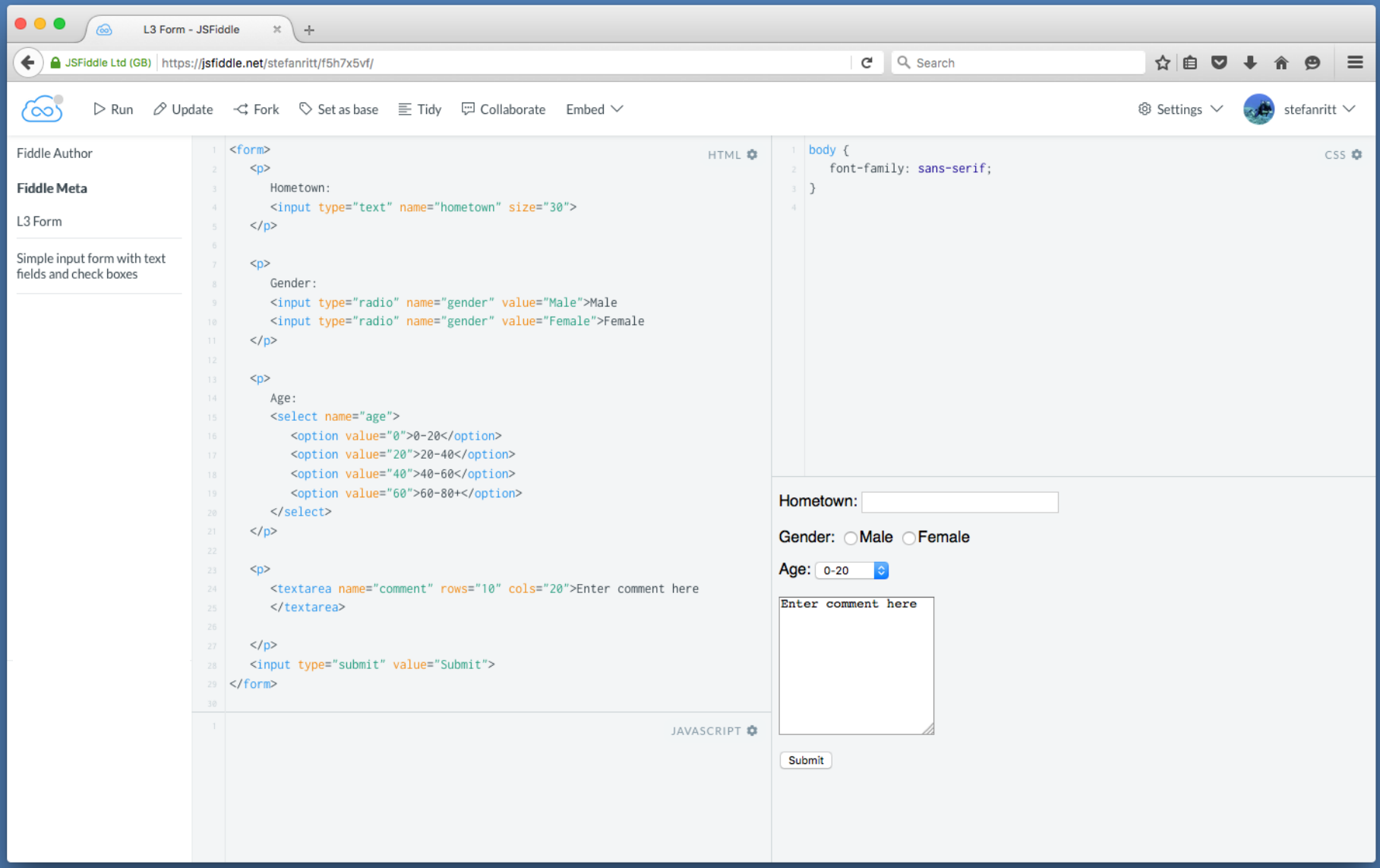
Page contents



Forms

- Forms must be embedded in <form>… </form> tag
- Text input, check box, radio box, drop-down list, submit button
- Form contents gets submitted in URL (for "get" method):
  `http://your.host?name=Stefan&gender=Male`
- Form submission is obsolete!

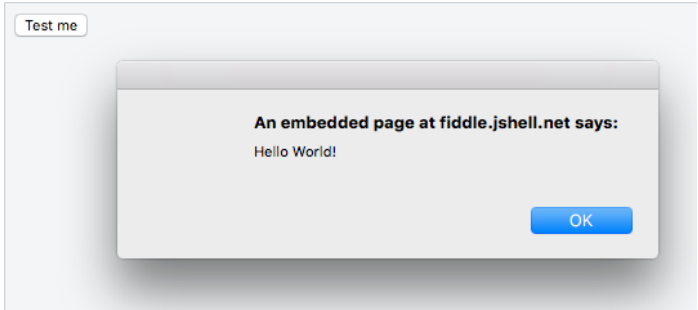
Form Example



JavaScript

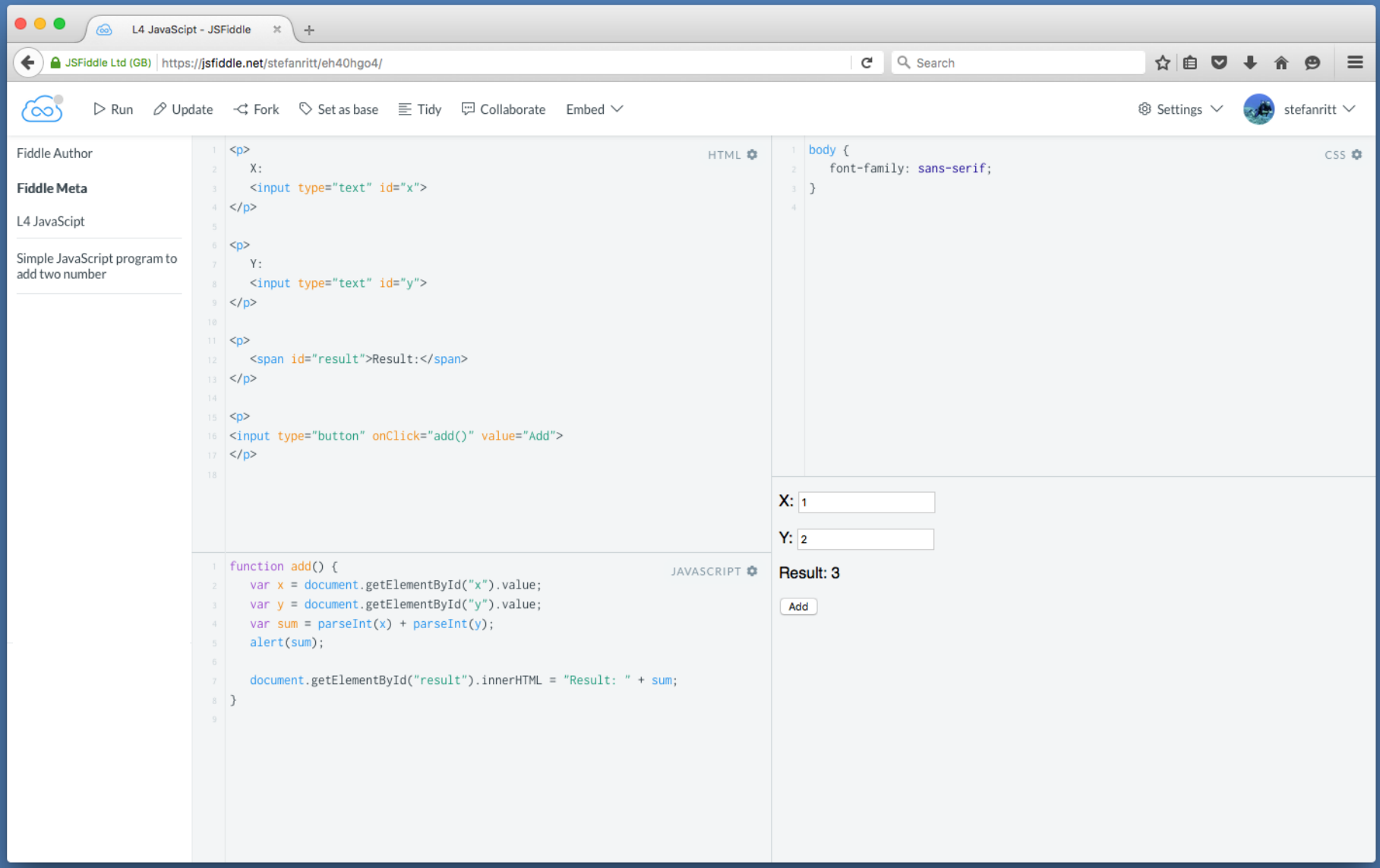
- Standardized *interpreted* language running in your browser
- Very slim:

```
<input type="button" value="Test me" onclick="alert('Hello World')">
```

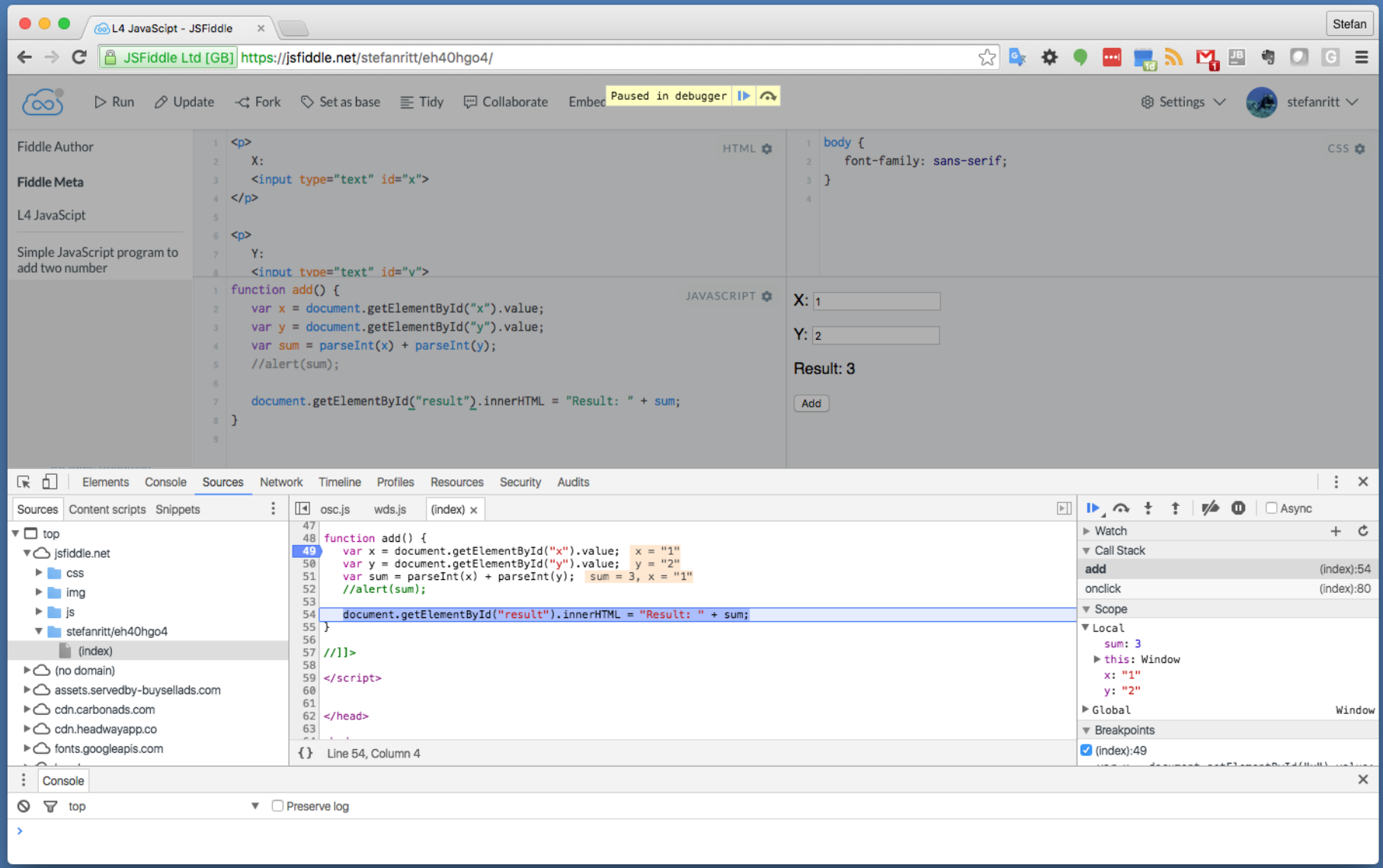


- Similar to C/C++
- Browser-"war" for the fastest interpreter: JavaScript runs as fast as compiled code about ten years ago
  → JS can be used for complicated things

JavaScript Example



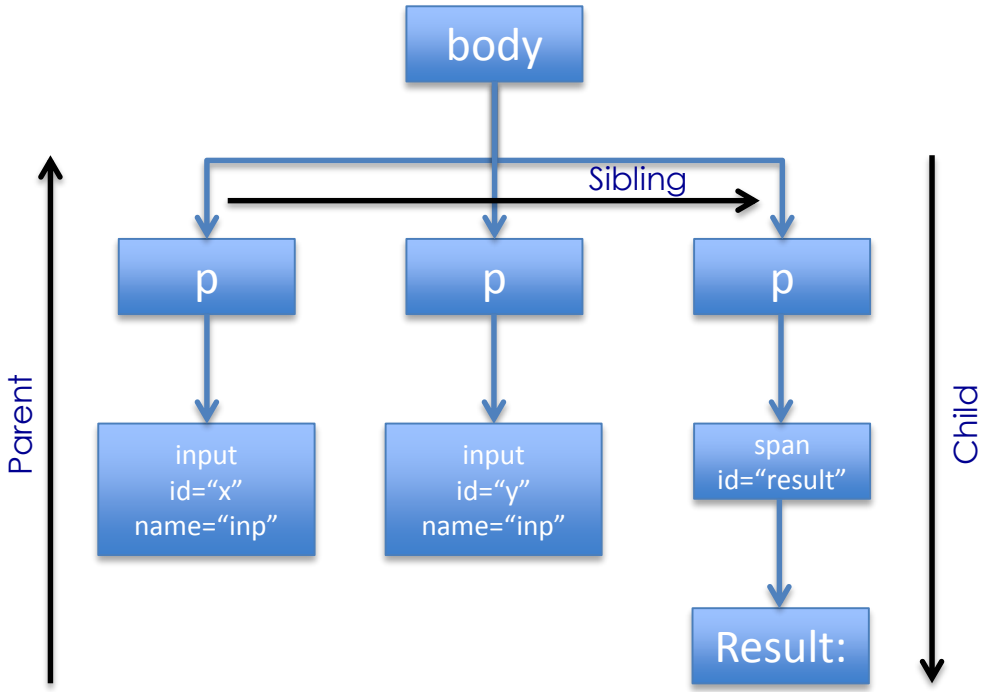
Debugging JavaScript



DOM

Document Object Model behind any web page *plus* interface to that model

```
<body>
  <p>
    <input id="x" name="inp">
  </p>
  <p>
    <input id="y" name="inp">
  </p>
  <p>
    <span id="result">
      Result:
    </span>
  </p>
</body>
```



JavaScript DOM modifications

- Access by ID:
```
var e = document.getElementById("result");
```
- Access by Name:
```
var e = document.getElementsByName("input");
for (i=0 ; i<e.length ; i++)
  e[i].value = "0";
```
- Access by Class Name:
```
document.getElementsByClassName("subtle");
```
- By relation:
```
e.firstChild e.nextSibling e.parentNode …
```
- Predefined elements:
```
document.title document.images …
```
- CSS Style:
```
e.style.color e.style.fontFamily …
```

jQuery

- jQuery is a JavaScript library which simplifies JavaScript programming
- Include it with

```
<script
src="https://ajax.googleapis.com/ajax/libs/jquery/1.12.2/jquery.min.js">
```

- Use "$" to select elements and special jQuery functions

JavaScript

```
var e = document.getElementsByClass("subtle");
for (var i=0 ; i<e.length ; i++)
   e.style.color = "red";
```

jQuery

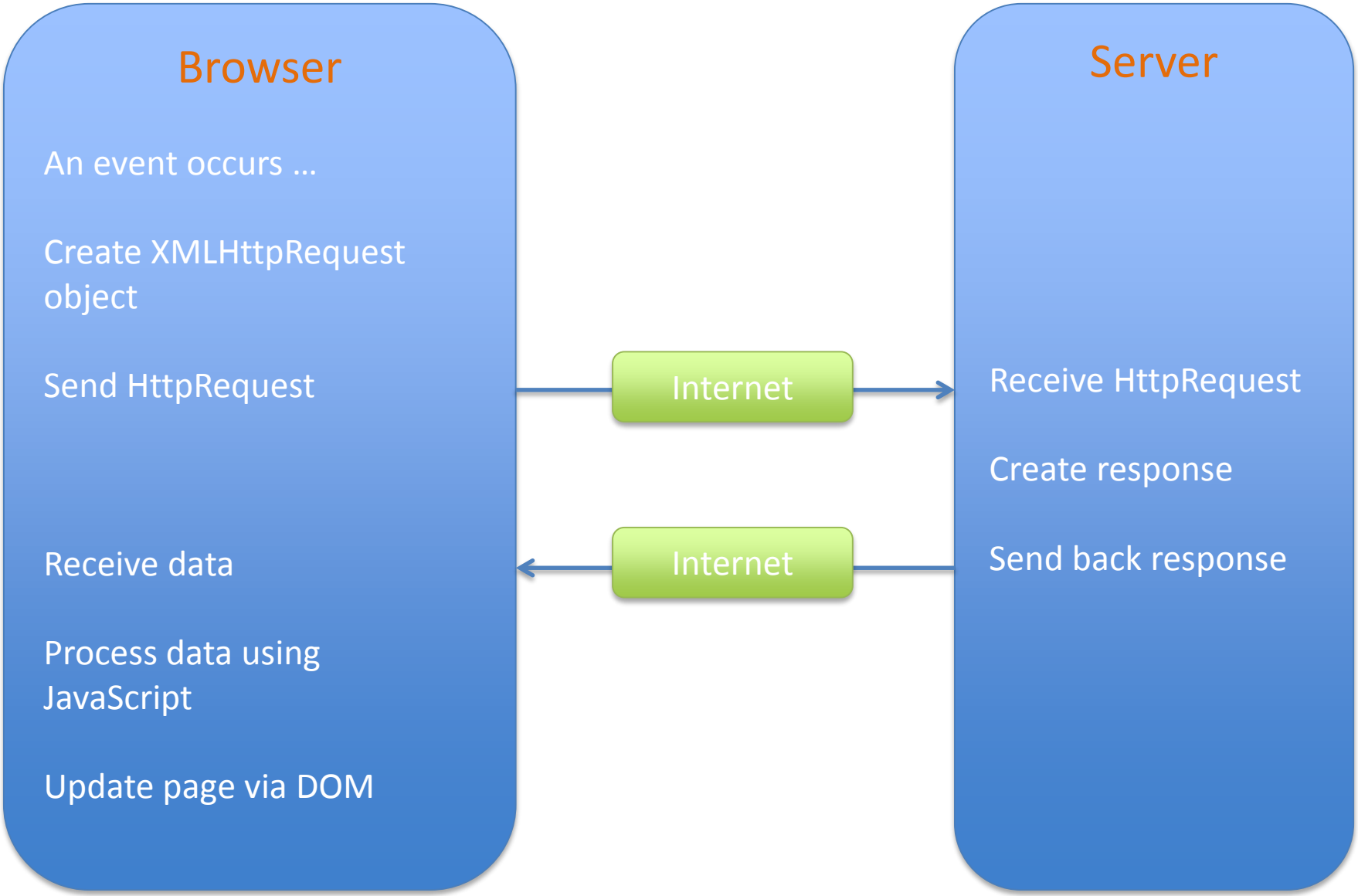
```
$(".subtle").css("color", "red");
```

CSS selector

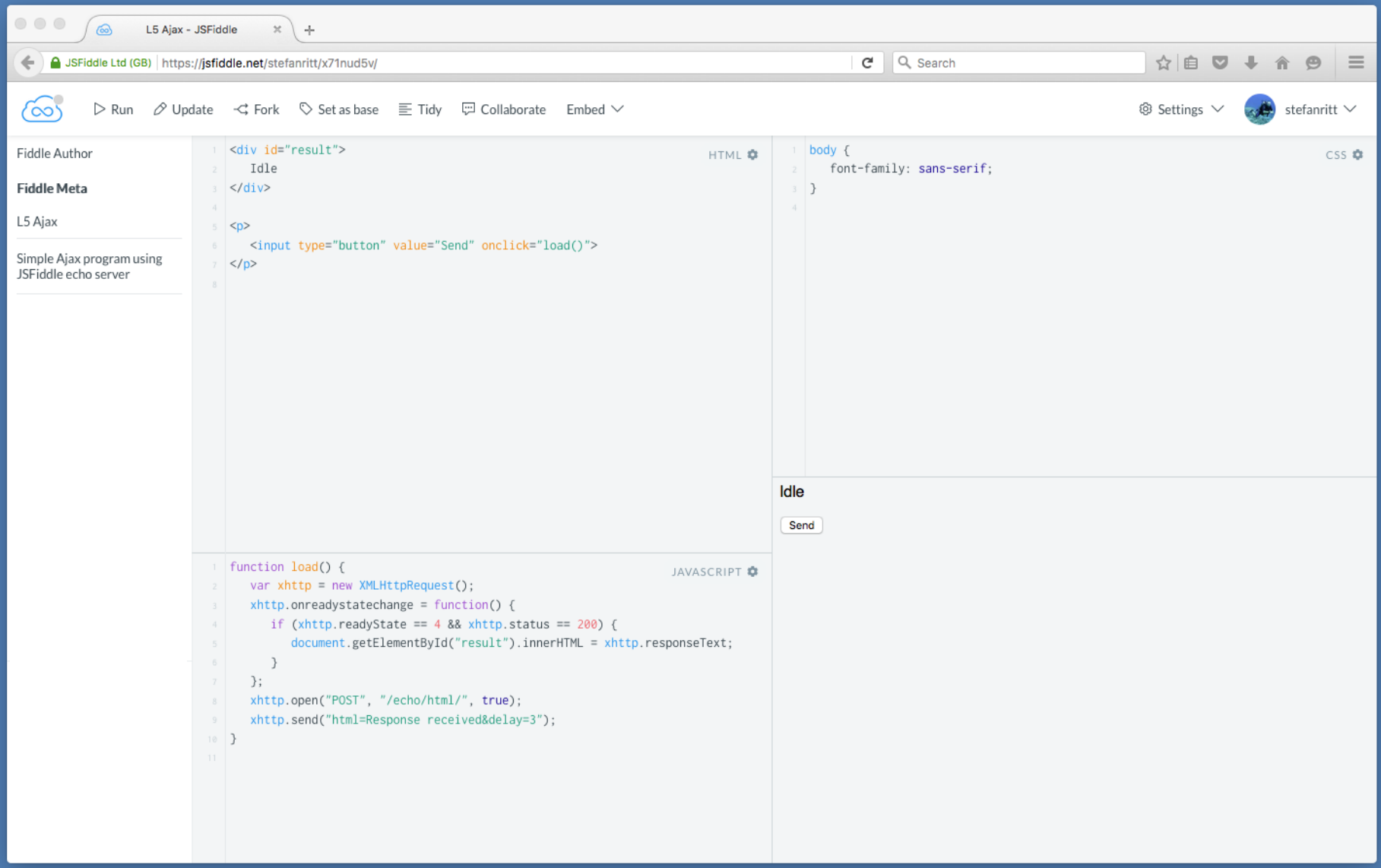
AJAX

- Old days: Form – Submit – New Page
- Slow, network intensive, page flicker
- Asynchronous Javascript and (XML)
  - Update web page without reloading the whole page
  - Send data to the server AFTER the page has loaded
  - Receive data from server AFTER the page has loaded
  - Technique for fast dynamic web pages
- Getting popular in 2005 by Google Suggest

How AJAX Works



AJAX example



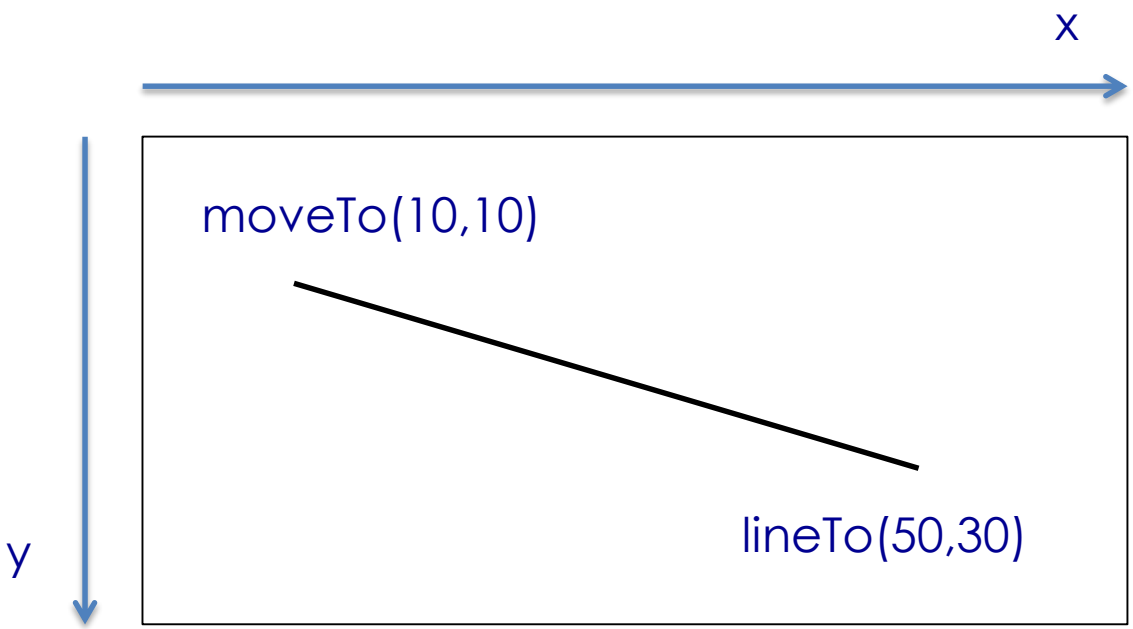
JSON

- JavaScript Object Notation
- ASCII format for storing and transportation of objects
- Pure text format, language independent, self-describing

JSON	Notation	Example
Data	“name”:”value”	“firstName”:”Stefan”
Object	{ Data, Data }	{“firstName”:”Stefan”, ”lastName”:”Ritt” }
Array	“name”:[Object,Object]	“attendees”:[{“firstName”:”Stefan”, ”lastName”:”Ritt” }, {“firstName”:”Linus”, ”lastName”:”Torvalds” }]

Canvas

- Basic HTML is mainly for text display
- Vector graphics with SVG, icons and **canvas**
- A canvas is a HTML5 element on which one can draw dynamic graphics via JavaScript



Canvas Example

L7 Canvas - JSFiddle

JSFiddle Ltd (GB) | https://jsfiddle.net/stefanritt/0rj05pqo/

Search

Run | Update | Fork | Set as base | Tidy | Collaborate | Embed | Settings | stefanritt

Fiddle Author

Fiddle Meta

L7 Canvas

Simple Canvas Demo

HTML

```
<h1>
Canvas Demo
</h1>

<canvas id="cvs" width="200" height="200"></canvas>
```

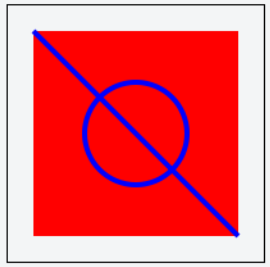
CSS

```
body {
  font-family: sans-serif;
}

canvas {
  border: 1px solid black;
}
```

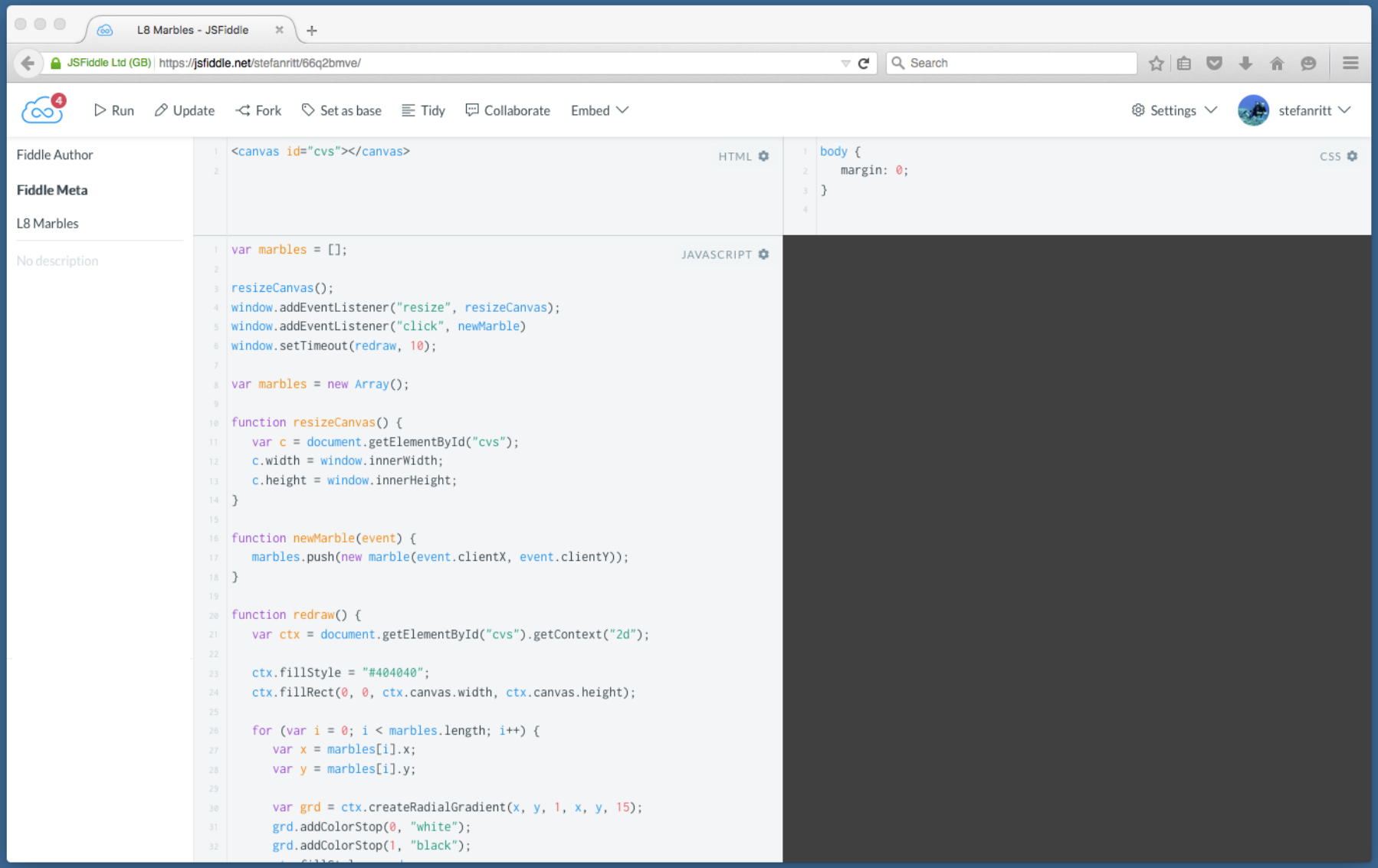
JAVASCRIPT

```
var c = document.getElementById("cvs");
var ctx = c.getContext("2d");

ctx.fillStyle = "red";
ctx.fillRect(20, 20, 160, 160);

ctx.beginPath();
ctx.lineWidth = 4;
ctx.strokeStyle = "blue";
ctx.moveTo(20, 20);
ctx.lineTo(180, 180);
ctx.stroke();

ctx.beginPath();
ctx.arc(100, 100, 40, 0, 2 * Math.PI);
ctx.stroke();
```

Canvas Demo



More complex example



Balls 1

```
<head>
<script>
var balls = [];
var lastTime = 0;
var lastTimeFrame = 0;
var nFrames = 0;
var fps = 0;

function init() {
   resizeCanvas();

   // attach event handlers to canvas
   var c = document.getElementById("cvs");
   c.addEventListener("resize", resizeCanvas);
   c.addEventListener("click", newBall);
   c.addEventListener("touchstart", newBall, true);
   window.addEventListener("keypress", keyPress)

   window.requestAnimationFrame(frame);
}

function resizeCanvas()
{
   // stretch canvas to the whole client area
   var c = document.getElementById("cvs");
   c.width = document.documentElement.clientWidth;
   c.height = document.documentElement.clientHeight;
   if (c.height > 1000)
      c.height = 1000;
}
```

```
function newBall(e)
{
   // create new ball at cursor position
   if (e.type == "click")
      balls.push(new ball(e.clientX, e.clientY));
   else if (e.type == "touchstart") {
      e.preventDefault();
      balls.push(new ball(e.targetTouches[0].clientX,
                          e.targetTouches[0].clientY));
      }
}

function keyPress(e)
{
   var c = (typeof e.which == "number") ?
               e.which : e.keyCode;
   if (c == 'c'.charCodeAt(0)) // 'c' clears all balls
      balls = [];
   if (c == ' '.charCodeAt(0)) // space pushes up
      balls.forEach(function(m) {
         m.vy = Math.random() * 1000 - 1500;
         m.vx = Math.random() * 1000 - 500;
      });
   e.preventDefault();
}
```

Balls 2

```
function frame()
{
   var ctx =
document.getElementById("cvs").getContext("2d");

   // fill background
   ctx.fillStyle = "#606060";
   ctx.fillRect(0, 0, ctx.canvas.width,
ctx.canvas.height);

   // time since last frame
   var now = new Date().getTime(); // get time in ms
   var dt = lastTime > 0 ?
            (now - lastTime) / 1000 : 0;
   lastTime = now;

   // calculate frames per second
   nFrames++;
   if (now >= lastTimeFrame + 1000) {
      lastTimeFrame = now;
      fps = nFrames;
      nFrames = 0;
   }

   // display number of frames
   ctx.font = "20px sans-serif";
   ctx.fillStyle = "white";
   ctx.strokeStyle = "none";
   ctx.fillText(fps, 10, 20);
```

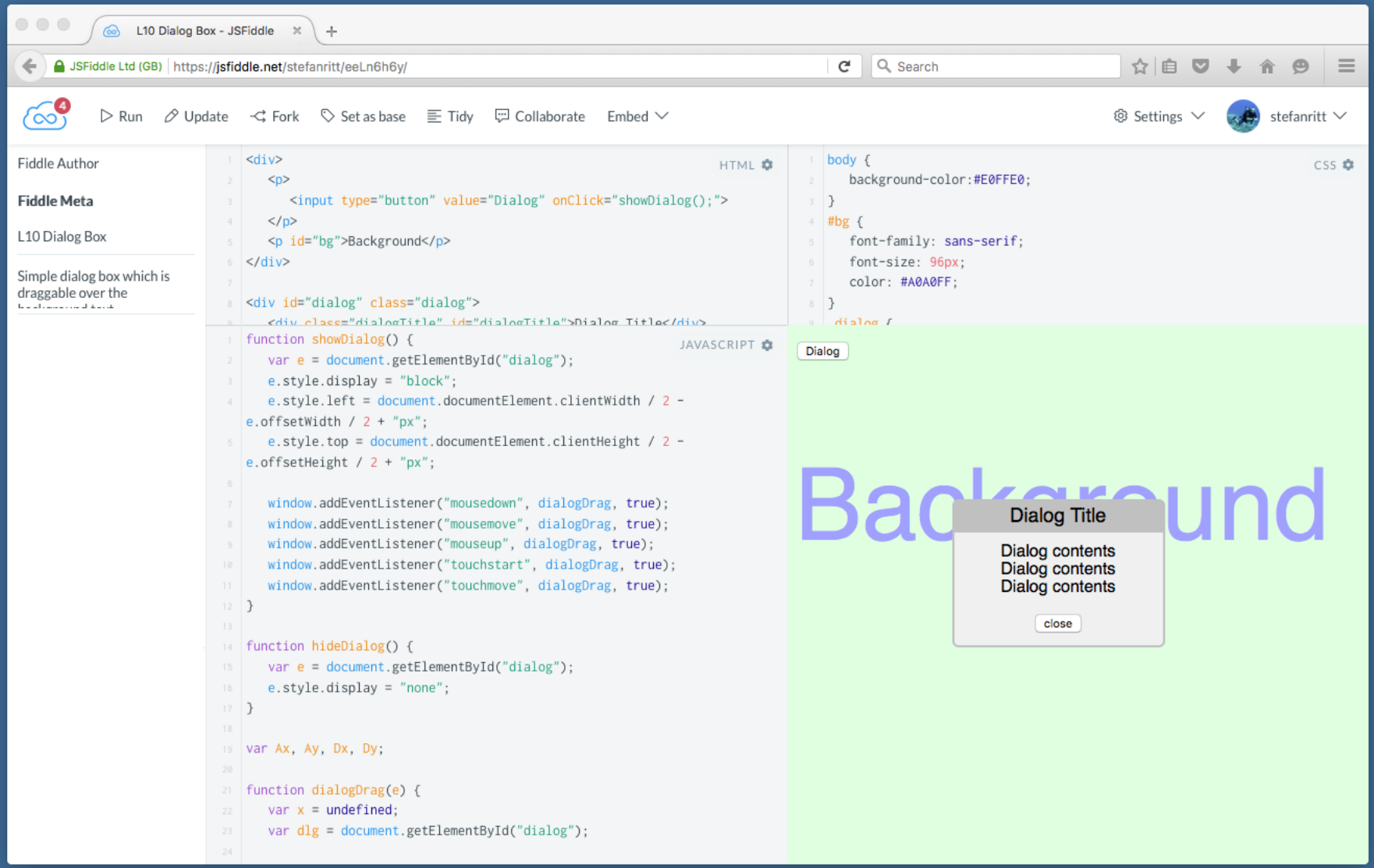
```
for (var i = 0; i < balls.length; i++) {
     var x = balls[i].x;
     var y = balls[i].y;

     var grd = ctx.createRadialGradient(x, y,
                  1, x, y, 15);
     grd.addColorStop(0, "white");
     grd.addColorStop(1, "black");
     ctx.fillStyle = grd;

     // draw ball
     ctx.beginPath();
     ctx.arc(x, y, 10, 0, 2 * Math.PI);
     ctx.fill();

     // integrate equations of motion
     balls[i].x += balls[i].vx * dt;
     balls[i].y += balls[i].vy * dt;
```

Balls 3

```
      // handle wall reflections
      if (balls[i].x + balls[i].vx*dt <= 10) {
         balls[i].x = 10;
         balls[i].vx = -balls[i].vx;
      }
      if (balls[i].x + balls[i].vx*dt >=
          ctx.canvas.width - 10) {
         balls[i].x = ctx.canvas.width - 10;
         balls[i].vx = -balls[i].vx;
      }
      if (balls[i].y + balls[i].vy*dt <= 10) {
         balls[i].vy = -balls[i].vy;
         balls[i].y = 10;
      }
      if (balls[i].y + balls[i].vy*dt >=
          ctx.canvas.height - 10) {
         balls[i].y = ctx.canvas.height - 10;
         balls[i].vy = -balls[i].vy;
      }

      // apply friction and gravity
      balls[i].vx *= 0.995; // friction
      balls[i].vy *= 0.995;
      balls[i].vy += 3;     // gravity
   }

   window.requestAnimationFrame(frame);
}
```

```
function ball(x, y)
{
   // initialize new ball with random velocity
   this.x = x;
   this.y = y;
   this.vx = Math.random() * 1000 - 500;
   this.vy = Math.random() * 1000 - 1000;
}
</script>

<style>
body { margin: 0; }
</style>
</head>

<body onload="init()">
<canvas id="cvs"></canvas>
</body>
```

Dialog Box

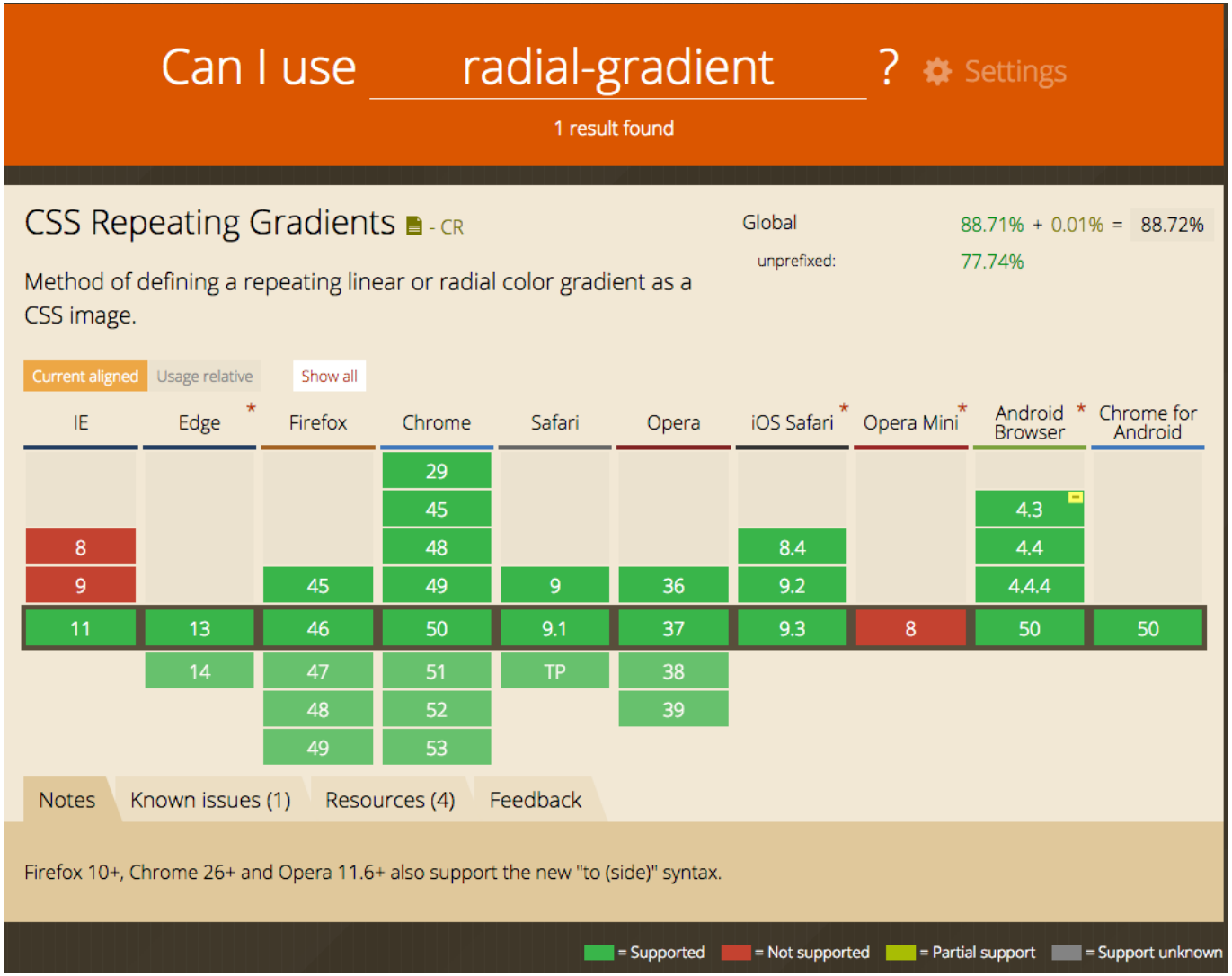

L10 Dialog Box - JSFiddle
JSFiddle Ltd (GB) https://jsfiddle.net/stefanritt/eeLn6h6y/
Search
Run
Update
Fork
Set as base
Tidy
Collaborate
Embed
Settings
stefanritt
Fiddle Author
Fiddle Meta
L10 Dialog Box
Simple dialog box which is draggable over the
HTML

<input type="button" value="Dialog" onClick="showDialog();">

Background

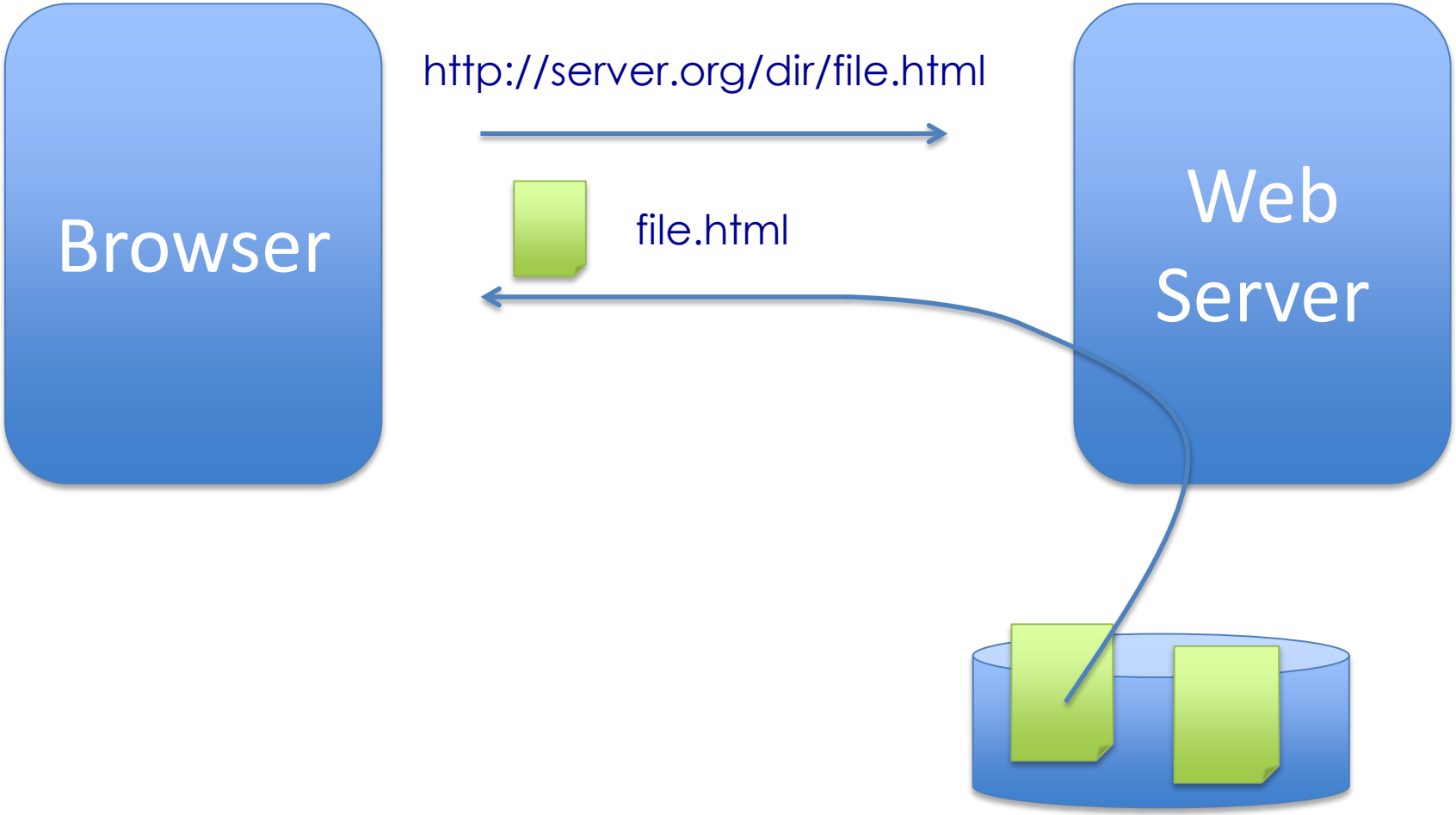
CSS
body {
background-color:#E0FFE0;
}
#bg {
font-family: sans-serif;
font-size: 96px;
color: #A0A0FF;
}
JAVASCRIPT
function showDialog() {
var e = document.getElementById("dialog");
e.style.display = "block";
e.style.left = document.documentElement.clientWidth / 2 -
e.offsetWidth / 2 + "px";
e.style.top = document.documentElement.clientHeight / 2 -
e.offsetHeight / 2 + "px";
window.addEventListener("mousedown", dialogDrag, true);
window.addEventListener("mousemove", dialogDrag, true);
window.addEventListener("mouseup", dialogDrag, true);
window.addEventListener("touchstart", dialogDrag, true);
window.addEventListener("touchmove", dialogDrag, true);
}
function hideDialog() {
var e = document.getElementById("dialog");
e.style.display = "none";
}
var Ax, Ay, Dx, Dy;
function dialogDrag(e) {
var x = undefined;
var dlg = document.getElementById("dialog");
Dialog
Background
Dialog Title
Dialog contents
Dialog contents
Dialog contents
close

Browser Compatibility http://caniuse.com



Web servers

www.apache.org

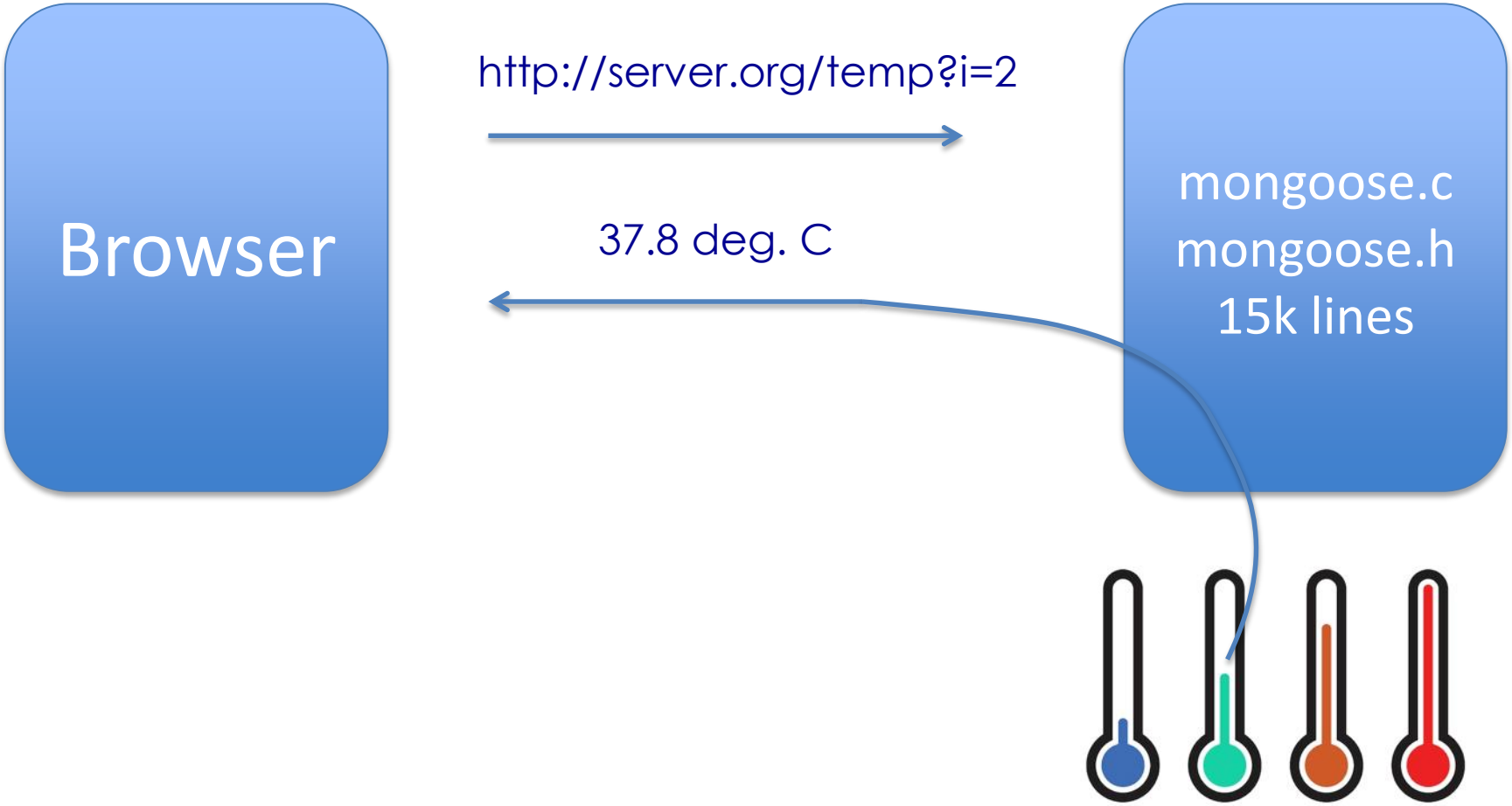


Web Servers

- Web servers are historically file based
- Apache is a large complex but powerful server
- For real-time control and monitoring, we need:
  - Slim server (e.g. embedded devices)
  - Servers with direct access to hardware
  - Support of protocols such as Websockets and SSL
  - Should compile everywhere
  - Easy to install and extend

Mongoose Server

https://github.com/cesanta/mongoose



Minimal mongoose program 1

```
#include "mongoose.h"

static struct mg_serve_http_opts s_http_server_opts;
static char *s_http_port = "8080";

int main(int argc, char *argv[])
{
  struct mg_mgr mgr;
  struct mg_connection *nc;

  mg_mgr_init(&mgr, NULL);
  nc = mg_bind(&mgr, s_http_port, ev_handler);
  if (nc == NULL) {
    fprintf(stderr, "Error starting server on port %s\n", s_http_port);
    exit(1);
  }

  mg_set_protocol_http_websocket(nc);
  s_http_server_opts.document_root = ".";
  s_http_server_opts.enable_directory_listing = "yes";

  printf("Starting server on port %s\n", s_http_port);

  while(1) {
    mg_mgr_poll(&mgr, 1000);
  }

  return 0;
}
```

Minimal mongoose program 2

```
static void ev_handler(struct mg_connection *nc, int ev, void *ev_data)
{
  char str[100];
  int  index;
  double temp;
  struct http_message *hm = (struct http_message *) ev_data;

  if (ev == MG_EV_HTTP_REQUEST) {
    if (mg_vcmp(&hm->uri, "/temp") == 0) {

      // retrieve index from URL
      mg_get_http_var(&hm->query_string, "index", str, sizeof(str));
      index = atoi(str);

      // read temperature
      temp = 20+(int)(100.0*rand()/RAND_MAX)/10.0;

      // send reply
      mg_printf(nc, "%s", "HTTP/1.1 200 OK\r\nTransfer-Encoding: chunked\r\n\r\n");
      mg_printf_http_chunk(nc, "{\r\n");
      mg_printf_http_chunk(nc, "  \"index\": %d,\r\n", index);
      mg_printf_http_chunk(nc, "  \"temp\": %lg\r\n", temp);
      mg_printf_http_chunk(nc, "}\r\n");
      mg_send_http_chunk(nc, "", 0); // send empty chunk as end of response
    } else {
      // serve static content
      mg_serve_http(nc, hm, s_http_server_opts);
    }
  }
}
```

HTML page

```
<!DOCTYPE html>
<html>
<head>
   <title>Temperature Display</title>

<style>
   body {
      margin: 0;
   }
   #temp {
      height: 300px;
      background: yellow;
      background: linear-gradient(red,
yellow);

      font-family: sans-serif;
      font-size: 250px;
      text-align: center;
   }
</style>
```

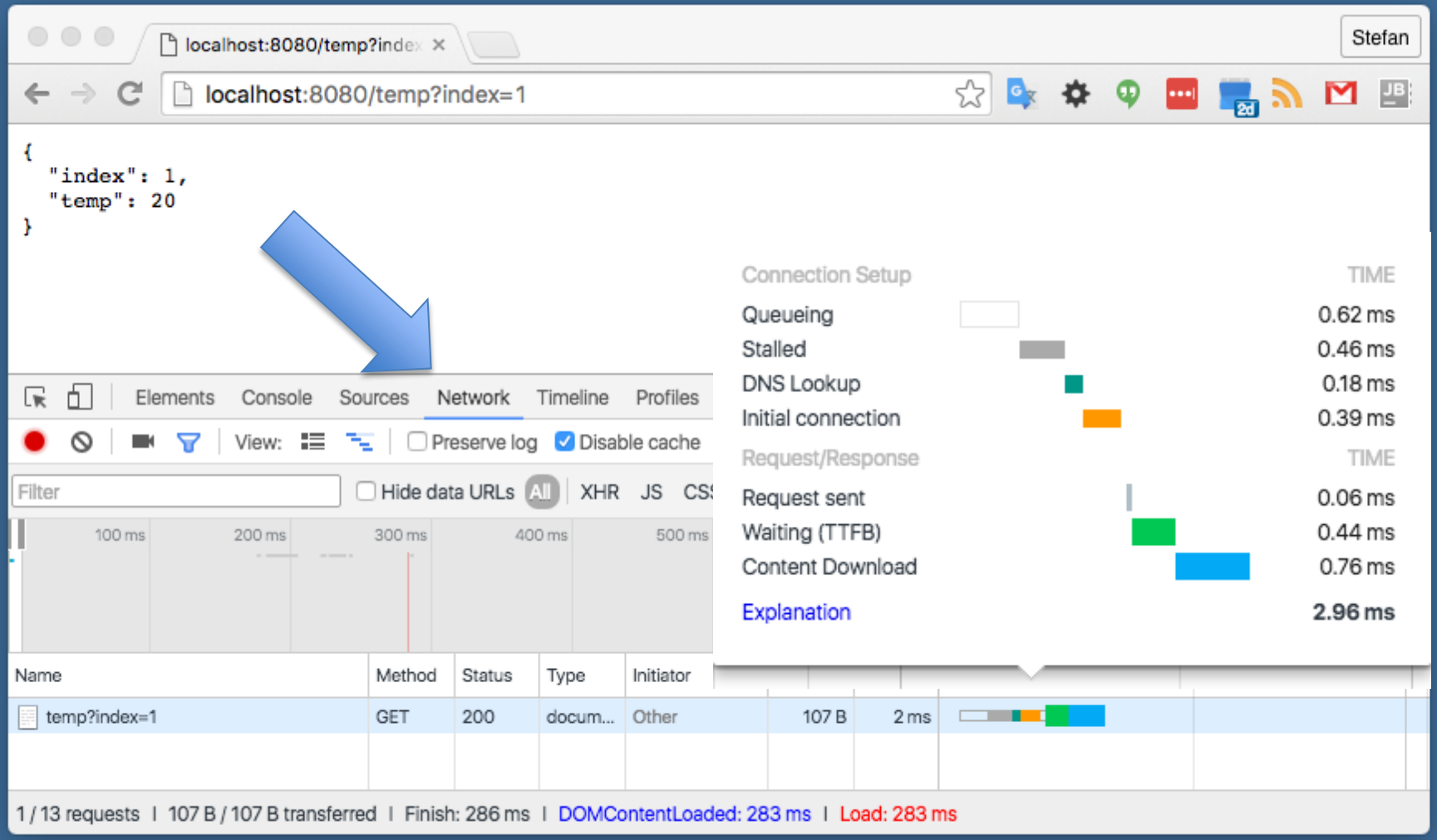
```
<script>

window.setTimeout(load, 1000);

function load()
{
   var xhttp = new XMLHttpRequest();
   xhttp.onreadystatechange = function() {
      if (xhttp.readyState == 4 &&
          xhttp.status == 200) {
         o = JSON.parse(xhttp.responseText);
         document.getElementById("temp").innerHTML
= o.temp;
         window.setTimeout(load, 1000);
      }
   };
   xhttp.open("GET", "/temp?index=1", true);
   xhttp.send();
}

</script>
</head>

<body>
   <div id="temp">0.0</div>
</body>

</html>
```

HTTP Requests

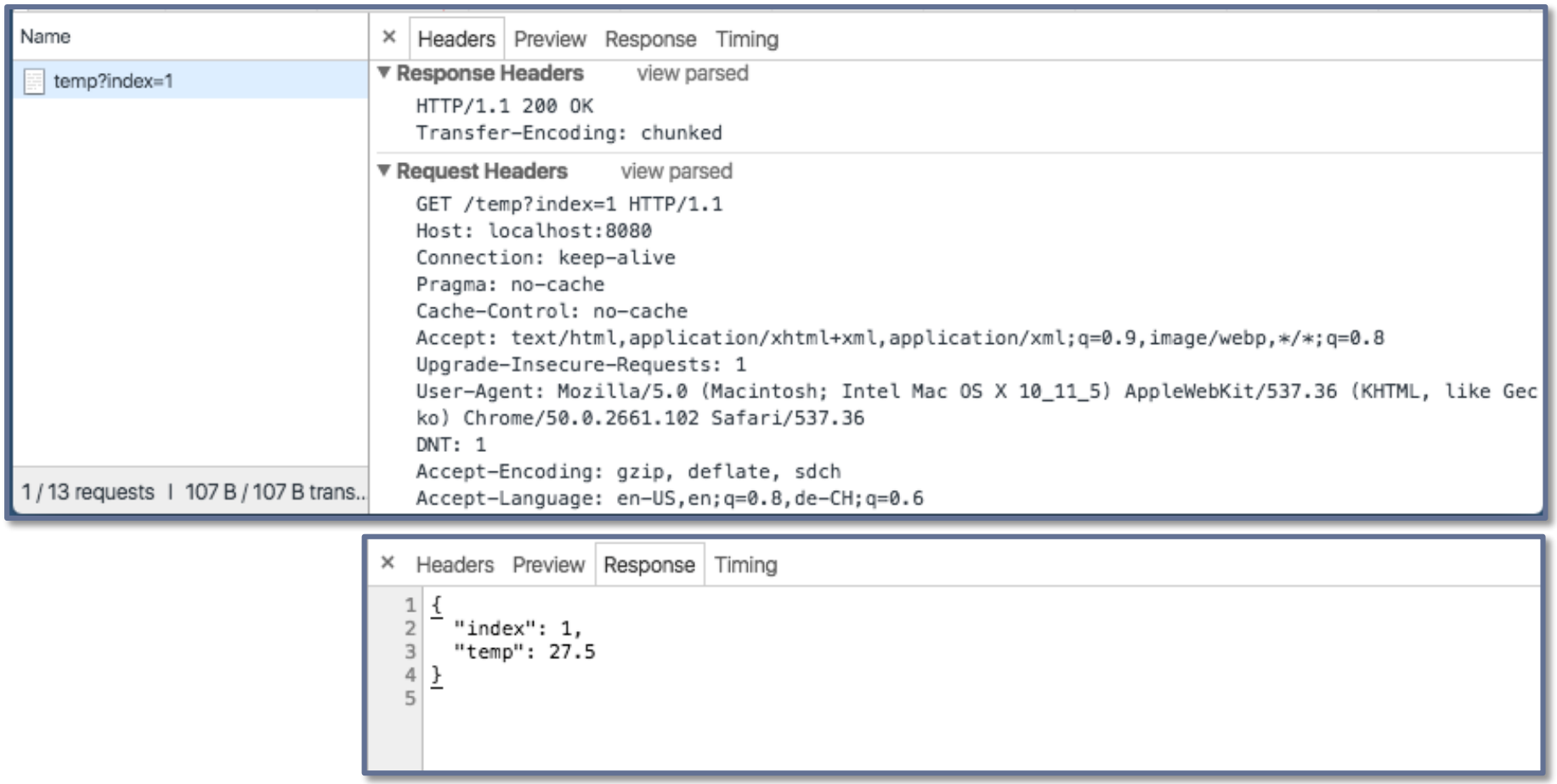
- Hypertext Transfer Protocol defined in https://tools.ietf.org/pdf/rfc2616.pdf
- For http:// requests, browser opens a TCP connection to port 80 of the server, sends a request header, and receives a response in plain text
- For https:// requests, encryption (SSL) is used to port 443
- Typical request:

```
GET /temp?index=1 HTTP/1.1\r\n
```

Network monitor (Chrome Developer Tools)

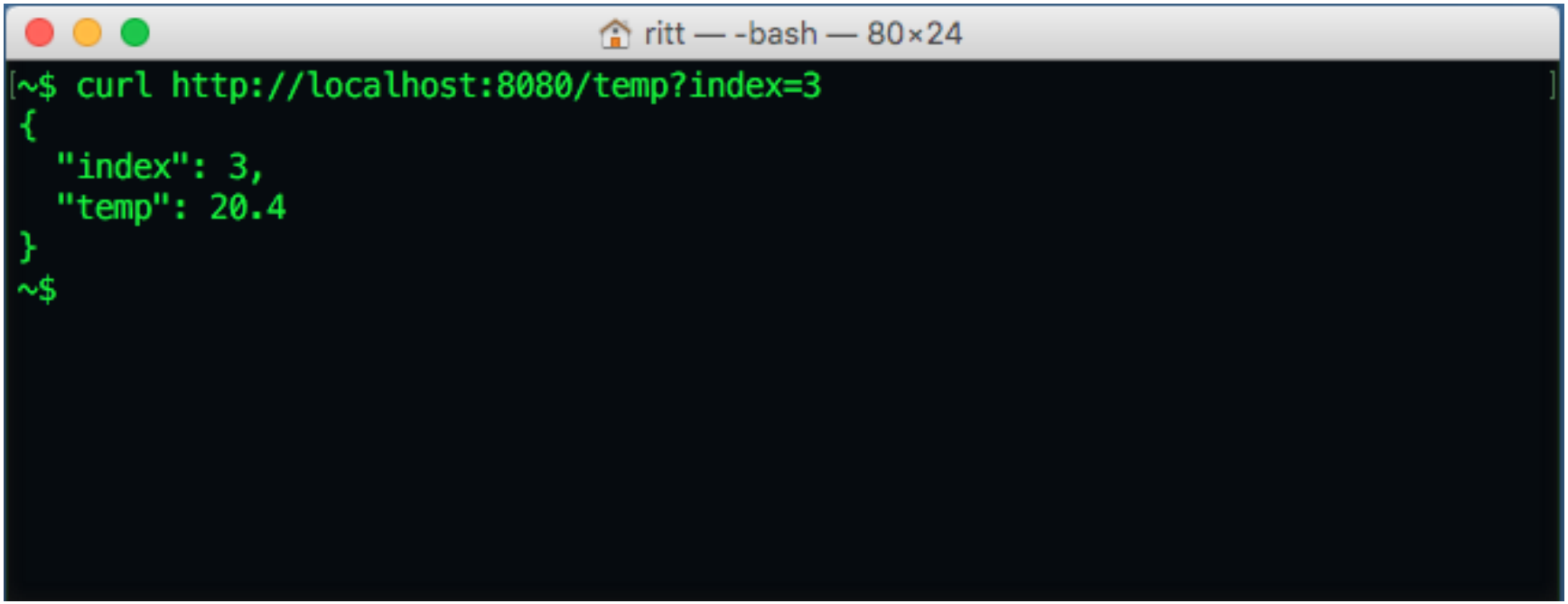


HTTP Request and Response



CURL

- Command line URL program to call servers from the terminal



JSON-RPC

- JSON-RPC implements Remote Procedure Calls:

→ {
"method":"getLight",
"params":
{"index":1},
"id":1234
}

← {
"result":"on",
"error":null,
"id":1234
}

- ID: value of any type to match the response with the request

JSON-RPC Client

```
function rpc_call()
{
  var xhttp = new XMLHttpRequest();
  xhttp.onreadystatechange = function() {
    if (xhttp.readyState == 4 && xhttp.status == 200) {
      o = JSON.parse(xhttp.responseText);
      document.getElementById("result").innerHTML = "Result: "+o.result;
    }
  };
  var request = {};
  request.jsonrpc = "2.0";
  request.method = "sum";
  request.params = [];
  request.params[0] = parseFloat(document.getElementById("n1").value);
  request.params[1] = parseFloat(document.getElementById("n2").value);
  request.id = 1;

  xhttp.open("POST", "/json-rpc", true);
  xhttp.setRequestHeader("Content-type", "application/json");
  xhttp.send(JSON.stringify(request));
}
...
<body>
  <input type="text" id="n1">
  <input type="text" id="n2">
  <div id="result">Result:</div>
  <input type="button" value="Add" onClick="rpc_call()">
</body>
```

```
{
  “jsonrpc”:”2.0”,
  “method”:”sum”,
  “params”:[1,2],
  “id”:1
}
```

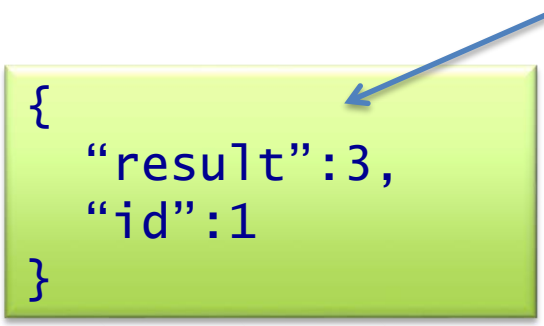
JSON-RPC Sever 1

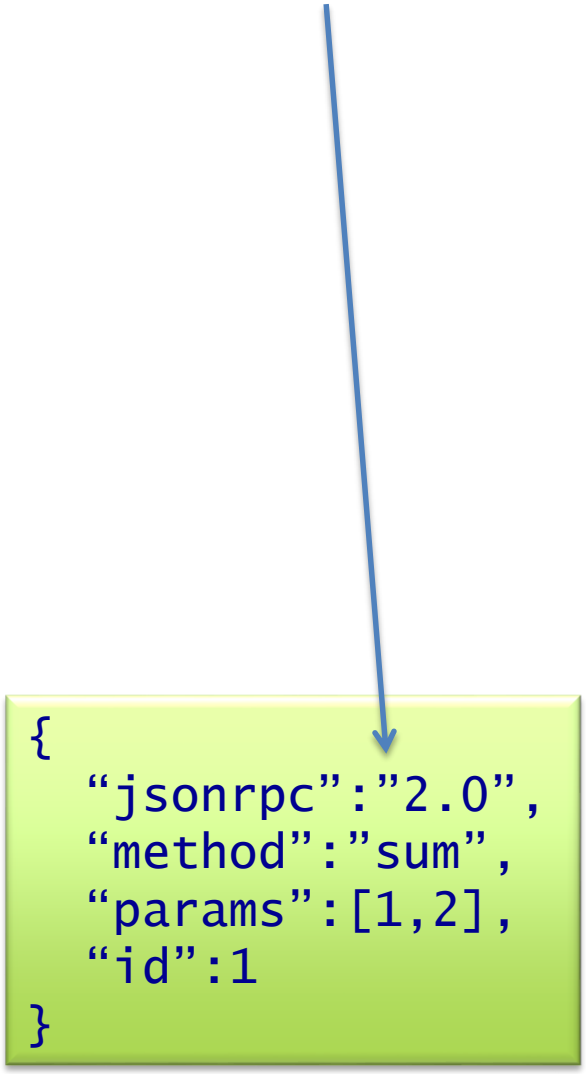
```
static void ev_handler(struct mg_connection *nc, int ev, void *ev_data)
{
  struct http_message *hm = (struct http_message *) ev_data;
  static const char *methods[] = { "sum", NULL };
  static mg_rpc_handler_t handlers[] = { rpc_sum, NULL };
  char buf[100];

  if (ev == MG_EV_HTTP_REQUEST) {
    if (mg_vcmp(&hm->uri, "/json-rpc") == 0) {
      mg_rpc_dispatch(hm->body.p, hm->body.len, buf, sizeof(buf),
                      methods, handlers);
      mg_printf(nc, "HTTP/1.0 200 OK\r\nContent-Length: %d\r\n"
                "Content-Type: application/json\r\n\r\n%s",
                (int) strlen(buf), buf);
      nc->flags |= MG_F_SEND_AND_CLOSE;
    } else {
      // serve static content
      mg_serve_http(nc, hm, s_http_server_opts);
    }
  }
}
```

```
{
  “jsonrpc”:”2.0”,
  “method”:”sum”,
  “params”:[1,2],
  “id”:1
}
```

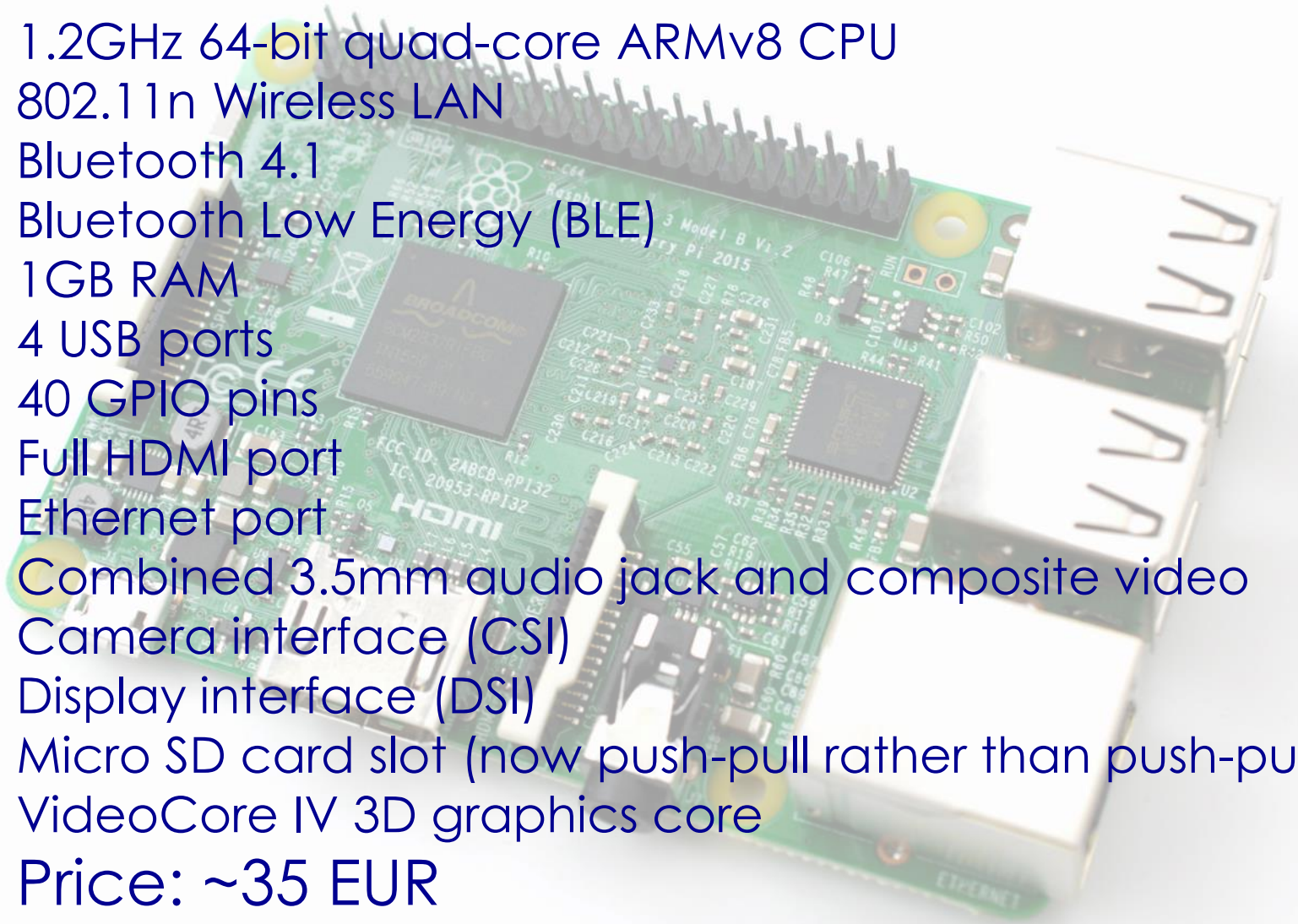
JSON-RPC Server1

```
static int rpc_sum(char *buf, int len, struct mg_rpc_request *req) {
  double sum = 0;
  int i;

  if (req->params[0].type != JSON_TYPE_ARRAY)
    return mg_rpc_create_std_error(buf, len, req,
                                   JSON_RPC_INVALID_PARAMS_ERROR);

  for (i = 0; i < req->params[0].num_desc; i++) {
    if (req->params[i + 1].type != JSON_TYPE_NUMBER)
      return mg_rpc_create_std_error(buf, len, req,
                                     JSON_RPC_INVALID_PARAMS_ERROR);

    sum += strtod(req->params[i + 1].ptr, NULL);
  }
  return mg_rpc_create_reply(buf, len, req, "f", sum);
}
```





Raspberry Pi



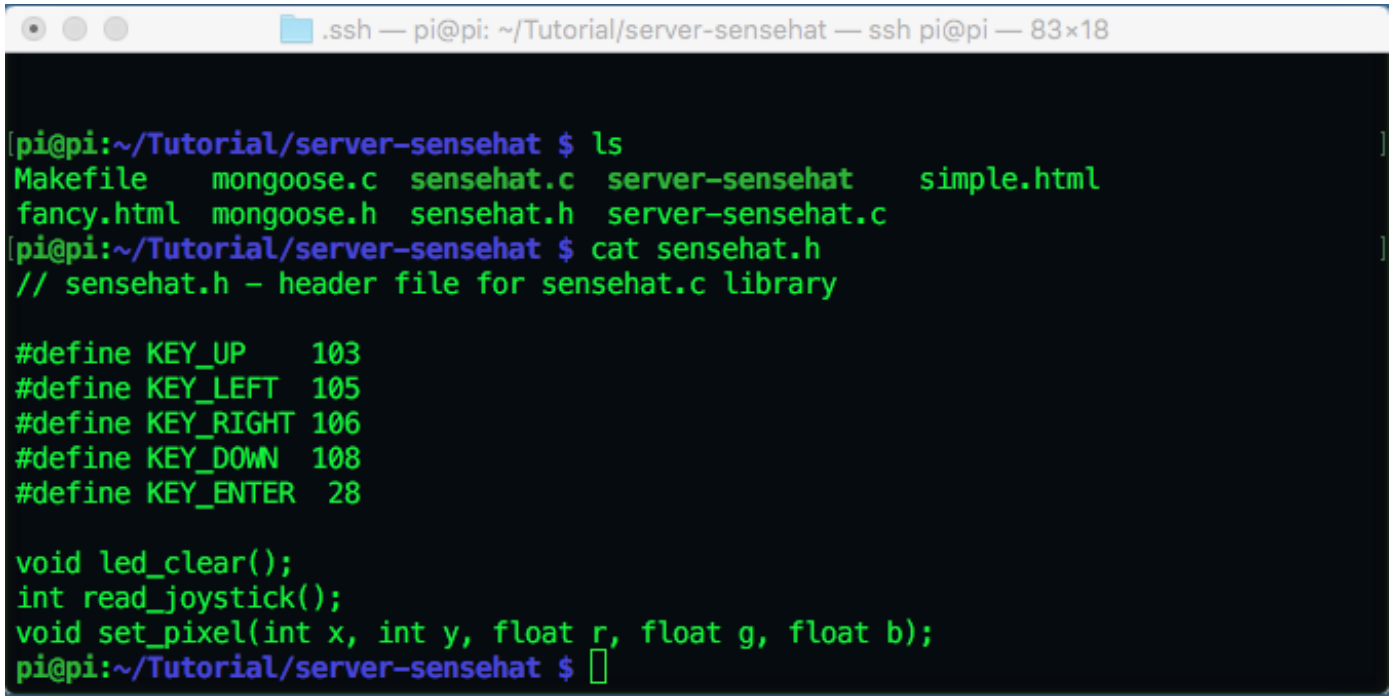
- 1.2GHz 64-bit quad-core ARMv8 CPU
- 802.11n Wireless LAN
- Bluetooth 4.1
- Bluetooth Low Energy (BLE)
- 1GB RAM
- 4 USB ports
- 40 GPIO pins
- Full HDMI port
- Ethernet port
- Combined 3.5mm audio jack and composite video
- Camera interface (CSI)
- Display interface (DSI)
- Micro SD card slot (now push-pull rather than push-push)
- VideoCore IV 3D graphics core
- Price: ~35 EUR

Raspberry Pi

- Huge support community
  www.raspberrypi.org
- Excellent learning tool
- Many different operating systems, will use Raspian (port of Debian)
- Need housing (8 EUR), Power supply (6 EUR), SD card (11 EUR)
- Many hardware extensions available

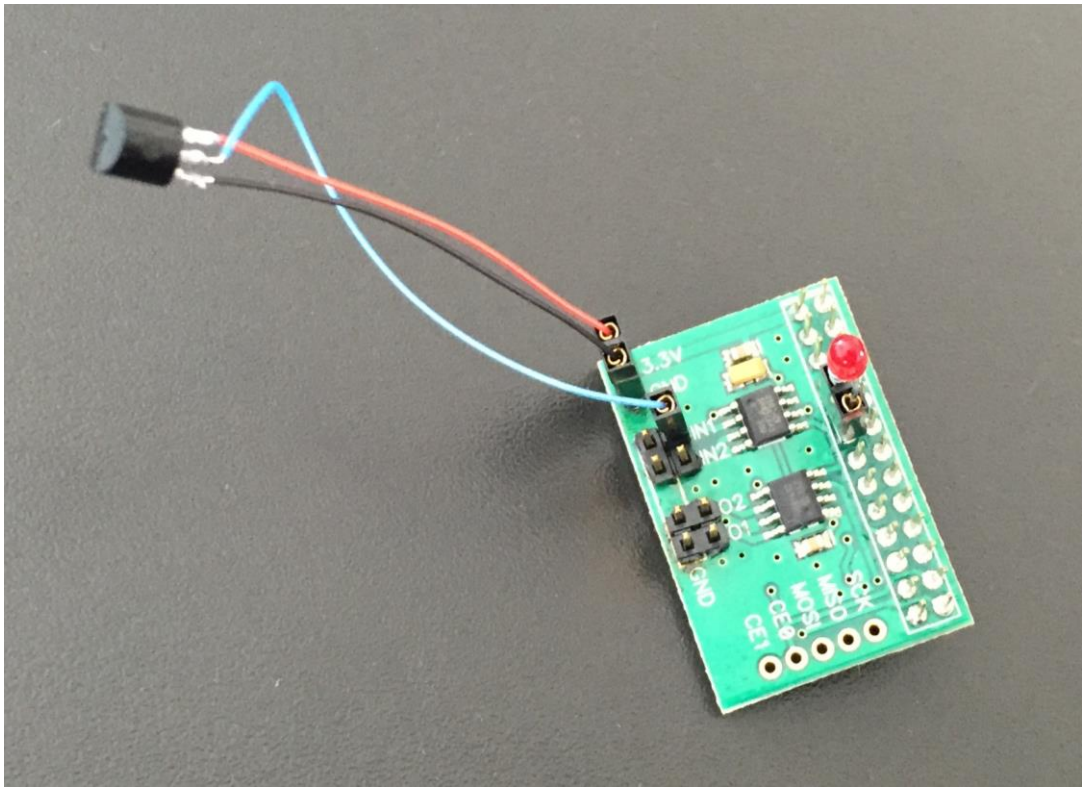
Mongoose on Raspberry Pi

- mongoose compiles on Raspberry Pi out of the box
- For hardware access, one needs to link specific libraries to the server



ADC / DAC Board

- Raspberry Pi “hat” with 2 channel 12 bit ADC and 2 channel 12 bit DAC



LM35 Temperature Sensor

National Semiconductor

July 1999

LM35
Precision Centigrade Temperature Sensors

General Description

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 μA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a −55° to +150°C temperature range, while the LM35C is rated for a −40° to +110°C range (−10° with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

Features

- Calibrated directly in ° Celsius (Centigrade)
- Linear + 10.0 mV/°C scale factor
- 0.5°C accuracy guaranteeable (at +25°C)
- Rated for full −55° to +150°C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 μA current drain
- Low self-heating, 0.08°C in still air
- Nonlinearity only ±¼°C typical
- Low impedance output, 0.1 Ω for 1 mA load

Typical Applications

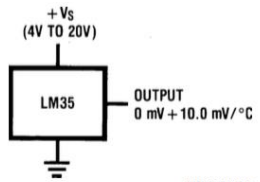
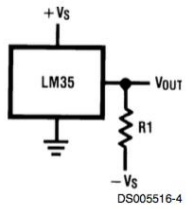


FIGURE 1. Basic Centigrade Temperature Sensor (+2°C to +150°C)



Choose $R_1 = -V_S/50\ \mu A$
V_{OUT} = +1,500 mV at +150°C
= +250 mV at +25°C
= −550 mV at −55°C

FIGURE 2. Full-Range Centigrade Temperature Sensor

Server 1

```
static int rpc_readtemp(char *buf, int len, struct mg_rpc_request *req)
{
   unsigned char spi_buf[3];
   double t;

   spi_buf[0] = 0x01; // Start
   spi_buf[1] = 0xA0; // SGL/DIFF=1, ODD/SING=0, MS/BF=1
   spi_buf[2] = 0x00;

   wiringPiSPIDataRW(spi_fd0, spi_buf, 3);

   // convert to Volts
   t = (((spi_buf[1] & 0x0F) << 8) | spi_buf[2])/4096.0 * 3.3;

   // convert to deg C
   t *= 100;

   // round to one digit
   t = (int)(t*10+0.5)/10.0;

 return mg_rpc_create_reply(buf, len, req, "
}
```

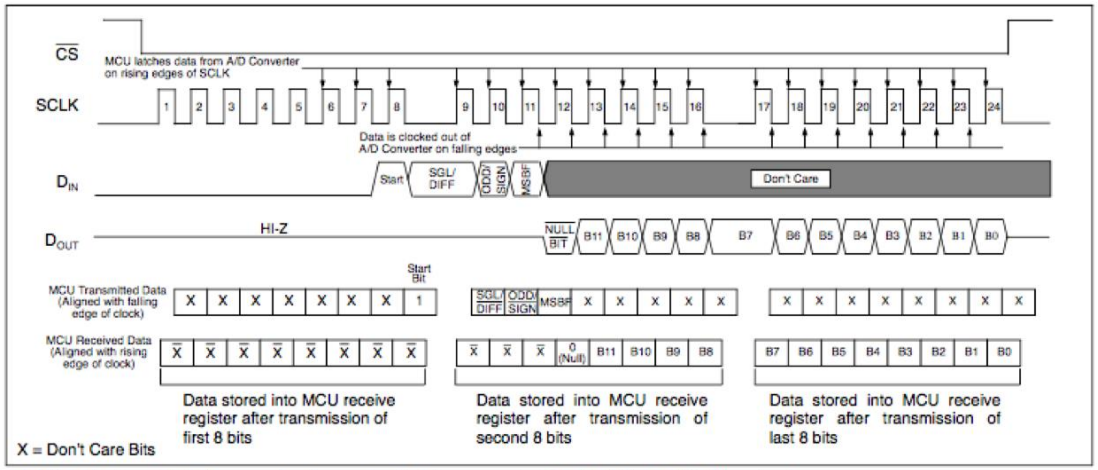
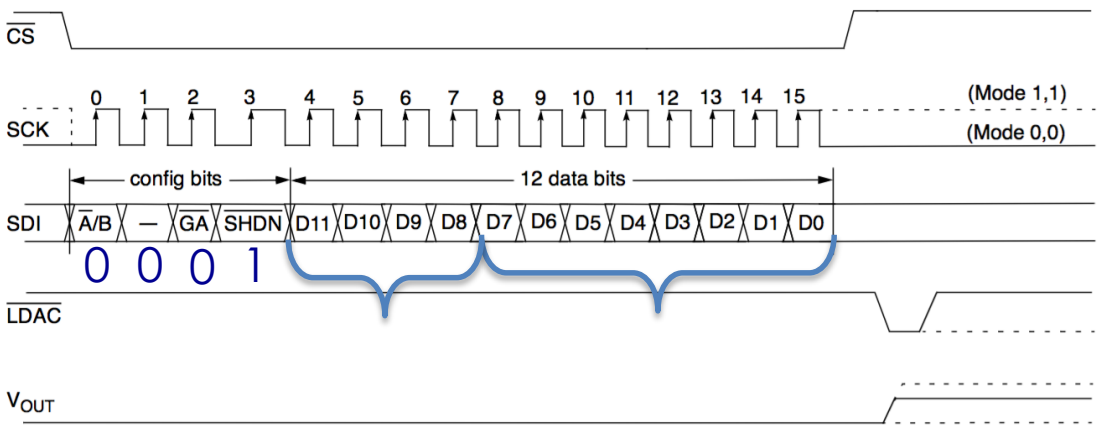


FIGURE 6-1: *SPI Communication using 8-bit segments (Mode 0,0: SCLK idles low).*

Server 2

```
static int rpc_sethv(char *buf, int len, struct mg_rpc_request *req)
{
   double hv;
   unsigned char spi_buf[2];
   unsigned int d;

   hv = atof(req->params[1].ptr);

   d = (unsigned int) (hv / 2 / 2.048 * 4096);
   spi_buf[0] = 0x10 | (d >> 8);  // MSB, Gain=2, /SHDN=1, Channel A
   spi_buf[1] = d & 0xFF;         // LSB
   wiringPiSPIDataRW(spi_fd1, spi_buf, 2);

   // toggle /LDAC
   digitalWrite(6, LOW);
   digitalWrite(6, HIGH);

   return mg_rpc_create_reply(buf, le
}
```



Server 3

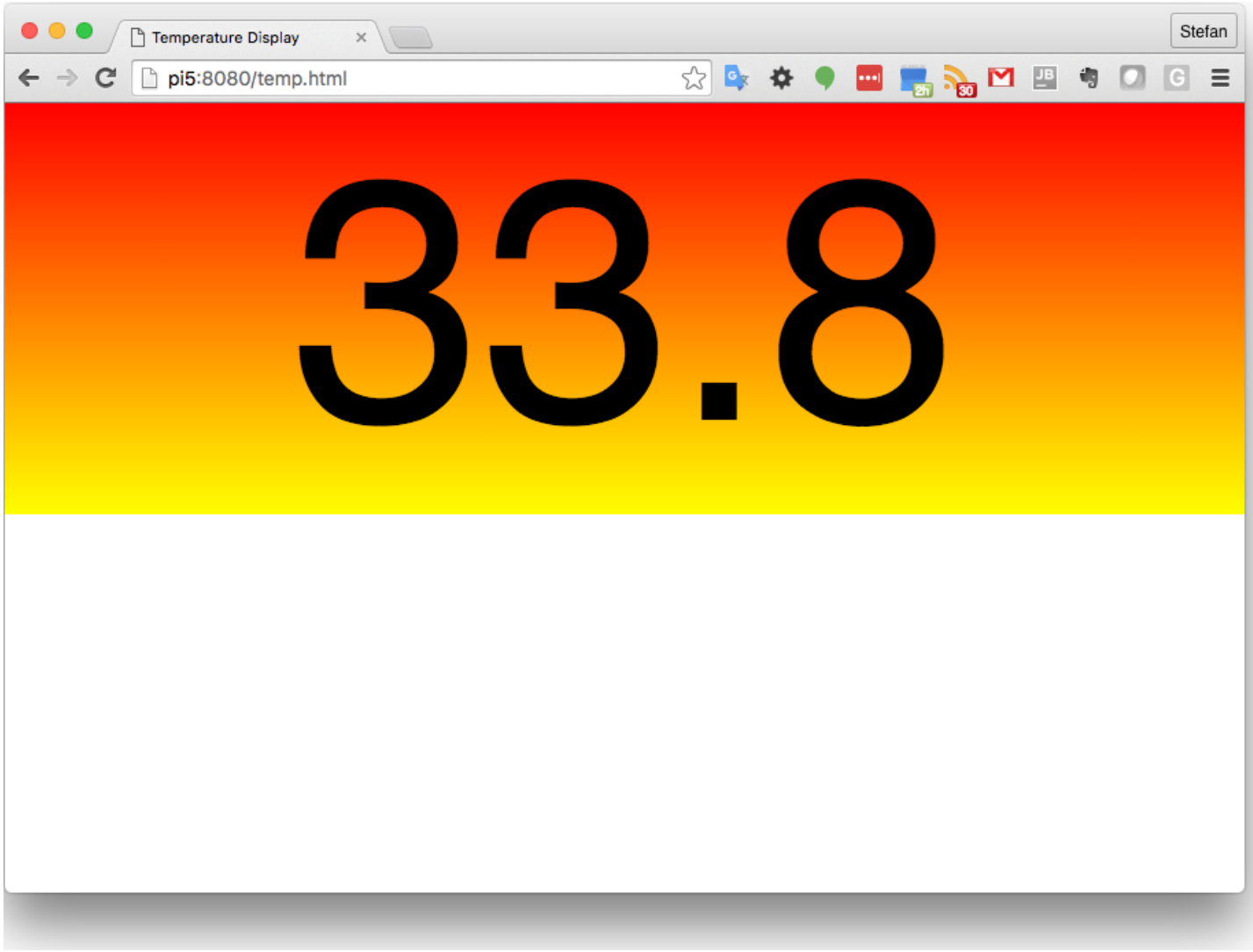
```
static void ev_handler(struct mg_connection *nc, int ev, void *ev_data)
{
  struct http_message *hm = (struct http_message *) ev_data;
  static const char *methods[] = { "sethv", "readtemp", NULL };
  static mg_rpc_handler_t handlers[] = { rpc_sethv, rpc_readtemp, NULL };
  char buf[1000];

  if (ev == MG_EV_HTTP_REQUEST) {
    if (mg_vcmp(&hm->uri, "/json-rpc") == 0) {
      mg_rpc_dispatch(hm->body.p, hm->body.len, buf, sizeof(buf),
                      methods, handlers);
      mg_printf(nc, "HTTP/1.0 200 OK\r\nContent-Length: %d\r\n"
                "Content-Type: application/json\r\n\r\n%s",
                (int) strlen(buf), buf);
      nc->flags |= MG_F_SEND_AND_CLOSE;
    } else {
      // serve static content
      mg_serve_http(nc, hm, s_http_server_opts);
    }
  }
}
```

Client Temperature

```
<!DOCTYPE html>
<html>
<head>
  <title>Temperature Display</title>

<style>
  body {
    margin: 0;
  }
  #temp {
    height: 300px;
    background: yellow;
    background: linear-gradient(red,
yellow);

    font-family: sans-serif;
    font-size: 250px;
    text-align: center;
  }
</style>
```

```
<script>

window.setTimeout(load, 1000);

function load()
{
  var xhttp = new XMLHttpRequest();
  xhttp.onreadystatechange = function() {
    if (xhttp.readyState == 4 && xhttp.status == 200) {
      o = JSON.parse(xhttp.responseText);
      document.getElementById("temp").innerHTML = o.result;
      window.setTimeout(load, 1000);
    }
  };

  var request = {};
  request.jsonrpc = "2.0";
  request.method = "readtemp";
  request.id = 1;

  xhttp.open("POST", "/json-rpc", true);
  xhttp.setRequestHeader("Content-type", "application/json");
  xhttp.send(JSON.stringify(request));
}

</script>
</head>

<body onload="load();">
  <div id="temp">0.0</div>
</body>

</html>
```

Client Temperature

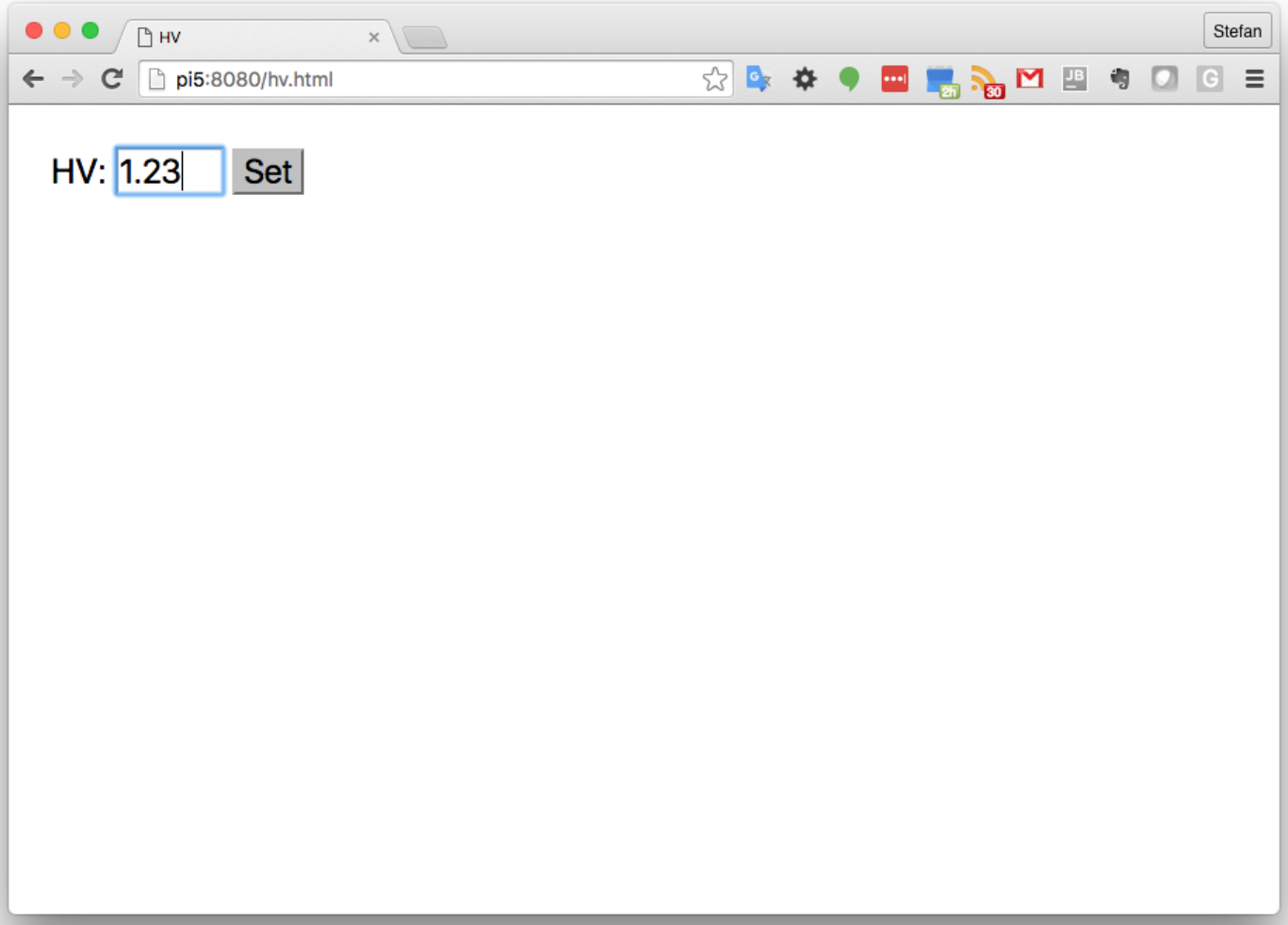


Client HV

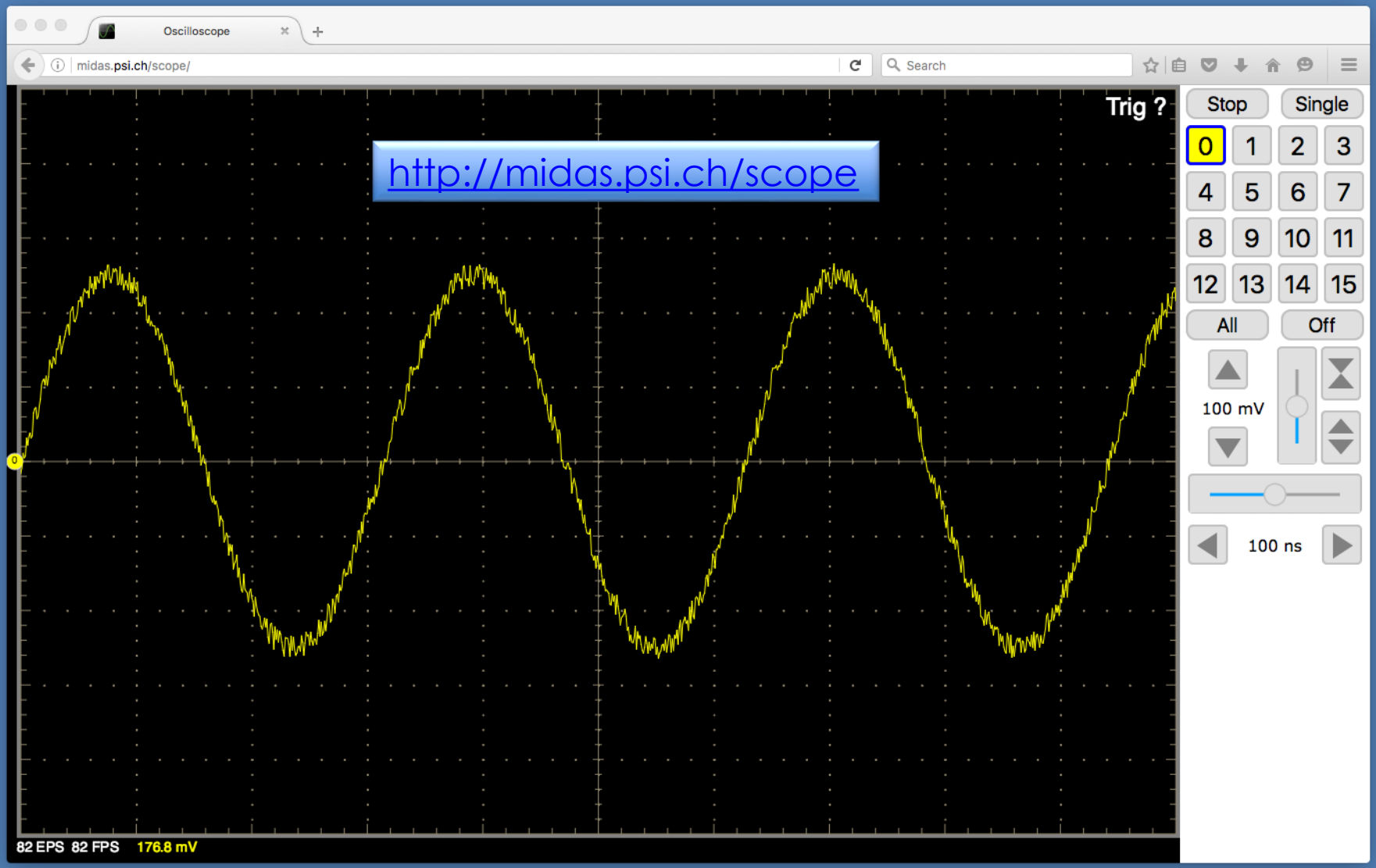
```
<!DOCTYPE html>
<html>
<head>
  <title>HV</title>

<style>
  body {
    font-family: sans-serif;
    font-size: 24px;
    margin: 30px;
  }
  input {
    line-height: 24px;
    font-size: 24px;
    -webkit-appearance:none;
  }
</style>
<script>
```

```
function rpc_sethv()
{
  var xhttp = new XMLHttpRequest();
  xhttp.onreadystatechange = function() {
    if (xhttp.readyState == 4 && xhttp.status == 200) {
      o = JSON.parse(xhttp.responseText);
    }
  };

  var request = {};
  request.jsonrpc = "2.0";
  request.method = "sethv";
  request.params = [];
  request.params[0] = document.getElementById("hv").value;
  request.id = 1;

  xhttp.open("POST", "/json-rpc", true);
  xhttp.setRequestHeader("Content-type", "application/json");
  xhttp.send(JSON.stringify(request));
}

</script>
</head>

<body>
  HV: <input type="text" id="hv" value="0" size="5">
  <input type="button" value="Set" onclick="rpc_sethv()">
</body>

</html>
```

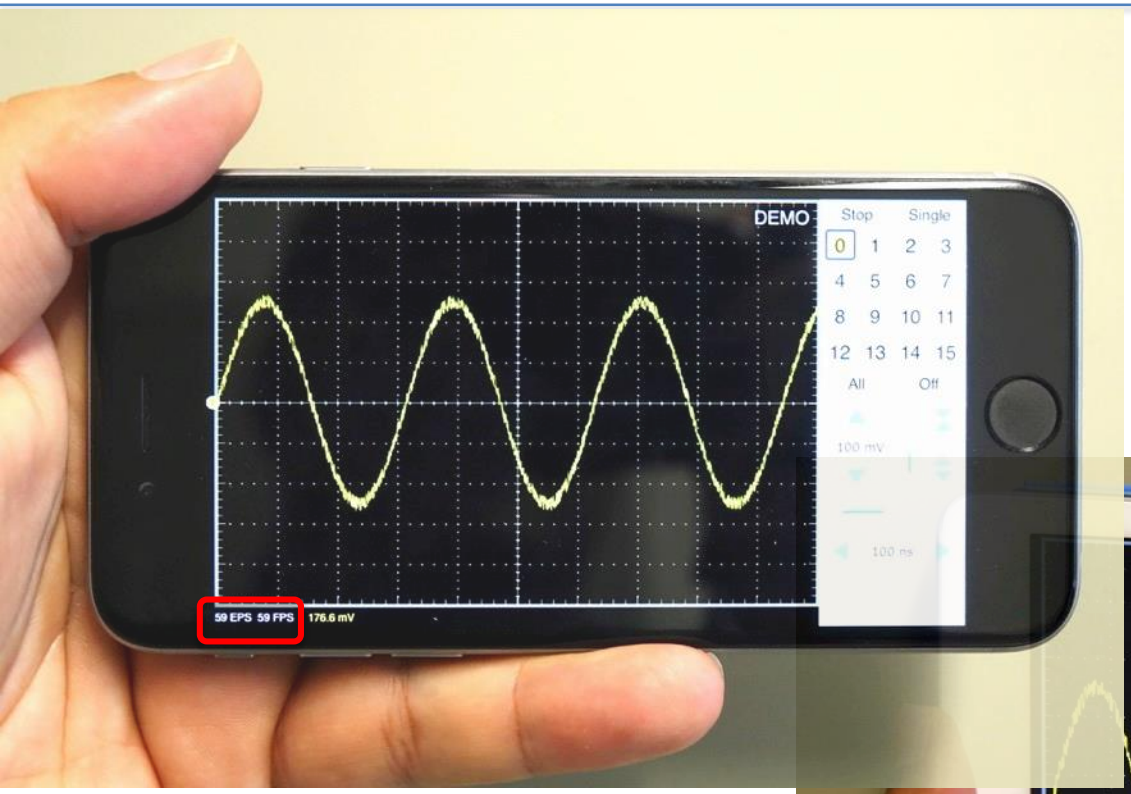
Client HV

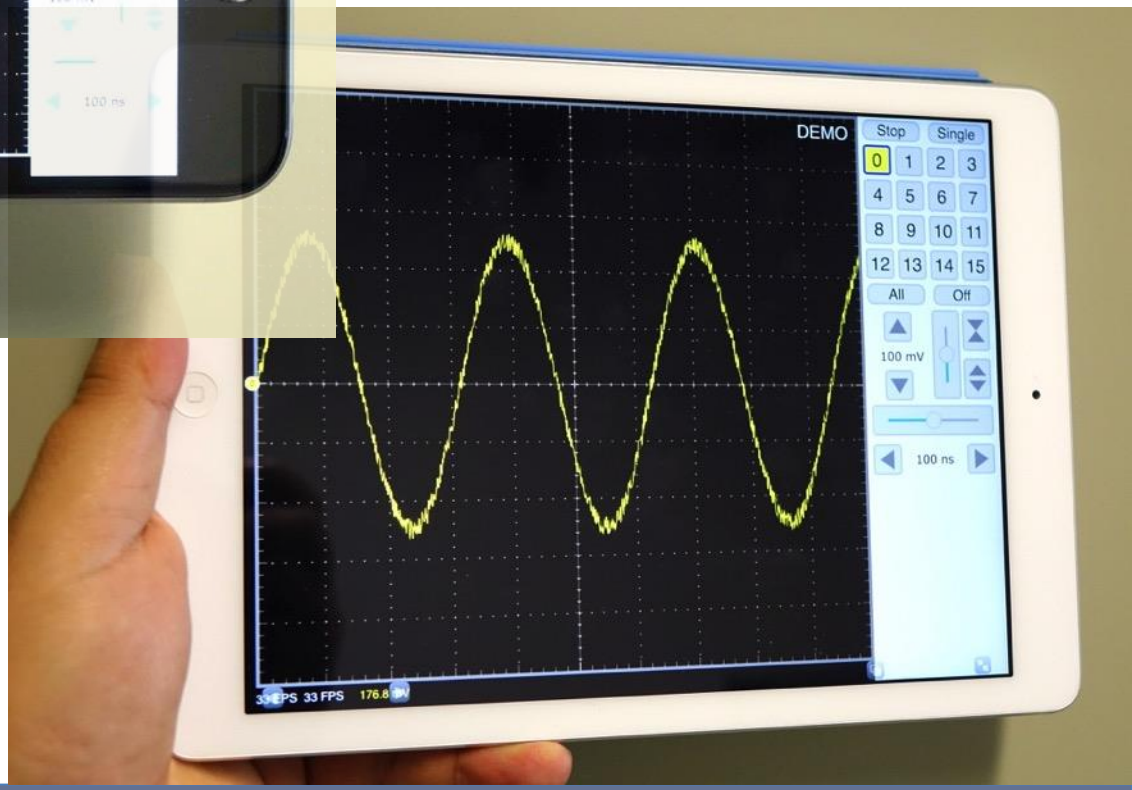


Oscilloscope Application



Smartphone and Tablet





Conclusion: Future of visualization

- Experiment data can be displayed on almost any browser
  - HTML5 is standardized through W3C
  - No software to install, no libraries required
  - Central updates of software
  - Only raw (binary) data needs to be transferred (as opposed to remote desktop applications)
  - Perfect for remote monitoring and control
  - Easy to learn (Scope took me one week from scratch)
- Web server can be incorporated into any web device ("Internet of Things (IoT)")
- Slides, programs, … on Dropbox: **https://db.tt/WWkBEhMQ**