nubomedia-vca Documentation

Release 6.6.0

NUBOMEDIA

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Contents

CHAPTER 1

Contents

1.1 Introduction

NUBOMEDIA-VCA is a part of the NUBOMEDIA , which is the first cloud platform specifically designed for hosting interactive multimedia services. NUBOMEDIA exposes to developers PaaS APIs for creating media pipelines. A media pipeline is a chain of elements providing media capabilities such as encryption, transcoding, augmented reality or video content analysis. These chains allow building arbitrarily complex media processing for applications. As a unique feature, from the point of view of the pipelines, the NUBOMEDIA cloud infrastructure behaves as a single virtual super-computer encompassing all the available resources of the physical network. This part of the project is in charge of the **Video Content Analysis (VCA)**, through which the developers can apply different computer vision filters to their media pipelines.

Through this documentation you can learn how to install and develop using the API of the following filters: **face detector**, **mouth detector**, **nose detector**, **eye detector**, **ear detector**, and **tracker filter**. Futhermore, you can find information about tutorials in order to test the different filters, and also you can read more about the architecture of VCA filter within NUBOMEDIA in the advanced guide.

1.2 Installation guide

This section is divided in two parts. On the one hand, we see how to install the NUBOMEDIA-VCA filters using the repositories of the project. On the other hand, we see how to install these filters from the source code.

1.2.1 From repositories

In order to install the latest stable version of the NUBOMEDIA-VCA filters in your local environment, first of all you need an instance of Kurento Media Server installed in your machine. To do that, use the following commands:

```
echo "deb http://ubuntu.kurento.org trusty kms6" | sudo tee /etc/apt/sources.list.d/kurento.list
wget -O - http://ubuntu.kurento.org/kurento.gpg.key | sudo apt-key add -
sudo apt-get update
sudo apt-get install kurento-media-server-6.0
```

Then you are able to install the NUBOMEDIA-VCA filters. To do that, you have type the following commands:

```
sudo apt-get install software-properties-common
sudo apt-key adv --keyserver keyserver.ubuntu.com --recv-keys F04B5A6F
sudo add-apt-repository "deb http://repository.nubomedia.eu/ trusty main"
sudo apt-get update

# To install ear detector filter
sudo apt-get install nubo-ear-detector nubo-ear-detector-dev

# To install eye detector filter
```

```
sudo apt-get install nubo-eye-detector nubo-eye-detector-dev

# To install face detector filter
sudo apt-get install nubo-face-detector nubo-face-detector-dev

# To install mouth detector filter
sudo apt-get install nubo-mouth-detector nubo-mouth-detector-dev

# To install nose detector filter
sudo apt-get install nubo-nose-detector nubo-nose-detector-dev

# To install tracker filter
sudo apt-get install nubo-tracker nubo-tracker-dev
```

1.2.2 From source code

In order to install the NUBOMEDIA-VCA from the source code you need the development packages for Kurento. To install these components use the following commands:

```
echo "deb http://ubuntu.kurento.org trusty kms6" | sudo tee /etc/apt/sources.list.d/kurento.list
wget -O - http://ubuntu.kurento.org/kurento.gpg.key | sudo apt-key add -
sudo apt-get update
sudo apt-get install kurento-media-server-6.0 kurento-media-server-6.0-dev
sudo apt-get install kms-core-6.0 kms-core-6.0-dev
sudo apt-get install cimg-dev
sudo apt-get install devscripts
```

After that, you are able to generate the Debian packages of the NUBOMEDIA-VCA filters from the source code. To do that, you need to clone the official repository on GitHub and the execute the build script.

```
git clone https://github.com/nubomedia/NUBOMEDIA-VCA.git
cd NUBOMEDIA-VCA
./build.sh
```

If everything goes well, a new folder called *output* will be created. Inside this folder you can find the Debian packages for the different filters. To install these filters, you need to run the following commands:

```
cd output

# To install ear detector filter
sudo dpkg -i nubo-ear-detector_6.6.0~rc1_amd64.deb nubo-ear-detector-dev_6.6.0~rc1_amd64.deb

# To install eye detector filter
sudo dpkg -i nubo-eye-detector_6.6.0~rc1_amd64.deb nubo-eye-detector-dev_6.6.0~rc1_amd64.deb

# To install face detector filter
sudo dpkg -i nubo-face-detector_6.6.0~rc1_amd64.deb nubo-face-detector-dev_6.6.0~rc1_amd64.deb

# To install mouth detector filter
sudo dpkg -i nubo-mouth-detector_6.6.0~rc1_amd64.deb nubo-mouth-detector-dev_6.6.0~rc1_amd64.deb

# To install nose detector filter
sudo dpkg -i nubo-nose-detector_6.6.0~rc1_amd64.deb nubo-nose-detector-dev_6.6.0~rc1_amd64.deb

# To install tracker filter
sudo dpkg -i nubo-tracker_6.6.0~rc1_amd64.deb nubo-tracker-dev_6.6.0~rc1_amd64.deb
```

1.3 Developer guide

On this section, we will see the different APIs to use every single filter. As it was explained on introduction, the following filters are available to use in the NUBOMEDIA platform: **face detector**, **mouth detector**, **nose detector**, **eye detector**, **ear detector** and **tracker filter**. From a developer point of view, these filters can be used in two scenarios:

1. Using your own instance of Kurento Media Server with the proper filter installed. If this is your case, please take a look to the installation guide for further information about filter installation.

2. Using the NUBOMEDIA PaaS to host your application. If this is your case, you don't need to worry about the filter installation since the platform has these filters installed out of the box.

In any case, you need to use the proper Java dependency in your application. To add this dependency, first you need to include the following directive in your pom.xml (this part is a must to locate the NUBOMEDIA-VCA Maven artifacts):

```
<repositories>
   <repository>
      <id>kurento-releases</id>
      <name>Kurento Repository</name>
      <url>http://maven.kurento.org/releases</url>
      <releases>
         <enabled>true</enabled>
      </releases>
      <snapshots>
         <enabled>false</enabled>
      </snapshots>
   </repository>
</repositories>
```

Then, you will be able to add the proper NUBOMEDIA-VCA Maven artifact, namely:

- Face detector:

```
<dependency>
   <groupId>org.kurento.module</groupId>
   <artifactId>nubofacedetector</artifactId>
   <version>6.6.0</version>
</dependency>
```

- Mouth detector:

```
<dependency>
   <groupId>org.kurento.module</groupId>
   <artifactId>nubomouthdetector</artifactId>
   <version>6.6.0</version>
</dependency>
```

- Nose detector:

```
<dependency>
   <groupId>org.kurento.module</groupId>
   <artifactId>nubonosedetector</artifactId>
   <version>6.6.0</version>
</dependency>
```

- Eye detector:

```
<dependency>
   <groupId>org.kurento.module</groupId>
```

```
   <artifactId>nuboeyedetector</artifactId>
   <version>6.6.0</version>
</dependency>
```

- Ear detector:

```
<dependency>
   <groupId>org.kurento.module</groupId>
   <artifactId>nuboeardetector</artifactId>
   <version>6.6.0</version>
</dependency>
```

- Tracker filter:

```
<dependency>
   <groupId>org.kurento.module</groupId>
   <artifactId>nubotracker</artifactId>
   <version>6.6.0</version>
</dependency>
```

The following sections provides information of the Java API provided by each NUBOMEDIA-VCA component.

1.3.1 Face, mouth, nose, eye and ear

All this filters have a similar API, for this reason, we are going to see all of them together.

NuboFaceDetector

This filter receives a stream of images as input. The output of the filter will be a collection of bounding boxes. Each bounding box represents the position of each face in the image. A bounding box is an area defined by two points. It is very important to highlight that this algorithm only detects front faces. Therefore, all the faces that are laterally focused will not be detected.

NuboMouthDetector , NuboNoseDetector, NuboEarDetector, NuboEyeDetector

As for mouth, nose, eye and ear detector, these filters receive a stream of images as input. The output of each filter will be a collection of bounding boxes. Each bounding box represents the position of each mouth,nose, eye and found in the image. These algorithms needs to detect previously the different faces included on the image, with the exception of the ear detector which have to detect the side of the face. The faces can be detected by its own, or can be received as an input.

The developers can use the following API for this filter:

Function	Description
void **showX(int)**	To show or hide the bounding boxes of the detected faces, mouths, ears, noses, and eyes within the image. Parameter's value: - 0 (default), the bounding boxes will not be shown. - 1, the bounding boxes will be drawn in the frame
void **detectByEvent(int)**	To indicate to the algorithm if it must process all the images or only when it receives a specific event such as motion detection. Parameter's value: - 0 (default) , process all the frames; - 1 , process a frame when it receives a specific event
void **sendMetaData(int)**	To send the bounding boxes of the faces, mouths, eyes noses and ears detected to another ME as a metadata. Parameter's value: - 0 (default) , metadata are not sent - 1 , metadata are sent
void **widthToProcess(int)**	To indicate the width of the image that the algorithm is going to process to another ME as a metadata. Parameter's value: - 160 (default), 240, 320, 640
void **processXevery4Frames(int)**	To indicate the number of frames that the algorithm process every 4 frames. Parameter's value: - 1, processes one image and discard 3 (8 fps) - 2, processes two images and discard 2 (12 fps) - 3, processes three images and discard 1 (18 fps) - 4, processes four images (24 fps)
void **setOverlayedImage(uri, float, float, float, float)**	

* **showX** can be depending on the algorithm: showFaces(int), showNoses(int), showMouths(int), showEyes(int), showEars(int).

1.3.2 Tracker

The developers can use the following API for this filter:

Function	Description
void **setVisualMode(int)**	To show or hide the objects detected. Parameter's value: - 0 (default), the bounding boxes will not be shown. - 1, the bounding boxes will be drawn in the frame
void **setThreshold(int)**	To set up the minumum difference among pixels to consider motion Parameter's value: - 0-255 (20 default)
void **setMinArea(int)**	To set up the minumum area to consider objects Parameter's value: - 0 - 10000 (50 default)
void **setMaxArea(int)**	To set up the maximum area to consider objects Parameter's value: - 0 - 300000 (30000 default)
void **setDistance(int)**	To set up the distance among object to merge them Parameter's value: - 0 - 2000 (35 Default)

1.4 Tutorials

This section contains tutorials showing how to use the different VCA filters. These tutorials can be found within the GitHub NUBOMEDIA organization. By default, this demos use a local Kurento Media Server with the proper filter installed. The available tutorials are the following:

- Ear detector. This web application consists on a WebRTC video communication with a **ear detector filter**.
- Eye detector. This web application consists on a WebRTC video communication with a **eye detector filter**.
- Face detector. This web application consists on a WebRTC video communication with a **face detector filter**.
- Face profile. This web application consists on a pipeline composed by a WebRTC video communication with **face, mouth, nose and eye detector filter**.
- Mouth detector. This web application consists on a WebRTC video communication with a **mouth detector filter**.
- Nose detector. This web application consists on a WebRTC video communication with a **nose detector filter**.

1.4.1 Ear Detector

This web application consists on a WebRTC video communication with a ear detector filter (loopback, the media stream going from client to the media server and back to client).

Compiling & Running

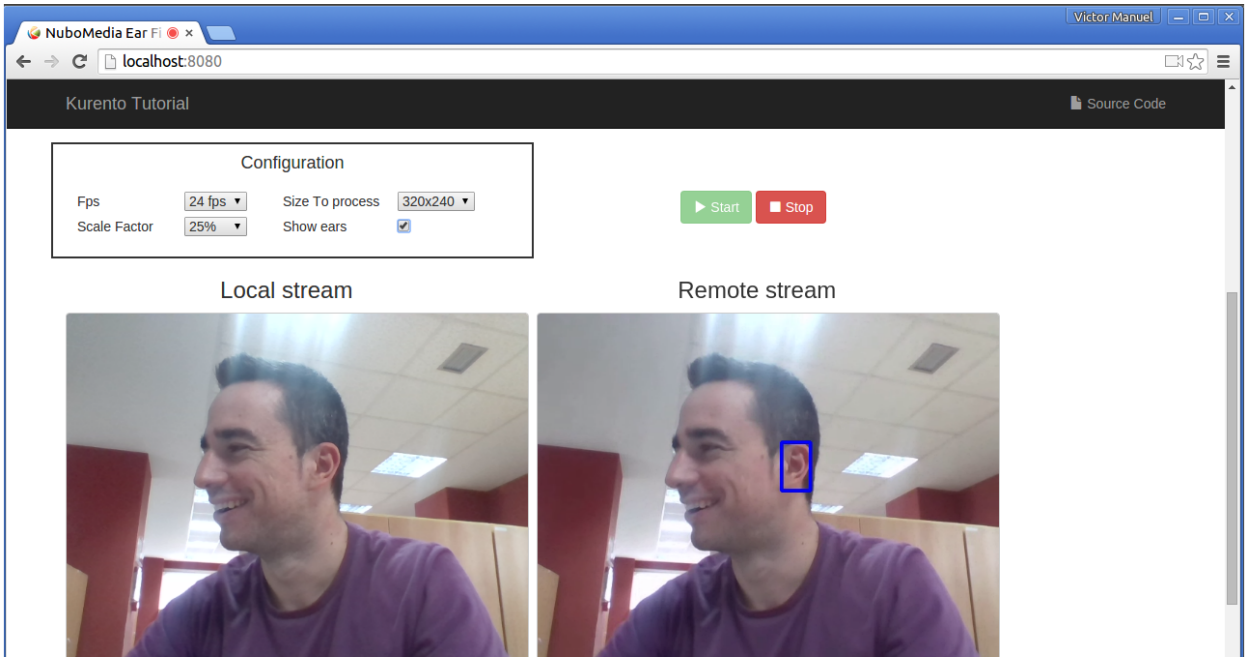
This section explain how to compile and run this tutorial in a local environment. To install the necessary software please see the installation guide. To compile and run this tutorial from the source code you can use the following commands:

```
git clone https://github.com/nubomedia/nubomedia-vca-ear-tutorial
cd nubomedia-vca-ear-tutorial
mvn spring-boot:run
```

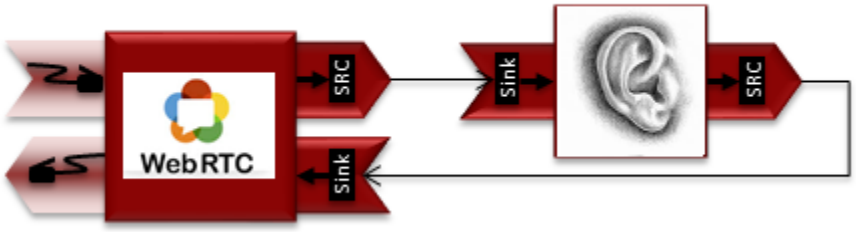
At this point we can test the application accessing the following URL: https://localhost:8443/.

Understanding this example

The following figure shows a screenshoot of this demo running.



The interface of the application (an HTML web page) is composed by two HTML5 video tags: one showing the local stream (as captured by the device webcam) and the other showing the remote stream sent by the media server back to the client. The video camera stream is sent to Kurento Media Server, which processes and sends it back to the client as a remote stream. To implement this, we need to create a Media Pipeline composed by the following Media Elements:

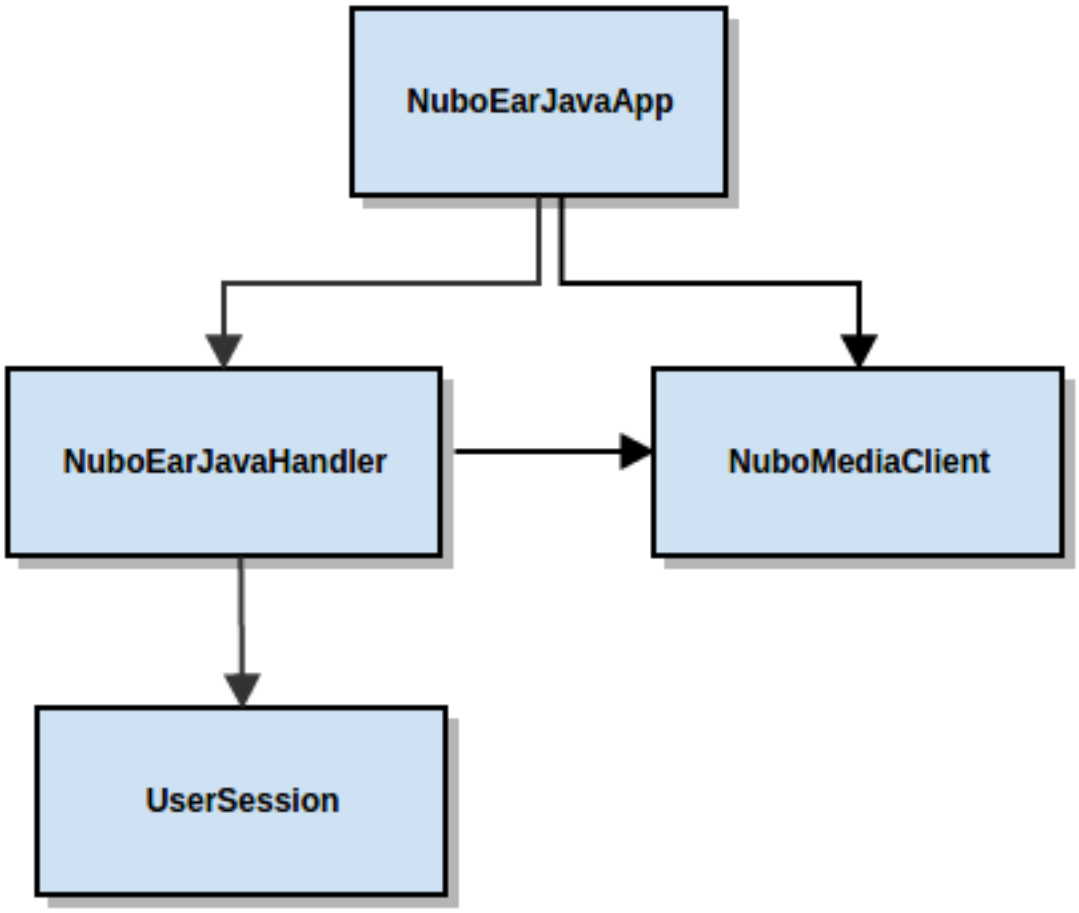


This is a web application, and therefore it follows a client-server architecture. At the client-side, the logic is implemented in JavaScript. At the server-side we use a Java EE application server consuming a Client API to control the Media Server capabilities. To communicate these entities, two WebSockets are used. First, a WebSocket is created between client and application server to implement a custom signaling protocol. Second, another WebSocket is used to perform the communication between the Java Client and the Media Server. To communicate the client with the Java EE application server the platform uses a simple signaling protocol based on JSON messages over WebSocket's. SDP and ICE candidates needs to be exchanged between client and server to establish the WebRtc session. If you are interested on knowing more about the messages exchanged between them, have a look to this example .

Application Server Side

This demo has been developed using a Java EE application server based on the Spring Boot framework. This technology can be used to embed the Tomcat web server in the application and thus simplify the development process.

In the following figure you can see a class diagram of the server side code:



The main class of this demo is named NuboEarJavaApp. As you can see, the NuboMediaClient is instantiated in this class as a Spring Bean. This bean is used to create Media Pipelines, which are used to add media capabilities to your applications. In this instantiation we see that we need to specify to the client library the location of the Kurento Media Server. In this example, we assume it's located at localhost listening in port 8888. If you reproduce this tutorial you'll need to insert the specific location of your Kurento Media Server instance there.

```
@Configuration
@EnableWebSocket
@EnableAutoConfiguration
public class NuboEarJavaApp implements WebSocketConfigurer {

 final static String DEFAULT_KMS_WS_URI = "ws://localhost:8888/kurento";

 @Bean
 public NuboEarJavaHandler handler() {
  return new NuboEarJavaHandler();
 }

 @Bean
 public KurentoClient kurentoClient() {
  return KurentoClient.create(System.getProperty("kms.ws.uri",
    DEFAULT_KMS_WS_URI));
 }

 @Override
 public void registerWebSocketHandlers(WebSocketHandlerRegistry registry) {
```

```
  registry.addHandler(handler(), "/nuboeardetector");
 }

 public static void main(String[] args) throws Exception {
  new SpringApplication(NuboEarJavaApp.class).run(args);
 }
}
```

This web application follows Single Page Application architecture and uses a WebSocket to communicate client with application server by means of requests and responses. Specifically, the main app class implements the interface WebSocketConfigurer to register a WebSocketHanlder to process WebSocket requests in the path /nuboeardetector.

NuboEarJavaHandler class implements TextWebSocketHandler to handle text WebSocket requests. The central piece of this class is the method handleTextMessage. This method implements the actions for requests, returning responses through the WebSocket. In other words, it implements the server part of the signaling protocol depicted.

In the designed protocol there are three different kinds of incoming messages to the Server: start, show_ears, scale_factor, process_num_frames, width_to_process, stop and onIceCandidates. These messages are treated in the switch clause, taking the proper steps in each case.

```
public class NuboEarJavaHandler extends TextWebSocketHandler {

 @Override
 public void handleTextMessage(WebSocketSession session, TextMessage message)
 throws Exception {
  JsonObject jsonMessage = gson.fromJson(message.getPayload(),
   JsonObject.class);

  log.debug("Incoming message: {}", jsonMessage);

  switch (jsonMessage.get("id").getAsString()) {
   case "start":
    start(session, jsonMessage);
    break;
   case "show_ears":
    setVisualization(session, jsonMessage);
    break;
   case "scale_factor":
    log.debug("Case scale factor");
    setScaleFactor(session, jsonMessage);
    break;
   case "process_num_frames":
    log.debug("Case process num frames");
    setProcessNumberFrames(session, jsonMessage);
    break;
   case "width_to_process":
    log.debug("Case width to process");
    setWidthToProcess(session, jsonMessage);
    break;

   case "stop":
    {
     UserSession user = users.remove(session.getId());
     if (user != null) {
      user.release();
     }
     break;
    }
   case "onIceCandidate":
```

```
    {
     JsonObject candidate = jsonMessage.get("candidate")
     .getAsJsonObject();

     UserSession user = users.get(session.getId());
     if (user != null) {
      IceCandidate cand = new IceCandidate(candidate.get("candidate")
       .getAsString(), candidate.get("sdpMid").getAsString(),
       candidate.get("sdpMLineIndex").getAsInt());
      user.addCandidate(cand);
     }
     break;
    }

   default:
    sendError(session,
     "Invalid message with id " + jsonMessage.get("id").getAsString());
    break;
  }
 }

 private void start(WebSocketSession session, JsonObject jsonMessage) {
  ...
 }

 private void sendError(WebSocketSession session, String message) {
   ...
  }
  ...
}
```

In the following snippet, we can see the start method. It handles the ICE candidates gathering, creates a Media Pipeline, creates the Media Elements (WebRtcEndpoint and NuboEarDetectorFilter) and make the connections among them. A startResponse message is sent back to the client with the SDP answer.

```
private void start(final WebSocketSession session, JsonObject jsonMessage) {
 try {
  // Media Logic (Media Pipeline and Elements)
  UserSession user = new UserSession();
  MediaPipeline pipeline = kurento.createMediaPipeline();
  user.setMediaPipeline(pipeline);
  webRtcEndpoint = new WebRtcEndpoint.Builder(pipeline).build();
  user.setWebRtcEndpoint(webRtcEndpoint);
  users.put(session.getId(), user);

  webRtcEndpoint
   .addOnIceCandidateListener(new EventListener < OnIceCandidateEvent > () {
    @Override
    public void onEvent(OnIceCandidateEvent event) {
     JsonObject response = new JsonObject();
     response.addProperty("id", "iceCandidate");
     response.add("candidate", JsonUtils
      .toJsonObject(event.getCandidate()));
     try {
      synchronized(session) {
       session.sendMessage(new TextMessage(
        response.toString()));
      }
```

```
      } catch (IOException e) {
       log.debug(e.getMessage());
      }
     }
    });

  ear = new NuboEarDetector.Builder(pipeline).build();
  webRtcEndpoint.connect(ear);
  ear.connect(webRtcEndpoint);

  // SDP negotiation (offer and answer)
  String sdpOffer = jsonMessage.get("sdpOffer").getAsString();
  String sdpAnswer = webRtcEndpoint.processOffer(sdpOffer);

  // Sending response back to client
  JsonObject response = new JsonObject();
  response.addProperty("id", "startResponse");
  response.addProperty("sdpAnswer", sdpAnswer);

  synchronized(session) {
   session.sendMessage(new TextMessage(response.toString()));
  }
  webRtcEndpoint.gatherCandidates();

 } catch (Throwable t) {
  sendError(session, t.getMessage());
 }
}
```

The sendError method is quite simple: it sends an error message to the client when an exception is caught in the server-side.

```
private void sendError(WebSocketSession session, String message) {
 try {
  JsonObject response = new JsonObject();
  response.addProperty("id", "error");
  response.addProperty("message", message);
  session.sendMessage(new TextMessage(response.toString()));
 } catch (IOException e) {
  log.error("Exception sending message", e);
 }
}
```

Application Client Side

Let's move now to the client-side of the application. To call the previously created WebSocket service in the server-side, we use the JavaScript class WebSocket. We use an specific JavaScript library called kurento-utils.js to simplify the WebRTC interaction with the server. This library depends on adapter.js, which is a JavaScript WebRTC utility maintained by Google that abstracts away browser differences. Finally jquery.js is also needed in this application.

These libraries are linked in the index.html web page, and are used in the index.js. In the following snippet we can see the creation of the WebSocket (variable ws) in the path /nuboeardetector. Then, the onmessage listener of the WebSocket is used to implement the JSON signaling protocol in the client-side. Notice that there are three incoming messages to client: startResponse, error, and iceCandidate. Convenient actions are taken to implement each step in the communication. For example, in functions start the function WebRtcPeer.WebRtcPeerSendrecv of kurento-utils.js is used to start a WebRTC communication.

```
var ws = new WebSocket('ws://' + location.host + '/nuboeardetector');

ws.onmessage = function(message) {
 var parsedMessage = JSON.parse(message.data);
 console.info('Received message: ' + message.data);

 switch (parsedMessage.id) {
  case 'startResponse':
   startResponse(parsedMessage);
   break;

  case 'iceCandidate':
   webRtcPeer.addIceCandidate(parsedMessage.candidate, function(error) {
    if (!error) return;
    console.error("Error adding candidate: " + error);
   });
   break;

  case 'error':
   if (state == I_AM_STARTING) {
    setState(I_CAN_START);
   }
   onError("Error message from server: " + parsedMessage.message);
   break;
  default:
   if (state == I_AM_STARTING) {
    setState(I_CAN_START);
   }
   onError('Unrecognized message', parsedMessage);
 }
}

function start() {
 console.log("Starting video call ...")
  // Disable start button
 setState(I_AM_STARTING);
 showSpinner(videoInput, videoOutput);

 console.log("Creating WebRtcPeer and generating local sdp offer ...");
 var options = {
  localVideo: videoInput,
  remoteVideo: videoOutput,
  onicecandidate: onIceCandidate
 }

 webRtcPeer = new kurentoUtils.WebRtcPeer.WebRtcPeerSendrecv(options,
  function(error) {
   if (error) {
    return console.error(error);
   }
   webRtcPeer.generateOffer(onOffer);
  });
}

function onOffer(error, offerSdp) {
 if (error) return console.error("Error generating the offer");
 console.info('Invoking SDP offer callback function ' + location.host);
 var message = {
```

```
  id: 'start',
  sdpOffer: offerSdp
 }
 sendMessage(message);
}

function onIceCandidate(candidate) {
 console.log("Local candidate" + JSON.stringify(candidate));

 var message = {
  id: 'onIceCandidate',
  candidate: candidate
 };
 sendMessage(message);
}
```

Dependencies

This Java Spring application is implemented using Maven. The relevant part of the pom.xml is where NUBOMEDIA dependencies are declared. we need two dependencies: the Client Java dependency (kurento-client) and the JavaScript Kurento utility library (kurento-utils) for the client-side. Browser dependencies (i.e. *bootstrap*, *ekko-lightbox*, and *adapter.js*) are handled with Webjars.

```
<dependencies>
   <dependency>
      <groupId>org.kurento</groupId>
      <artifactId>kurento-client</artifactId>
   </dependency>
   <dependency>
      <groupId>org.kurento</groupId>
      <artifactId>kurento-utils-js</artifactId>
   </dependency>
</dependencies>
```

Note: We are in active development. You can find the latest version of Kurento Java Client at Maven Central.

1.4.2 Eye Detector

This web application consists on a WebRTC video communication with a eye detector filter (loopback, the media stream going from client to the media server and back to client).

Compiling & Running

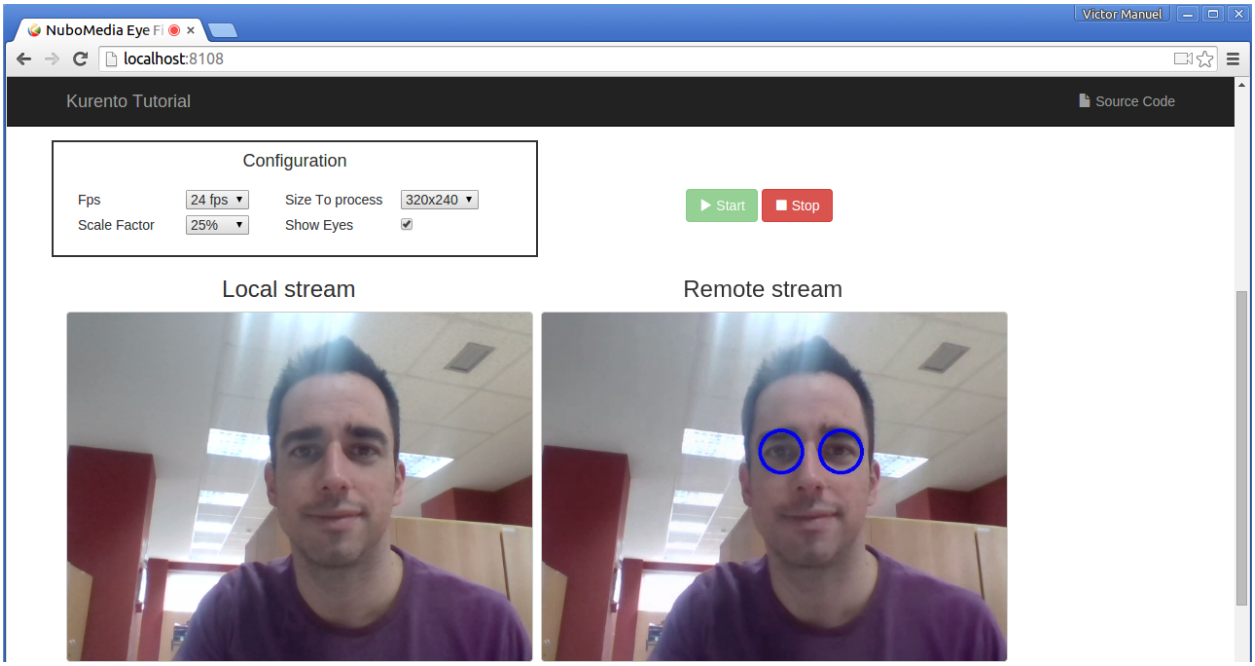
This section explain how to compile and run this tutorial in a local environment. To install the necessary software please see the installation guide. To compile and run this tutorial from the source code you can use the following commands:

```
git clone https://github.com/nubomedia/nubomedia-vca-eye-tutorial
cd nubomedia-vca-eye-tutorial
mvn spring-boot:run
```

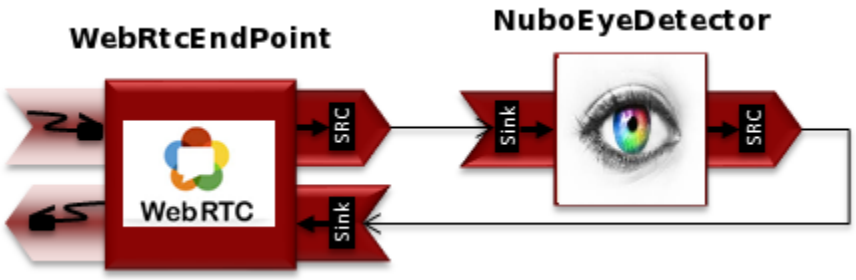
At this point we can test the application accessing the following URL: https://localhost:8443/.

Understanding this example

The following figure shows a screenshoot of this demo running.



The interface of the application (an HTML web page) is composed by two HTML5 video tags: one showing the local stream (as captured by the device webcam) and the other showing the remote stream sent by the media server back to the client. The video camera stream is sent to Kurento Media Server, which processes and sends it back to the client as a remote stream. To implement this, we need to create a Media Pipeline composed by the following Media Elements:

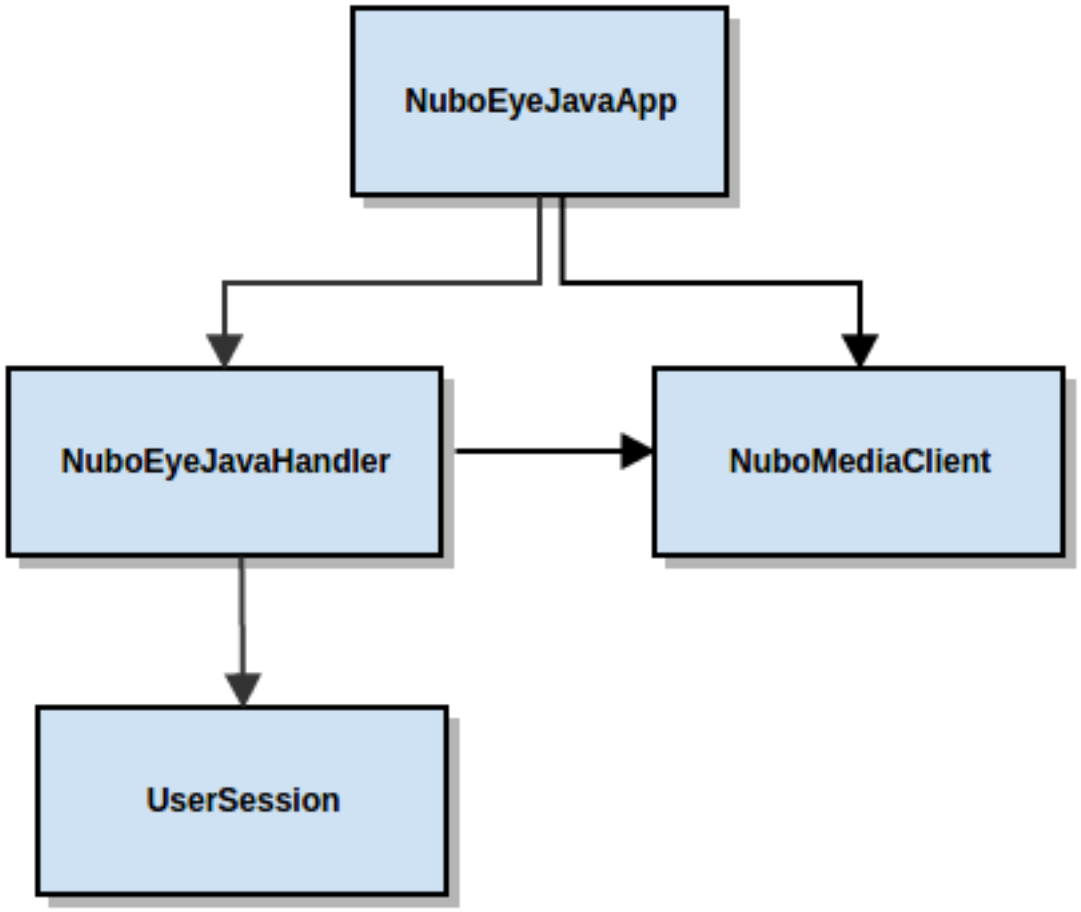


This is a web application, and therefore it follows a client-server architecture. At the client-side, the logic is implemented in JavaScript. At the server-side we use a Java EE application server consuming a Client API to control the Media Server capabilities. To communicate these entities, two WebSockets are used. First, a WebSocket is created between client and application server to implement a custom signaling protocol. Second, another WebSocket is used to perform the communication between the Java Client and the Media Server. To communicate the client with the Java EE application server the platform uses a simple signaling protocol based on JSON messages over WebSocket's. SDP and ICE candidates needs to be exchanged between client and server to establish the WebRtc session. If you are interested on knowing more about the messages exchanged between them, have a look to this example .

Application Server Side

This demo has been developed using a Java EE application server based on the Spring Boot framework. This technology can be used to embed the Tomcat web server in the application and thus simplify the development process.

In the following figure you can see a class diagram of the server side code:



The main class of this demo is named NuboEyeJavaApp. As you can see, the NuboMediaClient is instantiated in this class as a Spring Bean. This bean is used to create Media Pipelines, which are used to add media capabilities to your applications. In this instantiation we see that we need to specify to the client library the location of the Kurento Media Server. In this example, we assume it's located at localhost listening in port 8888. If you reproduce this tutorial you'll need to insert the specific location of your Kurento Media Server instance there.

```
@Configuration
@EnableWebSocket
@EnableAutoConfiguration
public class NuboEyeJavaApp implements WebSocketConfigurer {

 final static String DEFAULT_KMS_WS_URI = "ws://localhost:8888/kurento";

 @Bean
 public NuboEyeJavaHandler handler() {
  return new NuboEyeJavaHandler();
 }

 @Bean
 public KurentoClient kurentoClient() {
  return KurentoClient.create(System.getProperty("kms.ws.uri",
   DEFAULT_KMS_WS_URI));
 }
```

```
 @Override
 public void registerWebSocketHandlers(WebSocketHandlerRegistry registry) {
  registry.addHandler(handler(), "/nuboeyedetector");
 }

 public static void main(String[] args) throws Exception {
  new SpringApplication(NuboEyeJavaApp.class).run(args);
 }
}
```

This web application follows Single Page Application architecture and uses a WebSocket to communicate client with application server by means of requests and responses. Specifically, the main app class implements the interface WebSocketConfigurer to register a WebSocketHanlder to process WebSocket requests in the path /nuboeyedetector.

NuboEyeJavaHandler class implements TextWebSocketHandler to handle text WebSocket requests. The central piece of this class is the method handleTextMessage. This method implements the actions for requests, returning responses through the WebSocket. In other words, it implements the server part of the signaling protocol depicted.

In the designed protocol there are three different kinds of incoming messages to the Server: start, show_eyes, scale_factor, process_num_frames, width_to_process, stop and onIceCandidates. These messages are treated in the switch clause, taking the proper steps in each case.

```
public class NuboEyeJavaHandler extends TextWebSocketHandler {

 @Override
 public void handleTextMessage(WebSocketSession session, TextMessage message)
 throws Exception {
  JsonObject jsonMessage = gson.fromJson(message.getPayload(),
   JsonObject.class);

  log.debug("Incoming message: {}", jsonMessage);

  switch (jsonMessage.get("id").getAsString()) {
   case "start":
    start(session, jsonMessage);
    break;
   case "show_eyes":
    setVisualization(session, jsonMessage);
    break;
   case "scale_factor":
    log.debug("Case scale factor");
    setScaleFactor(session, jsonMessage);
    break;
   case "process_num_frames":
    log.debug("Case process num frames");
    setProcessNumberFrames(session, jsonMessage);
    break;
   case "width_to_process":
    log.debug("Case width to process");
    setWidthToProcess(session, jsonMessage);
    break;


   case "stop":
    {
     UserSession user = users.remove(session.getId());
     if (user != null) {
      user.release();
```

```
      }
      break;
     }
    case "onIceCandidate":
     {
      JsonObject candidate = jsonMessage.get("candidate")
      .getAsJsonObject();

      UserSession user = users.get(session.getId());
      if (user != null) {
       IceCandidate cand = new IceCandidate(candidate.get("candidate")
        .getAsString(), candidate.get("sdpMid").getAsString(),
        candidate.get("sdpMLineIndex").getAsInt());
       user.addCandidate(cand);
      }
      break;
     }

    default:
     sendError(session,
      "Invalid message with id " + jsonMessage.get("id").getAsString());
     break;
   }
  }

  private void start(WebSocketSession session, JsonObject jsonMessage) {
   ...
  }

  private void sendError(WebSocketSession session, String message) {
    ...
   }
   ...
}
```

In the following snippet, we can see the start method. It handles the ICE candidates gathering, creates a Media Pipeline, creates the Media Elements (WebRtcEndpoint and NuboEyeDetectorFilter) and make the connections among them. A startResponse message is sent back to the client with the SDP answer.

```
private void start(final WebSocketSession session, JsonObject jsonMessage) {
 try {
  // Media Logic (Media Pipeline and Elements)
  UserSession user = new UserSession();
  MediaPipeline pipeline = kurento.createMediaPipeline();
  user.setMediaPipeline(pipeline);
  webRtcEndpoint = new WebRtcEndpoint.Builder(pipeline).build();
  user.setWebRtcEndpoint(webRtcEndpoint);
  users.put(session.getId(), user);

  webRtcEndpoint
   .addOnIceCandidateListener(new EventListener < OnIceCandidateEvent > () {

    @Override
    public void onEvent(OnIceCandidateEvent event) {
     JsonObject response = new JsonObject();
     response.addProperty("id", "iceCandidate");
     response.add("candidate", JsonUtils
      .toJsonObject(event.getCandidate()));
```

```
      try {
       synchronized(session) {
        session.sendMessage(new TextMessage(
         response.toString()));
       }
      } catch (IOException e) {
       log.debug(e.getMessage());
      }
     }
    });

  eye = new NuboEyeDetector.Builder(pipeline).build();
  webRtcEndpoint.connect(eye);
  eye.connect(webRtcEndpoint);

  // SDP negotiation (offer and answer)
  String sdpOffer = jsonMessage.get("sdpOffer").getAsString();
  String sdpAnswer = webRtcEndpoint.processOffer(sdpOffer);

  // Sending response back to client
  JsonObject response = new JsonObject();
  response.addProperty("id", "startResponse");
  response.addProperty("sdpAnswer", sdpAnswer);

  synchronized(session) {
   session.sendMessage(new TextMessage(response.toString()));
  }
  webRtcEndpoint.gatherCandidates();

 } catch (Throwable t) {
  sendError(session, t.getMessage());
 }
}
```

The sendError method is quite simple: it sends an error message to the client when an exception is caught in the server-side.

```
private void sendError(WebSocketSession session, String message) {
 try {
  JsonObject response = new JsonObject();
  response.addProperty("id", "error");
  response.addProperty("message", message);
  session.sendMessage(new TextMessage(response.toString()));
 } catch (IOException e) {
  log.error("Exception sending message", e);
 }
}
```

Application Client Side

Let's move now to the client-side of the application. To call the previously created WebSocket service in the server-side, we use the JavaScript class WebSocket. We use an specific JavaScript library called kurento-utils.js to simplify the WebRTC interaction with the server. This library depends on adapter.js, which is a JavaScript WebRTC utility maintained by Google that abstracts away browser differences. Finally jquery.js is also needed in this application.

These libraries are linked in the index.html web page, and are used in the index.js. In the following snippet we can see the creation of the WebSocket (variable ws) in the path /nuboeyedetector. Then, the onmessage listener of the

WebSocket is used to implement the JSON signaling protocol in the client-side. Notice that there are three incoming messages to client: startResponse, error, and iceCandidate. Convenient actions are taken to implement each step in the communication. For example, in functions start the function WebRtcPeer.WebRtcPeerSendrecv of kurento-utils.js is used to start a WebRTC communication.

```
var ws = new WebSocket('ws://' + location.host + '/nuboeyedetector');

ws.onmessage = function(message) {
 var parsedMessage = JSON.parse(message.data);
 console.info('Received message: ' + message.data);

 switch (parsedMessage.id) {
  case 'startResponse':
   startResponse(parsedMessage);
   break;

  case 'iceCandidate':
   webRtcPeer.addIceCandidate(parsedMessage.candidate, function(error) {
    if (!error) return;
    console.error("Error adding candidate: " + error);
   });
   break;

  case 'error':
   if (state == I_AM_STARTING) {
    setState(I_CAN_START);
   }
   onError("Error message from server: " + parsedMessage.message);
   break;
  default:
   if (state == I_AM_STARTING) {
    setState(I_CAN_START);
   }
   onError('Unrecognized message', parsedMessage);
 }
}

function start() {
 console.log("Starting video call ...")
  // Disable start button
 setState(I_AM_STARTING);
 showSpinner(videoInput, videoOutput);

 console.log("Creating WebRtcPeer and generating local sdp offer ...");
 var options = {
  localVideo: videoInput,
  remoteVideo: videoOutput,
  onicecandidate: onIceCandidate
 }

 webRtcPeer = new kurentoUtils.WebRtcPeer.WebRtcPeerSendrecv(options,
  function(error) {
   if (error) {
    return console.error(error);
   }
   webRtcPeer.generateOffer(onOffer);
  });
}
```

```
function onOffer(error, offerSdp) {
 if (error) return console.error("Error generating the offer");
 console.info('Invoking SDP offer callback function ' + location.host);
 var message = {
  id: 'start',
  sdpOffer: offerSdp
 }
 sendMessage(message);
}

function onIceCandidate(candidate) {
 console.log("Local candidate" + JSON.stringify(candidate));

 var message = {
  id: 'onIceCandidate',
  candidate: candidate
 };
 sendMessage(message);
}
```

Dependencies

This Java Spring application is implemented using Maven. The relevant part of the pom.xml is where NUBOMEDIA dependencies are declared. we need two dependencies: the Client Java dependency (kurento-client) and the JavaScript Kurento utility library (kurento-utils) for the client-side. Browser dependencies (i.e. *bootstrap*, *ekko-lightbox*, and *adapter.js*) are handled with Webjars.

```
<dependencies>
   <dependency>
      <groupId>org.kurento</groupId>
      <artifactId>kurento-client</artifactId>
   </dependency>
   <dependency>
      <groupId>org.kurento</groupId>
      <artifactId>kurento-utils-js</artifactId>
   </dependency>
</dependencies>
```

Note: We are in active development. You can find the latest version of Kurento Java Client at Maven Central.

1.4.3 Face Detector

This web application consists on a WebRTC video communication with a face detector filter (loopback, the media stream going from client to the media server and back to client).

Compiling & Running

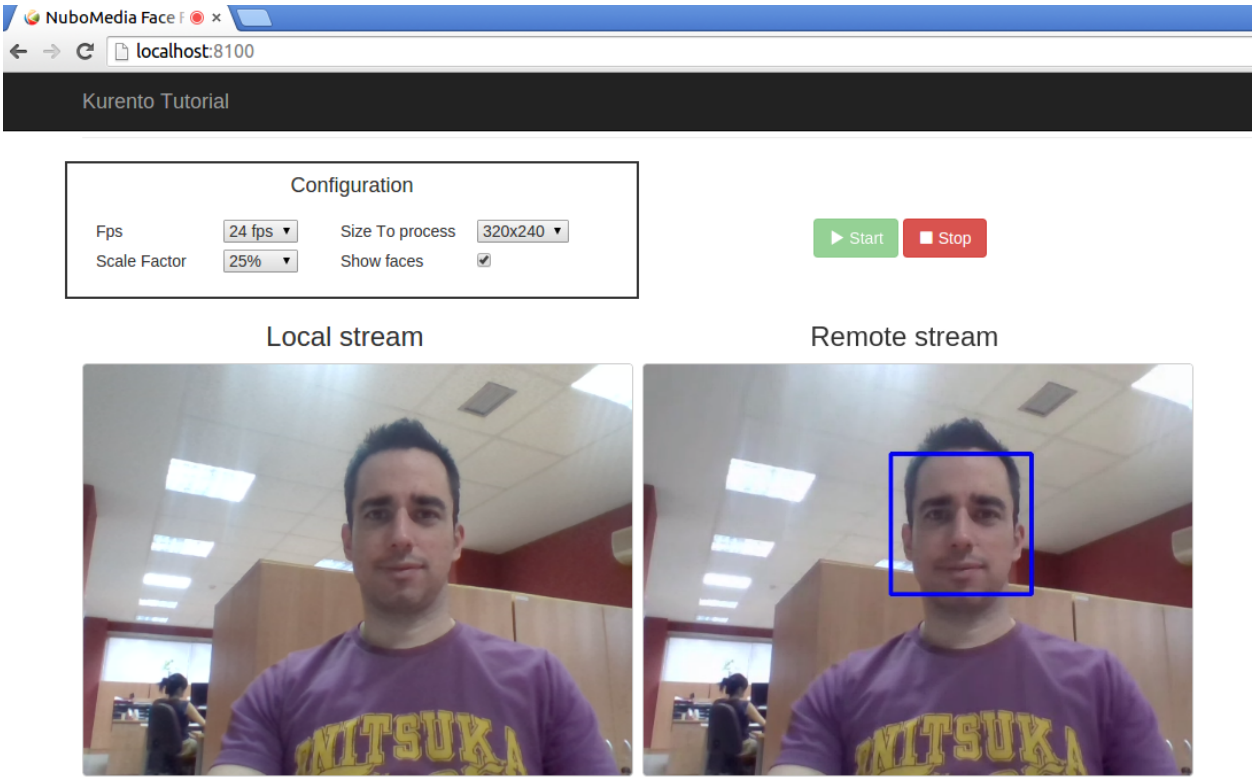
This section explain how to compile and run this tutorial in a local environment. To install the necessary software please see the installation guide. To compile and run this tutorial from the source code you can use the following commands:

```
git clone https://github.com/nubomedia/nubomedia-vca-face-tutorial
cd nubomedia-vca-face-tutorial
mvn spring-boot:run
```

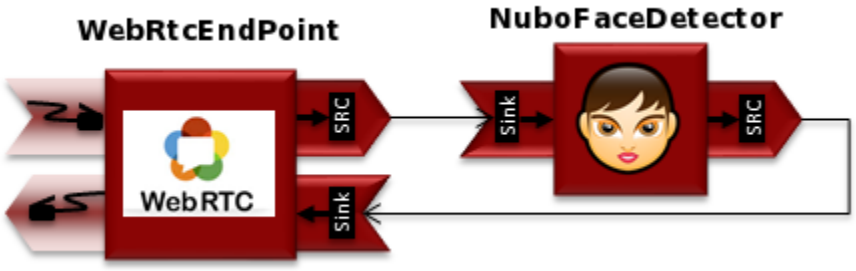
At this point we can test the application accessing the following URL: https://localhost:8443/.

Understanding this example

The following figure shows a screenshoot of this demo running.



The interface of the application (an HTML web page) is composed by two HTML5 video tags: one showing the local stream (as captured by the device webcam) and the other showing the remote stream sent by the media server back to the client. The video camera stream is sent to Kurento Media Server, which processes and sends it back to the client as a remote stream. To implement this, we need to create a Media Pipeline composed by the following Media Elements:



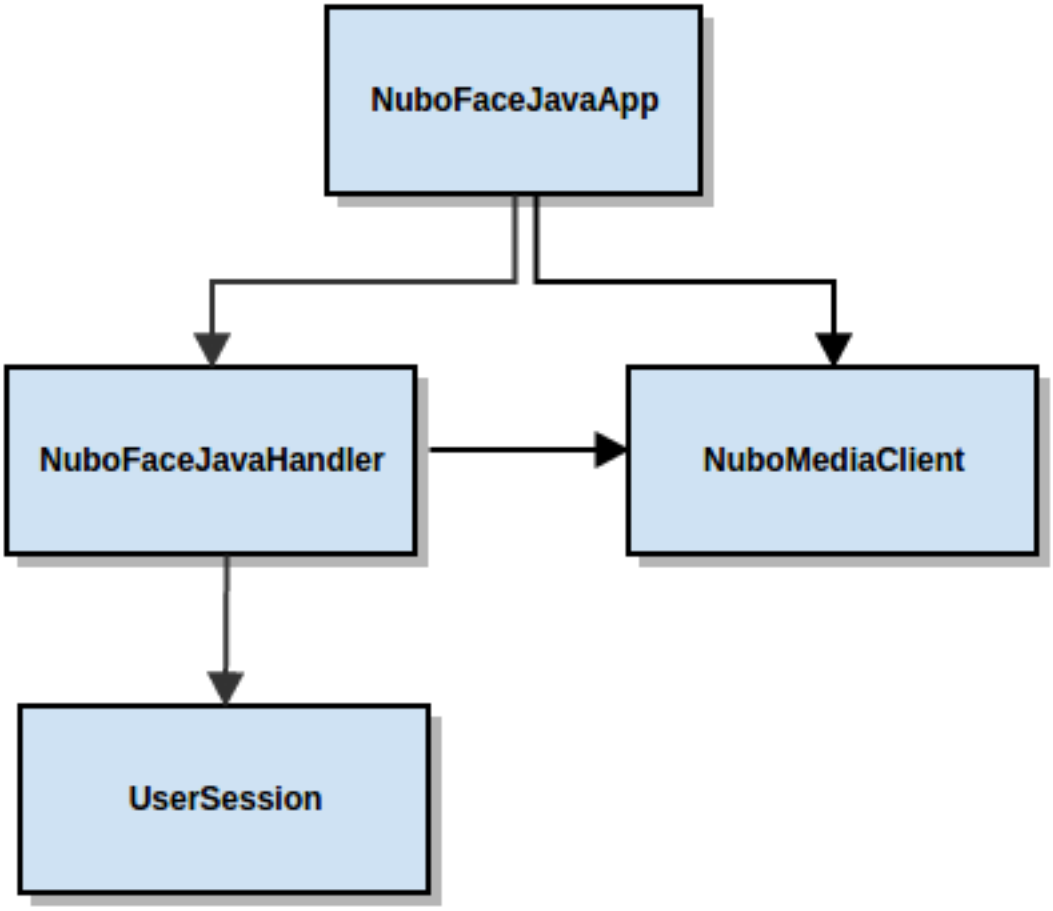
This is a web application, and therefore it follows a client-server architecture. At the client-side, the logic is implemented in JavaScript. At the server-side we use a Java EE application server consuming a Client API to control the Media Server capabilities. To communicate these entities, two WebSockets are used. First, a WebSocket is created

between client and application server to implement a custom signaling protocol. Second, another WebSocket is used to perform the communication between the Java Client and the Media Server. To communicate the client with the Java EE application server the platform uses a simple signaling protocol based on JSON messages over WebSocket's. SDP and ICE candidates needs to be exchanged between client and server to establish the WebRtc session. If you are interested on knowing more about the messages exchanged between them, have a look to this example .

Application Server Side

This demo has been developed using a Java EE application server based on the Spring Boot framework. This technology can be used to embed the Tomcat web server in the application and thus simplify the development process.

In the following figure you can see a class diagram of the server side code:



The main class of this demo is named NuboFaceJavaApp. As you can see, the NuboMediaClient is instantiated in this class as a Spring Bean. This bean is used to create Media Pipelines, which are used to add media capabilities to your applications. In this instantiation we see that we need to specify to the client library the location of the Kurento Media Server. In this example, we assume it's located at localhost listening in port 8888. If you reproduce this tutorial you'll need to insert the specific location of your Kurento Media Server instance there.

```
@Configuration
@EnableWebSocket
@EnableAutoConfiguration
public class NuboFaceJavaApp implements WebSocketConfigurer {
```

```
 final static String DEFAULT_KMS_WS_URI = "ws://localhost:8888/kurento";

 @Bean
 public NuboFaceJavaHandler handler() {
  return new NuboFaceJavaHandler();
 }

 @Bean
 public KurentoClient kurentoClient() {
  return KurentoClient.create(System.getProperty("kms.ws.uri",
   DEFAULT_KMS_WS_URI));
 }

 @Override
 public void registerWebSocketHandlers(WebSocketHandlerRegistry registry) {
  registry.addHandler(handler(), "/nubofacedetector");
 }

 public static void main(String[] args) throws Exception {
  new SpringApplication(NuboFaceJavaApp.class).run(args);
 }
}
```

This web application follows Single Page Application architecture and uses a WebSocket to communicate client with application server by means of requests and responses. Specifically, the main app class implements the interface WebSocketConfigurer to register a WebSocketHanlder to process WebSocket requests in the path /nubofacedetector.

NuboFaceJavaHandler class implements TextWebSocketHandler to handle text WebSocket requests. The central piece of this class is the method handleTextMessage. This method implements the actions for requests, returning responses through the WebSocket. In other words, it implements the server part of the signaling protocol depicted.

In the designed protocol there are three different kinds of incoming messages to the Server: start, show_faces, scale_factor, process_num_frames, width_to_process, stop and onIceCandidates. These messages are treated in the switch clause, taking the proper steps in each case.

```
public class NuboFaceJavaHandler extends TextWebSocketHandler {

 @Override
 public void handleTextMessage(WebSocketSession session, TextMessage message)
 throws Exception {
  JsonObject jsonMessage = gson.fromJson(message.getPayload(),
   JsonObject.class);

  log.debug("Incoming message: {}", jsonMessage);

  switch (jsonMessage.get("id").getAsString()) {
   case "start":
    start(session, jsonMessage);
    break;
   case "show_faces":
    setVisualization(session, jsonMessage);
    break;
   case "scale_factor":
    log.debug("Case scale factor");
    setScaleFactor(session, jsonMessage);
    break;
   case "process_num_frames":
    log.debug("Case process num frames");
```

```
    setProcessNumberFrames(session, jsonMessage);
    break;
   case "width_to_process":
    log.debug("Case width to process");
    setWidthToProcess(session, jsonMessage);
    break;

   case "stop":
    {
     UserSession user = users.remove(session.getId());
     if (user != null) {
      user.release();
     }
     break;
    }
   case "onIceCandidate":
    {
     JsonObject candidate = jsonMessage.get("candidate")
     .getAsJsonObject();

     UserSession user = users.get(session.getId());
     if (user != null) {
      IceCandidate cand = new IceCandidate(candidate.get("candidate")
       .getAsString(), candidate.get("sdpMid").getAsString(),
       candidate.get("sdpMLineIndex").getAsInt());
      user.addCandidate(cand);
     }
     break;
    }

   default:
    sendError(session,
     "Invalid message with id " + jsonMessage.get("id").getAsString());
    break;
  }
 }

 private void start(WebSocketSession session, JsonObject jsonMessage) {
  ...
 }

 private void sendError(WebSocketSession session, String message) {
   ...
  }
  ...
}
```

In the following snippet, we can see the start method. It handles the ICE candidates gathering, creates a Media Pipeline, creates the Media Elements (WebRtcEndpoint and NuboFaceDetectorFilter) and make the connections among them. A startResponse message is sent back to the client with the SDP answer.

```
private void start(final WebSocketSession session, JsonObject jsonMessage) {
 try {
  // Media Logic (Media Pipeline and Elements)
  UserSession user = new UserSession();
  MediaPipeline pipeline = kurento.createMediaPipeline();
  user.setMediaPipeline(pipeline);
  webRtcEndpoint = new WebRtcEndpoint.Builder(pipeline).build();
```

```
  user.setWebRtcEndpoint(webRtcEndpoint);
  users.put(session.getId(), user);

  webRtcEndpoint
   .addOnIceCandidateListener(new EventListener < OnIceCandidateEvent > () {

    @Override
    public void onEvent(OnIceCandidateEvent event) {
     JsonObject response = new JsonObject();
     response.addProperty("id", "iceCandidate");
     response.add("candidate", JsonUtils
      .toJsonObject(event.getCandidate()));
     try {
      synchronized(session) {
       session.sendMessage(new TextMessage(
        response.toString()));
      }
     } catch (IOException e) {
      log.debug(e.getMessage());
     }
    }
   });

  face = new NuboFaceDetector.Builder(pipeline).build();
  webRtcEndpoint.connect(face);
  face.connect(webRtcEndpoint);

  // SDP negotiation (offer and answer)
  String sdpOffer = jsonMessage.get("sdpOffer").getAsString();
  String sdpAnswer = webRtcEndpoint.processOffer(sdpOffer);

  // Sending response back to client
  JsonObject response = new JsonObject();
  response.addProperty("id", "startResponse");
  response.addProperty("sdpAnswer", sdpAnswer);

  synchronized(session) {
   session.sendMessage(new TextMessage(response.toString()));
  }
  webRtcEndpoint.gatherCandidates();

 } catch (Throwable t) {
  sendError(session, t.getMessage());
 }
}
```

The sendError method is quite simple: it sends an error message to the client when an exception is caught in the server-side.

```
private void sendError(WebSocketSession session, String message) {
 try {
  JsonObject response = new JsonObject();
  response.addProperty("id", "error");
  response.addProperty("message", message);
  session.sendMessage(new TextMessage(response.toString()));
 } catch (IOException e) {
  log.error("Exception sending message", e);
 }
```

```
}
```

Application Client Side

Let's move now to the client-side of the application. To call the previously created WebSocket service in the server-side, we use the JavaScript class WebSocket. We use an specific JavaScript library called kurento-utils.js to simplify the WebRTC interaction with the server. This library depends on adapter.js, which is a JavaScript WebRTC utility maintained by Google that abstracts away browser differences. Finally jquery.js is also needed in this application.

These libraries are linked in the index.html web page, and are used in the index.js. In the following snippet we can see the creation of the WebSocket (variable ws) in the path /nubofacedetector. Then, the onmessage listener of the WebSocket is used to implement the JSON signaling protocol in the client-side. Notice that there are three incoming messages to client: startResponse, error, and iceCandidate. Convenient actions are taken to implement each step in the communication. For example, in functions start the function WebRtcPeer.WebRtcPeerSendrecv of kurento-utils.js is used to start a WebRTC communication.

```
var ws = new WebSocket('ws://' + location.host + '/nubofacedetector');

ws.onmessage = function(message) {
 var parsedMessage = JSON.parse(message.data);
 console.info('Received message: ' + message.data);

 switch (parsedMessage.id) {
  case 'startResponse':
   startResponse(parsedMessage);
   break;

  case 'iceCandidate':
   webRtcPeer.addIceCandidate(parsedMessage.candidate, function(error) {
    if (!error) return;
    console.error("Error adding candidate: " + error);
   });
   break;

  case 'error':
   if (state == I_AM_STARTING) {
    setState(I_CAN_START);
   }
   onError("Error message from server: " + parsedMessage.message);
   break;
  default:
   if (state == I_AM_STARTING) {
    setState(I_CAN_START);
   }
   onError('Unrecognized message', parsedMessage);
 }
}

function start() {
 console.log("Starting video call ...")
  // Disable start button
 setState(I_AM_STARTING);
 showSpinner(videoInput, videoOutput);

 console.log("Creating WebRtcPeer and generating local sdp offer ...");
 var options = {
  localVideo: videoInput,
```

```
  remoteVideo: videoOutput,
  onicecandidate: onIceCandidate
 }

 webRtcPeer = new kurentoUtils.WebRtcPeer.WebRtcPeerSendrecv(options,
  function(error) {
   if (error) {
    return console.error(error);
   }
   webRtcPeer.generateOffer(onOffer);
  });
}

function onOffer(error, offerSdp) {
 if (error) return console.error("Error generating the offer");
 console.info('Invoking SDP offer callback function ' + location.host);
 var message = {
  id: 'start',
  sdpOffer: offerSdp
 }
 sendMessage(message);
}


function onIceCandidate(candidate) {
 console.log("Local candidate" + JSON.stringify(candidate));

 var message = {
  id: 'onIceCandidate',
  candidate: candidate
 };
 sendMessage(message);
}
```

Dependencies

This Java Spring application is implemented using Maven. The relevant part of the pom.xml is where NUBOMEDIA dependencies are declared. we need two dependencies: the Client Java dependency (kurento-client) and the JavaScript Kurento utility library (kurento-utils) for the client-side. Browser dependencies (i.e. *bootstrap*, *ekko-lightbox*, and *adapter.js*) are handled with Webjars.

```
<dependencies>
   <dependency>
      <groupId>org.kurento</groupId>
      <artifactId>kurento-client</artifactId>
   </dependency>
   <dependency>
      <groupId>org.kurento</groupId>
      <artifactId>kurento-utils-js</artifactId>
   </dependency>
</dependencies>
```

Note: We are in active development. You can find the latest version of Kurento Java Client at Maven Central.

1.4.4 Face Profile

This web application consists on a pipeline composed by a WebRTC video communication with an face, mouth, nose and eye detector filter (loopback, the media stream going from client to the media server and back to client).

Compiling & Running

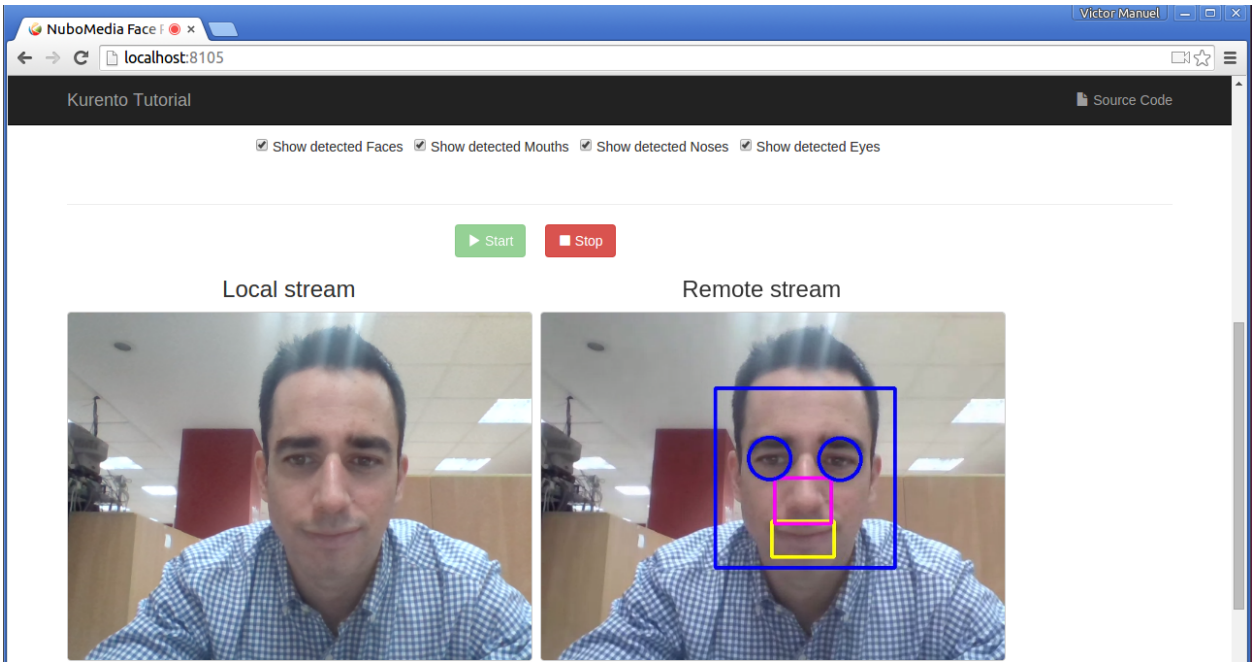
This section explain how to compile and run this tutorial in a local environment. To install the necessary software please see the installation guide. To compile and run this tutorial from the source code you can use the following commands:

```
git clone https://github.com/nubomedia/nubomedia-vca-face-profile-tutorial
cd nubomedia-vca-face-profile-tutorial
mvn spring-boot:run
```

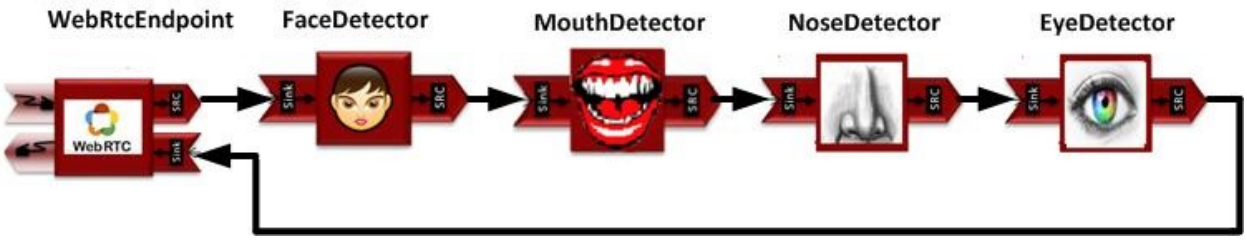
At this point we can test the application accessing the following URL: https://localhost:8443/.

Understanding this example

The following figure shows a screenshoot of this demo running.



The interface of the application (an HTML web page) is composed by two HTML5 video tags: one showing the local stream (as captured by the device webcam) and the other showing the remote stream sent by the media server back to the client. The video camera stream is sent to Kurento Media Server, which processes and sends it back to the client as a remote stream. To implement this, we need to create a Media Pipeline composed by the following Media Elements:

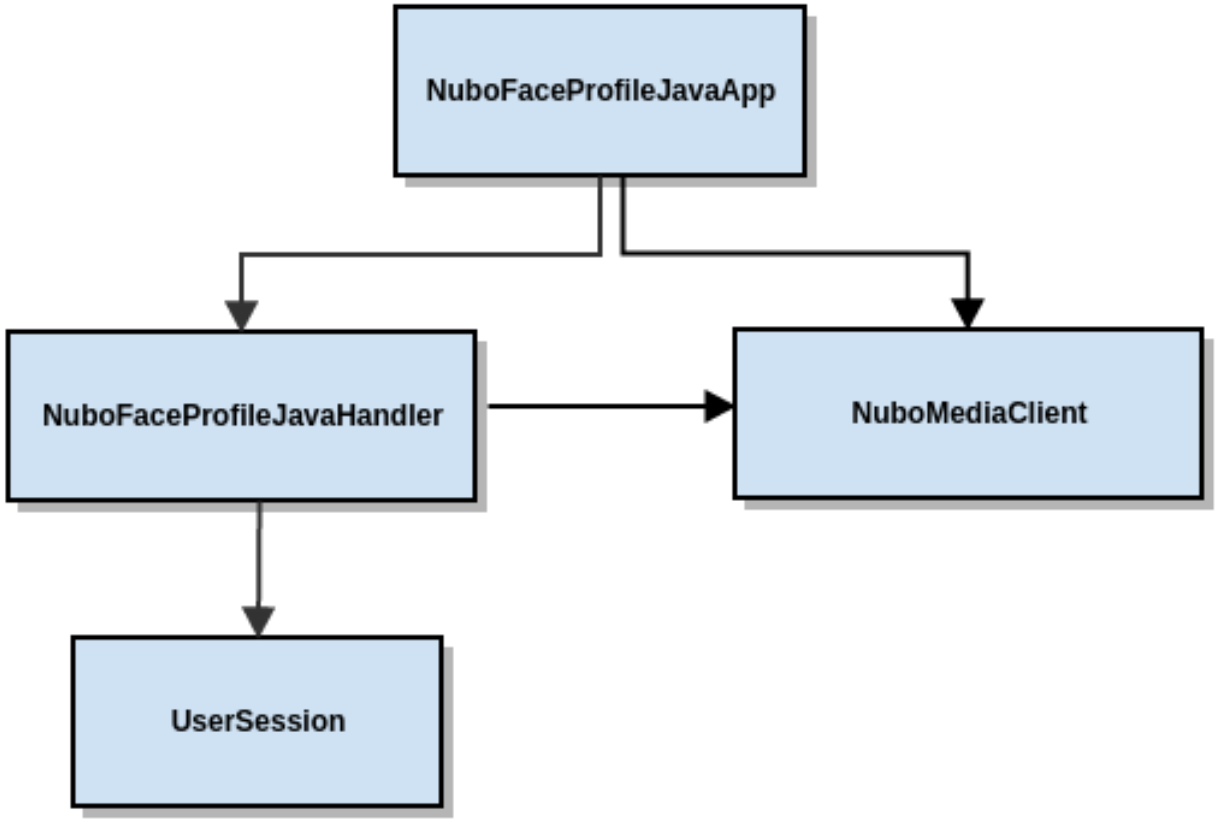


This is a web application, and therefore it follows a client-server architecture. At the client-side, the logic is implemented in JavaScript. At the server-side we use a Java EE application server consuming a Client API to control the Media Server capabilities. To communicate these entities, two WebSockets are used. First, a WebSocket is created between client and application server to implement a custom signaling protocol. Second, another WebSocket is used to perform the communication between the Java Client and the Media Server. To communicate the client with the Java EE application server the platform uses a simple signaling protocol based on JSON messages over WebSocket's. SDP and ICE candidates needs to be exchanged between client and server to establish the WebRtc session. If you are interested on knowing more about the messages exchanged between them, have a look to this example .

Application Server Side

This demo has been developed using a Java EE application server based on the Spring Boot framework. This technology can be used to embed the Tomcat web server in the application and thus simplify the development process.

In the following figure you can see a class diagram of the server side code:



The main class of this demo is named NuboFaceProfileJavaApp. As you can see, the NuboMediaClient is instantiated in this class as a Spring Bean. This bean is used to create Media Pipelines, which are used to add media capabilities to your applications. In this instantiation we see that we need to specify to the client library the location of the Kurento

Media Server. In this example, we assume it's located at localhost listening in port 8888. If you reproduce this tutorial you'll need to insert the specific location of your Kurento Media Server instance there.

```
@Configuration
@EnableWebSocket
@EnableAutoConfiguration
public class NuboFaceProfileJavaApp implements WebSocketConfigurer {

 final static String DEFAULT_KMS_WS_URI = "ws://localhost:8888/kurento";

 @Bean
 public NuboFaceProfileJavaHandler handler() {
  return new NuboFaceProfileJavaHandler();
 }

 @Bean
 public KurentoClient kurentoClient() {
  return KurentoClient.create(System.getProperty("kms.ws.uri",
   DEFAULT_KMS_WS_URI));
 }

 @Override
 public void registerWebSocketHandlers(WebSocketHandlerRegistry registry) {
  registry.addHandler(handler(), "/nubofaceprofiledetector");
 }

 public static void main(String[] args) throws Exception {
  new SpringApplication(NuboFaceProfileJavaApp.class).run(args);
 }
}
```

This web application follows Single Page Application architecture and uses a WebSocket to communicate client with application server by means of requests and responses. Specifically, the main app class implements the interface WebSocketConfigurer to register a WebSocketHanlder to process WebSocket requests in the path /nubofaceprofiledetector.

NuboFaceProfileJavaHandler class implements TextWebSocketHandler to handle text WebSocket requests. The central piece of this class is the method handleTextMessage. This method implements the actions for requests, returning responses through the WebSocket. In other words, it implements the server part of the signaling protocol depicted.

In the designed protocol there are three different kinds of incoming messages to the Server: start, show_faces, show_mouths, show_noses, show_eyes, scale_factor, process_num_frames, face_resolution, mouth_resolution, nose_resolution, eye_resolution, width_to_process, stop and onIceCandidates. These messages are treated in the switch clause, taking the proper steps in each case.

```
public class NuboFaceProfileJavaHandler extends TextWebSocketHandler {

 @Override
 public void handleTextMessage(WebSocketSession session, TextMessage message)
 throws Exception {
  JsonObject jsonMessage = gson.fromJson(message.getPayload(),
   JsonObject.class);

  log.debug("Incoming message: {}", jsonMessage);
  switch (jsonMessage.get("id").getAsString()) {
   case "start":
    start(session, jsonMessage);
    break;
   case "show_faces":
    setViewFaces(session, jsonMessage);
```

```
    break;

  case "show_mouths":
   setViewMouths(session, jsonMessage);
   break;

  case "show_noses":
   setViewNoses(session, jsonMessage);
   break;

  case "show_eyes":
   setViewEyes(session, jsonMessage);
   break;

  case "face_res":
   changeResolution(FACE_FILTER, session, jsonMessage);
   break;

  case "mouth_res":
   changeResolution(this.MOUTH_FILTER, session, jsonMessage);
   break;

  case "nose_res":
   changeResolution(this.NOSE_FILTER, session, jsonMessage);
   break;

  case "eye_res":
   changeResolution(this.EYE_FILTER, session, jsonMessage);
   break;

  case "fps":
   setFps(session, jsonMessage);
   break;

  case "scale_factor":
   setScaleFactor(session, jsonMessage);
   break;

  case "stop":
   {
    UserSession user = users.remove(session.getId());
    if (user != null) {
     user.release();
    }
    break;
   }
  case "onIceCandidate":
   {
    JsonObject candidate = jsonMessage.get("candidate")
    .getAsJsonObject();
    UserSession user = users.get(session.getId());
    if (user != null) {
     IceCandidate cand = new IceCandidate(candidate.get("candidate")
      .getAsString(), candidate.get("sdpMid").getAsString(),
      candidate.get("sdpMLineIndex").getAsInt());
     user.addCandidate(cand);
    }
    break;
```

```
    }

   default:
    System.out.println("Invalid message with id " + jsonMessage.get("id").getAsString());
    sendError(session,
     "Invalid message with id " + jsonMessage.get("id").getAsString());
    break;
  }
 }
 private void start(WebSocketSession session, JsonObject jsonMessage) {
  ...
 }

 private void sendError(WebSocketSession session, String message) {
   ...
  }
  ...
}
```

In the following snippet, we can see the start method. It handles the ICE candidates gathering, creates a Media Pipeline, creates the Media Elements and make the connections among them. A startResponse message is sent back to the client with the SDP answer.

```
private void start(final WebSocketSession session, JsonObject jsonMessage) {
  try {
   // Media Logic (Media Pipeline and Elements)
   UserSession user = new UserSession();
   pipeline = kurento.createMediaPipeline();
   user.setMediaPipeline(pipeline);
   webRtcEndpoint = new WebRtcEndpoint.Builder(pipeline).build();
   user.setWebRtcEndpoint(webRtcEndpoint);
   users.put(session.getId(), user);

   webRtcEndpoint.addOnIceCandidateListener(new EventListener < OnIceCandidateEvent > () {

     @Override
     public void onEvent(OnIceCandidateEvent event) {
      JsonObject response = new JsonObject();
      response.addProperty("id", "iceCandidate");
      response.add("candidate", JsonUtils.toJsonObject(event.getCandidate()));
      try {
       synchronized(session) {
        session.sendMessage(new TextMessage(response.toString()));
       }
      } catch (IOException e) {
       log.debug(e.getMessage());
      }

     });

    pipeline.setLatencyStats(true); face = new NuboFaceDetector.Builder(pipeline).build(); face.sendM


    mouth = new NuboMouthDetector.Builder(pipeline).build(); mouth.sendMetaData(0); mouth.detectByEve

    nose = new NuboNoseDetector.Builder(pipeline).build(); nose.sendMetaData(0); nose.detectByEvent(1

    eye = new NuboEyeDetector.Builder(pipeline).build(); eye.sendMetaData(0); eye.detectByEvent(1); e
```

```
    webRtcEndpoint.connect(face); face.connect(mouth); mouth.connect(nose); nose.connect(eye); eye.co

    // SDP negotiation (offer and answer)
    String sdpOffer = jsonMessage.get("sdpOffer").getAsString(); String sdpAnswer = webRtcEndpoint.pr

    // Sending response back to client
    JsonObject response = new JsonObject(); response.addProperty("id", "startResponse"); response.add

    synchronized(session) {
     session.sendMessage(new TextMessage(response.toString()));
    }
    webRtcEndpoint.gatherCandidates();

   } catch (Throwable t) {
    sendError(session, t.getMessage());
   }
  }
}
```

The sendError method is quite simple: it sends an error message to the client when an exception is caught in the server-side.

```
private void sendError(WebSocketSession session, String message) {
 try {
  JsonObject response = new JsonObject();
  response.addProperty("id", "error");
  response.addProperty("message", message);
  session.sendMessage(new TextMessage(response.toString()));
 } catch (IOException e) {
  log.error("Exception sending message", e);
 }
}
```

Application Client Side

Let's move now to the client-side of the application. To call the previously created WebSocket service in the server-side, we use the JavaScript class WebSocket. We use an specific JavaScript library called kurento-utils.js to simplify the WebRTC interaction with the server. This library depends on adapter.js, which is a JavaScript WebRTC utility maintained by Google that abstracts away browser differences. Finally jquery.js is also needed in this application.

These libraries are linked in the index.html web page, and are used in the index.js. In the following snippet we can see the creation of the WebSocket (variable ws) in the path /nubofaceprofiledetector. Then, the onmessage listener of the WebSocket is used to implement the JSON signaling protocol in the client-side. Notice that there are three incoming messages to client: startResponse, error, and iceCandidate. Convenient actions are taken to implement each step in the communication. For example, in functions start the function WebRtcPeer.WebRtcPeerSendrecv of kurento-utils.js is used to start a WebRTC communication.

```
var ws = new WebSocket('ws://' + location.host + '/nubofaceprofiledetector');

ws.onmessage = function(message) {
 var parsedMessage = JSON.parse(message.data);
 console.info('Received message: ' + message.data);

 switch (parsedMessage.id) {
  case 'startResponse':
   startResponse(parsedMessage);
```

```
    break;

  case 'iceCandidate':
   webRtcPeer.addIceCandidate(parsedMessage.candidate, function(error) {
    if (!error) return;
    console.error("Error adding candidate: " + error);
   });
   break;

  case 'error':
   if (state == I_AM_STARTING) {
    setState(I_CAN_START);
   }
   onError("Error message from server: " + parsedMessage.message);
   break;
  default:
   if (state == I_AM_STARTING) {
    setState(I_CAN_START);
   }
   onError('Unrecognized message', parsedMessage);
 }
}

function start() {
 console.log("Starting video call ...")
  // Disable start button
 setState(I_AM_STARTING);
 showSpinner(videoInput, videoOutput);

 console.log("Creating WebRtcPeer and generating local sdp offer ...");
 var options = {
  localVideo: videoInput,
  remoteVideo: videoOutput,
  onicecandidate: onIceCandidate
 }

 webRtcPeer = new kurentoUtils.WebRtcPeer.WebRtcPeerSendrecv(options,
  function(error) {
   if (error) {
    return console.error(error);
   }
   webRtcPeer.generateOffer(onOffer);
  });
}

function onOffer(error, offerSdp) {
 if (error) return console.error("Error generating the offer");
 console.info('Invoking SDP offer callback function ' + location.host);
 var message = {
  id: 'start',
  sdpOffer: offerSdp
 }
 sendMessage(message);
}


function onIceCandidate(candidate) {
 console.log("Local candidate" + JSON.stringify(candidate));
```

```
 var message = {
  id: 'onIceCandidate',
  candidate: candidate
 };
 sendMessage(message);
}
```

Dependencies

This Java Spring application is implemented using Maven. The relevant part of the pom.xml is where NUBOMEDIA dependencies are declared. we need two dependencies: the Client Java dependency (kurento-client) and the JavaScript Kurento utility library (kurento-utils) for the client-side. Browser dependencies (i.e. *bootstrap*, *ekko-lightbox*, and *adapter.js*) are handled with Webjars.

```
<dependencies>
   <dependency>
      <groupId>org.kurento</groupId>
      <artifactId>kurento-client</artifactId>
   </dependency>
   <dependency>
      <groupId>org.kurento</groupId>
      <artifactId>kurento-utils-js</artifactId>
   </dependency>
</dependencies>
```

Note: We are in active development. You can find the latest version of Kurento Java Client at Maven Central.

1.4.5 Mouth Detector

This web application consists on a WebRTC video communication with a mouth detector filter (loopback, the media stream going from client to the media server and back to client).

Compiling & Running

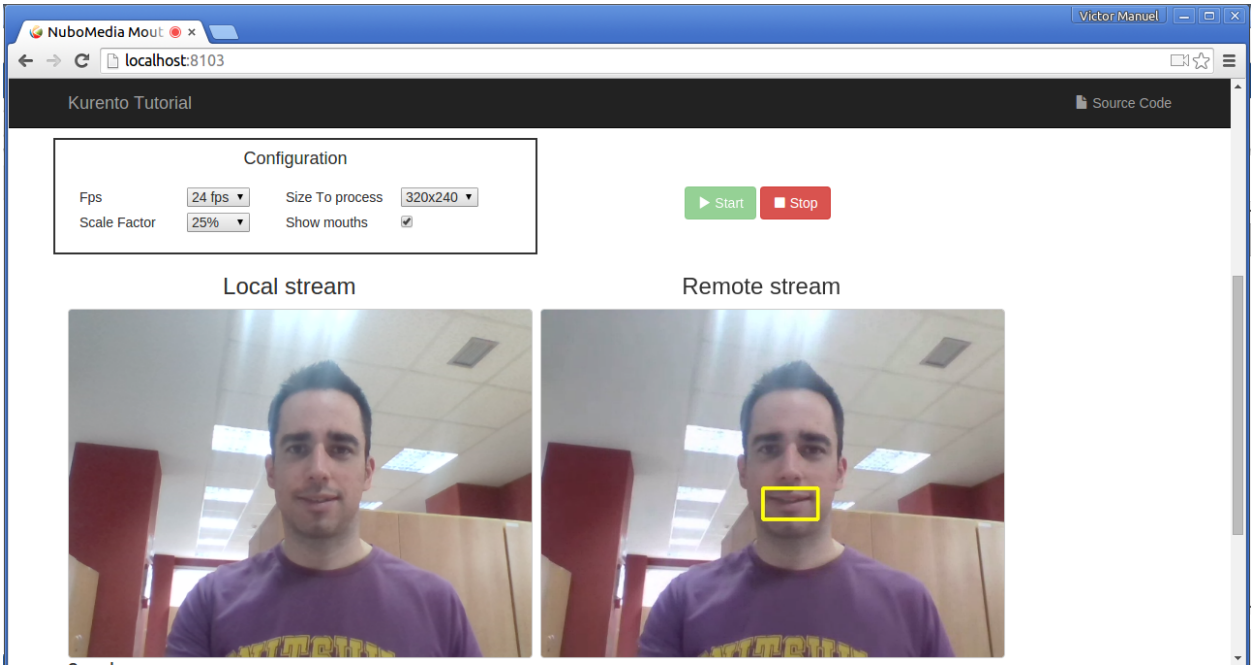
This section explain how to compile and run this tutorial in a local environment. To install the necessary software please see the installation guide. To compile and run this tutorial from the source code you can use the following commands:

```
git clone https://github.com/nubomedia/nubomedia-vca-mouth-tutorial
cd nubomedia-vca-mouth-tutorial
mvn spring-boot:run
```

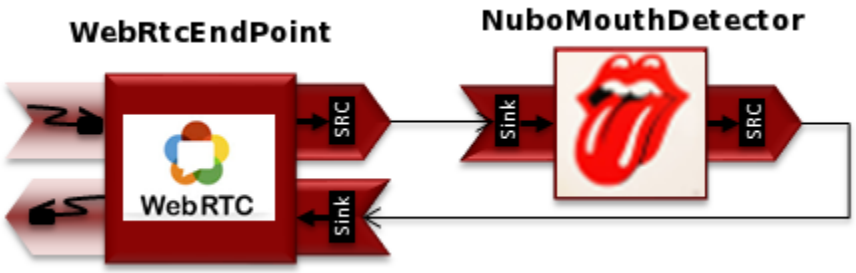
At this point we can test the application accessing the following URL: https://localhost:8443/.

Understanding this example

The following figure shows a screenshoot of this demo running.



The interface of the application (an HTML web page) is composed by two HTML5 video tags: one showing the local stream (as captured by the device webcam) and the other showing the remote stream sent by the media server back to the client. The video camera stream is sent to Kurento Media Server, which processes and sends it back to the client as a remote stream. To implement this, we need to create a Media Pipeline composed by the following Media Elements:

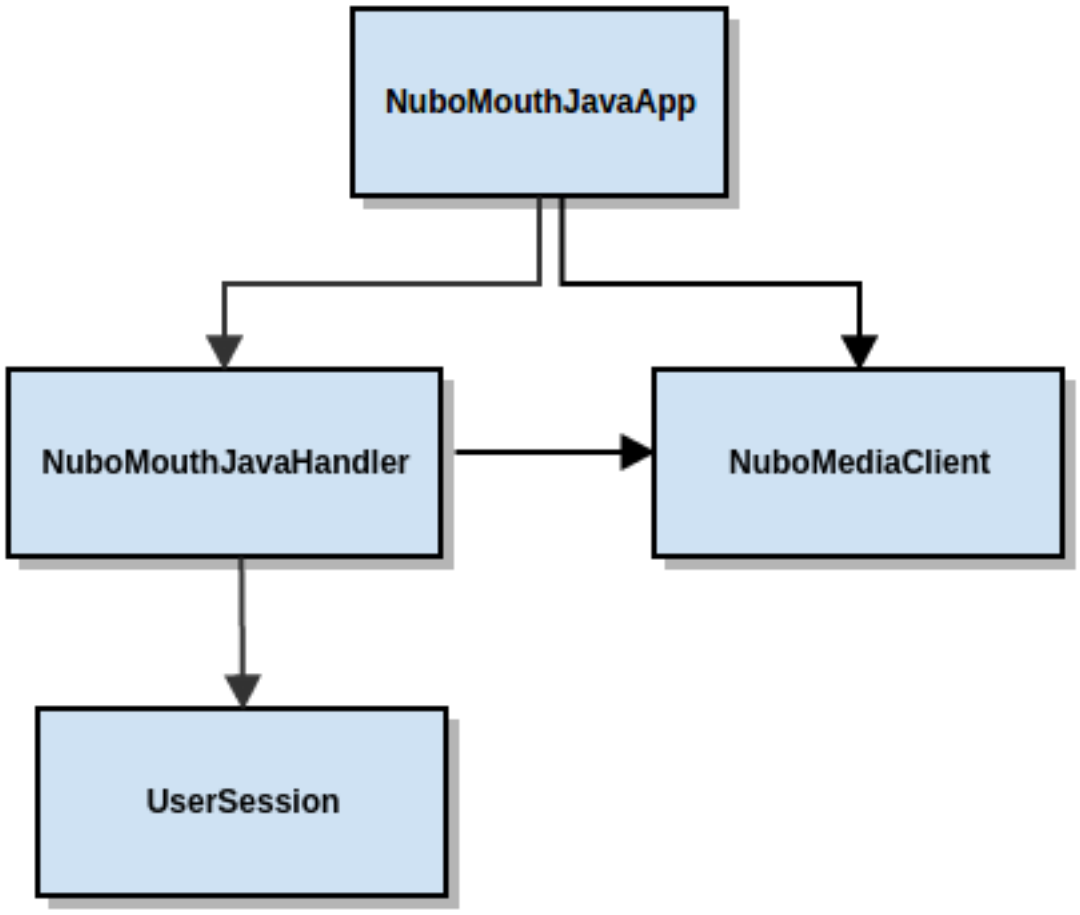


This is a web application, and therefore it follows a client-server architecture. At the client-side, the logic is implemented in JavaScript. At the server-side we use a Java EE application server consuming a Client API to control the Media Server capabilities. To communicate these entities, two WebSockets are used. First, a WebSocket is created between client and application server to implement a custom signaling protocol. Second, another WebSocket is used to perform the communication between the Java Client and the Media Server. To communicate the client with the Java EE application server the platform uses a simple signaling protocol based on JSON messages over WebSocket's. SDP and ICE candidates needs to be exchanged between client and server to establish the WebRtc session. If you are interested on knowing more about the messages exchanged between them, have a look to this example .

Application Server Side

This demo has been developed using a Java EE application server based on the Spring Boot framework. This technology can be used to embed the Tomcat web server in the application and thus simplify the development process.

In the following figure you can see a class diagram of the server side code:



The main class of this demo is named NuboMouthJavaApp. As you can see, the NuboMediaClient is instantiated in this class as a Spring Bean. This bean is used to create Media Pipelines, which are used to add media capabilities to your applications. In this instantiation we see that we need to specify to the client library the location of the Kurento Media Server. In this example, we assume it's located at localhost listening in port 8888. If you reproduce this tutorial you'll need to insert the specific location of your Kurento Media Server instance there.

```
@Configuration
@EnableWebSocket
@EnableAutoConfiguration
public class NuboMouthJavaApp implements WebSocketConfigurer {

 final static String DEFAULT_KMS_WS_URI = "ws://localhost:8888/kurento";

 @Bean
 public NuboMouthJavaHandler handler() {
  return new NuboMouthJavaHandler();
 }

 @Bean
 public KurentoClient kurentoClient() {
  return KurentoClient.create(System.getProperty("kms.ws.uri",
   DEFAULT_KMS_WS_URI));
 }

 @Override
 public void registerWebSocketHandlers(WebSocketHandlerRegistry registry) {
```

```
  registry.addHandler(handler(), "/nubomouthdetector");
 }

 public static void main(String[] args) throws Exception {
  new SpringApplication(NuboMouthJavaApp.class).run(args);
 }
}
```

This web application follows Single Page Application architecture and uses a WebSocket to communicate client with application server by means of requests and responses. Specifically, the main app class implements the interface WebSocketConfigurer to register a WebSocketHanlder to process WebSocket requests in the path /nubomouthdetector.

NuboMouthJavaHandler class implements TextWebSocketHandler to handle text WebSocket requests. The central piece of this class is the method handleTextMessage. This method implements the actions for requests, returning responses through the WebSocket. In other words, it implements the server part of the signaling protocol depicted.

In the designed protocol there are three different kinds of incoming messages to the Server: start, show_mouths, scale_factor, process_num_frames, width_to_process, stop and onIceCandidates. These messages are treated in the switch clause, taking the proper steps in each case.

```
public class NuboMouthJavaHandler extends TextWebSocketHandler {

 @Override
 public void handleTextMessage(WebSocketSession session, TextMessage message)
 throws Exception {
  JsonObject jsonMessage = gson.fromJson(message.getPayload(),
   JsonObject.class);

  log.debug("Incoming message: {}", jsonMessage);

  switch (jsonMessage.get("id").getAsString()) {
   case "start":
    start(session, jsonMessage);
    break;
   case "show_mouths":
    setVisualization(session, jsonMessage);
    break;
   case "scale_factor":
    log.debug("Case scale factor");
    setScaleFactor(session, jsonMessage);
    break;
   case "process_num_frames":
    log.debug("Case process num frames");
    setProcessNumberFrames(session, jsonMessage);
    break;
   case "width_to_process":
    log.debug("Case width to process");
    setWidthToProcess(session, jsonMessage);
    break;


   case "stop":
    {
     UserSession user = users.remove(session.getId());
     if (user != null) {
      user.release();
     }
     break;
    }
```

```
   case "onIceCandidate":
    {
     JsonObject candidate = jsonMessage.get("candidate")
     .getAsJsonObject();

     UserSession user = users.get(session.getId());
     if (user != null) {
      IceCandidate cand = new IceCandidate(candidate.get("candidate")
       .getAsString(), candidate.get("sdpMid").getAsString(),
       candidate.get("sdpMLineIndex").getAsInt());
      user.addCandidate(cand);
     }
     break;
    }

   default:
    sendError(session,
     "Invalid message with id " + jsonMessage.get("id").getAsString());
    break;
  }
 }

 private void start(WebSocketSession session, JsonObject jsonMessage) {
  ...
 }

 private void sendError(WebSocketSession session, String message) {
   ...
  }
  ...
}
```

In the following snippet, we can see the start method. It handles the ICE candidates gathering, creates a Media Pipeline, creates the Media Elements (WebRtcEndpoint and NuboMouthDetectorFilter) and make the connections among them. A startResponse message is sent back to the client with the SDP answer.

```
private void start(final WebSocketSession session, JsonObject jsonMessage) {
 try {
  // Media Logic (Media Pipeline and Elements)
  UserSession user = new UserSession();
  MediaPipeline pipeline = kurento.createMediaPipeline();
  user.setMediaPipeline(pipeline);
  webRtcEndpoint = new WebRtcEndpoint.Builder(pipeline).build();
  user.setWebRtcEndpoint(webRtcEndpoint);
  users.put(session.getId(), user);

  webRtcEndpoint
   .addOnIceCandidateListener(new EventListener < OnIceCandidateEvent > () {

    @Override
    public void onEvent(OnIceCandidateEvent event) {
     JsonObject response = new JsonObject();
     response.addProperty("id", "iceCandidate");
     response.add("candidate", JsonUtils
      .toJsonObject(event.getCandidate()));
     try {
      synchronized(session) {
       session.sendMessage(new TextMessage(
```

```
          response.toString()));
        }
      } catch (IOException e) {
       log.debug(e.getMessage());
      }
     }
    });

  mouth = new NuboMouthDetector.Builder(pipeline).build();
  webRtcEndpoint.connect(mouth);
  mouth.connect(webRtcEndpoint);

  // SDP negotiation (offer and answer)
  String sdpOffer = jsonMessage.get("sdpOffer").getAsString();
  String sdpAnswer = webRtcEndpoint.processOffer(sdpOffer);

  // Sending response back to client
  JsonObject response = new JsonObject();
  response.addProperty("id", "startResponse");
  response.addProperty("sdpAnswer", sdpAnswer);

  synchronized(session) {
   session.sendMessage(new TextMessage(response.toString()));
  }
  webRtcEndpoint.gatherCandidates();

 } catch (Throwable t) {
  sendError(session, t.getMessage());
 }
}
```

The sendError method is quite simple: it sends an error message to the client when an exception is caught in the server-side.

```
private void sendError(WebSocketSession session, String message) {
 try {
  JsonObject response = new JsonObject();
  response.addProperty("id", "error");
  response.addProperty("message", message);
  session.sendMessage(new TextMessage(response.toString()));
 } catch (IOException e) {
  log.error("Exception sending message", e);
 }
}
```

Application Client Side

Let's move now to the client-side of the application. To call the previously created WebSocket service in the server-side, we use the JavaScript class WebSocket. We use an specific JavaScript library called kurento-utils.js to simplify the WebRTC interaction with the server. This library depends on adapter.js, which is a JavaScript WebRTC utility maintained by Google that abstracts away browser differences. Finally jquery.js is also needed in this application.

These libraries are linked in the index.html web page, and are used in the index.js. In the following snippet we can see the creation of the WebSocket (variable ws) in the path /nubomouthdetector. Then, the onmessage listener of the WebSocket is used to implement the JSON signaling protocol in the client-side. Notice that there are three incoming messages to client: startResponse, error, and iceCandidate. Convenient actions are taken to implement each step in

the communication. For example, in functions start the function WebRtcPeer.WebRtcPeerSendrecv of kurento-utils.js is used to start a WebRTC communication.

```
var ws = new WebSocket('ws://' + location.host + '/nubomouthdetector');

ws.onmessage = function(message) {
 var parsedMessage = JSON.parse(message.data);
 console.info('Received message: ' + message.data);

 switch (parsedMessage.id) {
  case 'startResponse':
   startResponse(parsedMessage);
   break;

  case 'iceCandidate':
   webRtcPeer.addIceCandidate(parsedMessage.candidate, function(error) {
    if (!error) return;
    console.error("Error adding candidate: " + error);
   });
   break;

  case 'error':
   if (state == I_AM_STARTING) {
    setState(I_CAN_START);
   }
   onError("Error message from server: " + parsedMessage.message);
   break;
  default:
   if (state == I_AM_STARTING) {
    setState(I_CAN_START);
   }
   onError('Unrecognized message', parsedMessage);
 }
}

function start() {
 console.log("Starting video call ...")
  // Disable start button
 setState(I_AM_STARTING);
 showSpinner(videoInput, videoOutput);

 console.log("Creating WebRtcPeer and generating local sdp offer ...");
 var options = {
  localVideo: videoInput,
  remoteVideo: videoOutput,
  onicecandidate: onIceCandidate
 }

 webRtcPeer = new kurentoUtils.WebRtcPeer.WebRtcPeerSendrecv(options,
  function(error) {
   if (error) {
    return console.error(error);
   }
   webRtcPeer.generateOffer(onOffer);
  });
}

function onOffer(error, offerSdp) {
 if (error) return console.error("Error generating the offer");
```

```
 console.info('Invoking SDP offer callback function ' + location.host);
 var message = {
  id: 'start',
  sdpOffer: offerSdp
 }
 sendMessage(message);
}


function onIceCandidate(candidate) {
 console.log("Local candidate" + JSON.stringify(candidate));

 var message = {
  id: 'onIceCandidate',
  candidate: candidate
 };
 sendMessage(message);
}
```

Dependencies

This Java Spring application is implemented using Maven. The relevant part of the pom.xml is where NUBOMEDIA dependencies are declared. we need two dependencies: the Client Java dependency (kurento-client) and the JavaScript Kurento utility library (kurento-utils) for the client-side. Browser dependencies (i.e. *bootstrap*, *ekko-lightbox*, and *adapter.js*) are handled with Webjars.

```
<dependencies>
   <dependency>
      <groupId>org.kurento</groupId>
      <artifactId>kurento-client</artifactId>
   </dependency>
   <dependency>
      <groupId>org.kurento</groupId>
      <artifactId>kurento-utils-js</artifactId>
   </dependency>
</dependencies>
```

Note: We are in active development. You can find the latest version of Kurento Java Client at Maven Central.

1.4.6 Nose Detector

This web application consists on a WebRTC video communication with a nose detector filter (loopback, the media stream going from client to the media server and back to client).

Compiling & Running

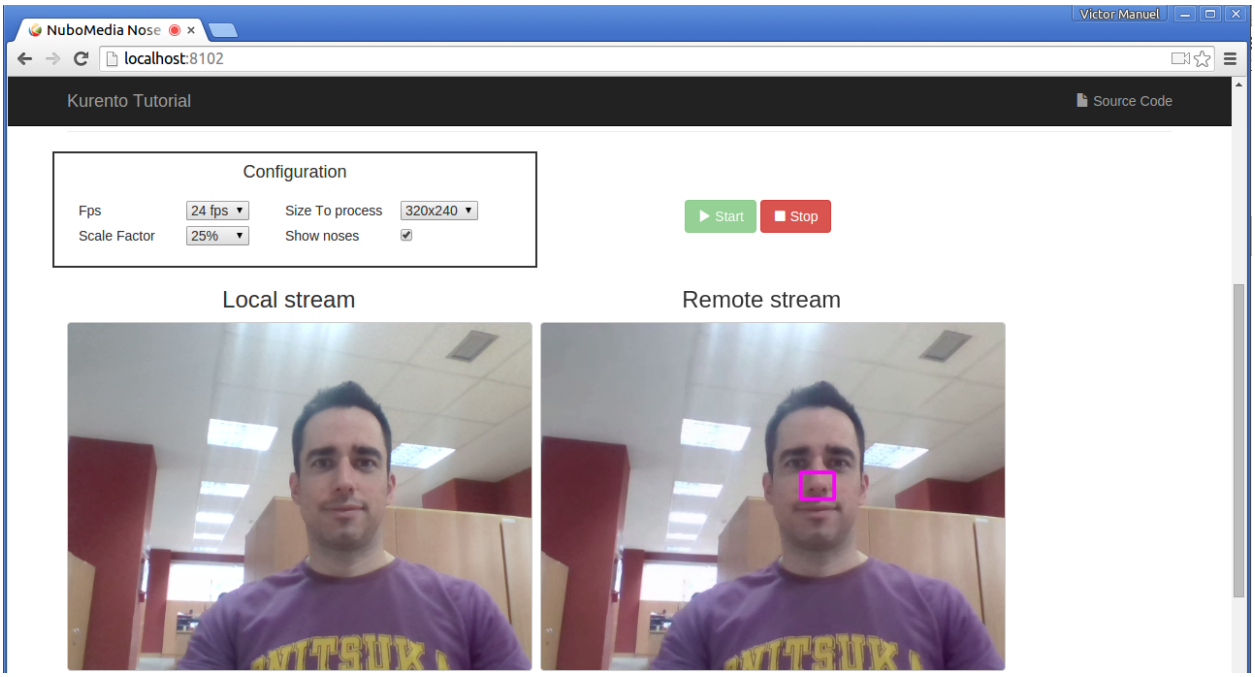
This section explain how to compile and run this tutorial in a local environment. To install the necessary software please see the installation guide. To compile and run this tutorial from the source code you can use the following commands:

```
git clone https://github.com/nubomedia/nubomedia-vca-nose-tutorial
cd nubomedia-vca-nose-tutorial
mvn spring-boot:run
```

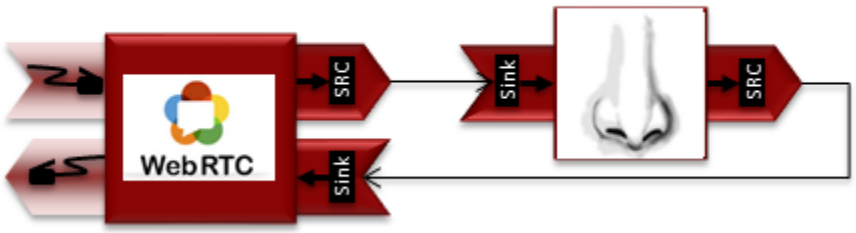
At this point we can test the application accessing the following URL: https://localhost:8443/.

Understanding this example

The following figure shows a screenshoot of this demo running.



The interface of the application (an HTML web page) is composed by two HTML5 video tags: one showing the local stream (as captured by the device webcam) and the other showing the remote stream sent by the media server back to the client. The video camera stream is sent to Kurento Media Server, which processes and sends it back to the client as a remote stream. To implement this, we need to create a Media Pipeline composed by the following Media Elements:



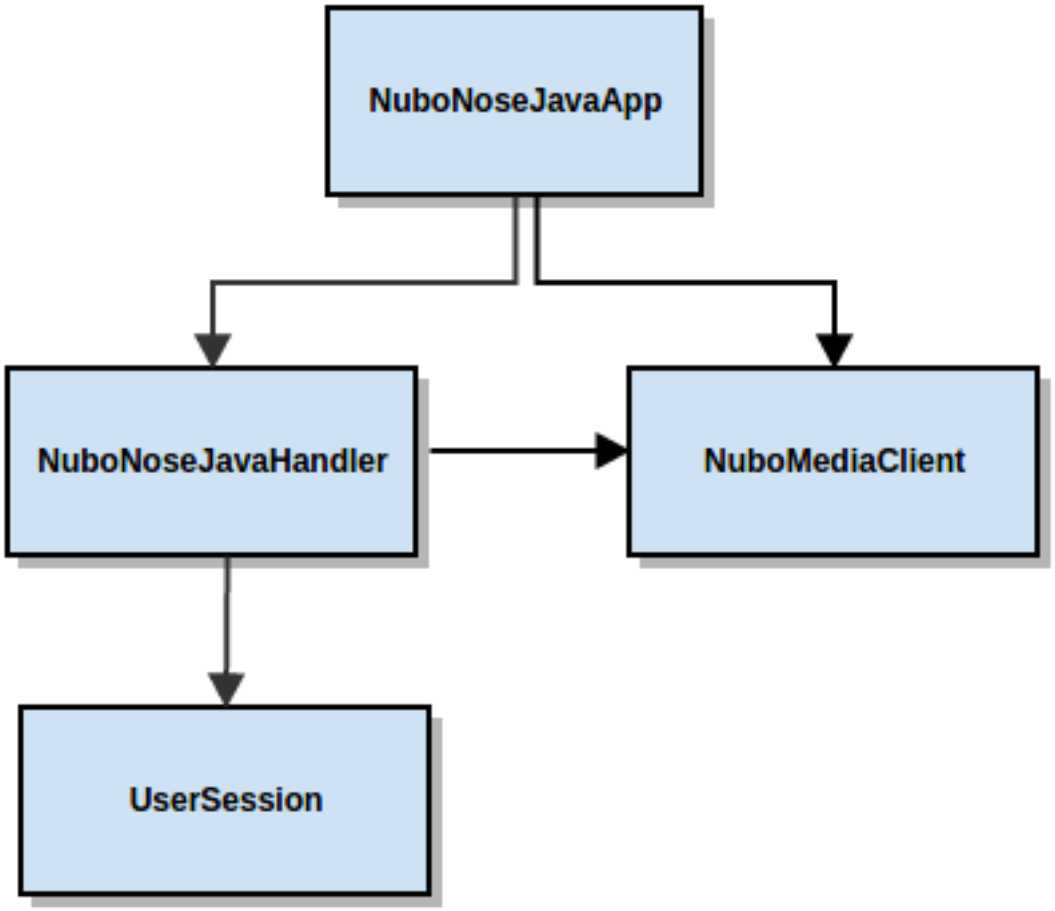
This is a web application, and therefore it follows a client-server architecture. At the client-side, the logic is implemented in JavaScript. At the server-side we use a Java EE application server consuming a Client API to control the Media Server capabilities. To communicate these entities, two WebSockets are used. First, a WebSocket is created between client and application server to implement a custom signaling protocol. Second, another WebSocket is used to perform the communication between the Java Client and the Media Server. To communicate the client with the Java EE application server the platform uses a simple signaling protocol based on JSON messages over WebSocket's.

SDP and ICE candidates needs to be exchanged between client and server to establish the WebRtc session. If you are interested on knowing more about the messages exchanged between them, have a look to this example .

Application Server Side

This demo has been developed using a Java EE application server based on the Spring Boot framework. This technology can be used to embed the Tomcat web server in the application and thus simplify the development process.

In the following figure you can see a class diagram of the server side code:



The main class of this demo is named NuboNoseJavaApp. As you can see, the NuboMediaClient is instantiated in this class as a Spring Bean. This bean is used to create Media Pipelines, which are used to add media capabilities to your applications. In this instantiation we see that we need to specify to the client library the location of the Kurento Media Server. In this example, we assume it's located at localhost listening in port 8888. If you reproduce this tutorial you'll need to insert the specific location of your Kurento Media Server instance there.

```
@Configuration
@EnableWebSocket
@EnableAutoConfiguration
public class NuboNoseJavaApp implements WebSocketConfigurer {

 final static String DEFAULT_KMS_WS_URI = "ws://localhost:8888/kurento";

 @Bean
 public NuboNoseJavaHandler handler() {
```

```
  return new NuboNoseJavaHandler();
 }

 @Bean
 public KurentoClient kurentoClient() {
  return KurentoClient.create(System.getProperty("kms.ws.uri",
   DEFAULT_KMS_WS_URI));
 }

 @Override
 public void registerWebSocketHandlers(WebSocketHandlerRegistry registry) {
  registry.addHandler(handler(), "/nubonosedetector");
 }

 public static void main(String[] args) throws Exception {
  new SpringApplication(NuboNoseJavaApp.class).run(args);
 }
}
```

This web application follows Single Page Application architecture and uses a WebSocket to communicate client with application server by means of requests and responses. Specifically, the main app class implements the interface WebSocketConfigurer to register a WebSocketHanlder to process WebSocket requests in the path /nubonosedetector.

NuboNoseJavaHandler class implements TextWebSocketHandler to handle text WebSocket requests. The central piece of this class is the method handleTextMessage. This method implements the actions for requests, returning responses through the WebSocket. In other words, it implements the server part of the signaling protocol depicted.

In the designed protocol there are three different kinds of incoming messages to the Server: start, show_noses, scale_factor, process_num_frames, width_to_process, stop and onIceCandidates. These messages are treated in the switch clause, taking the proper steps in each case.

```
public class NuboNoseJavaHandler extends TextWebSocketHandler {

 @Override
 public void handleTextMessage(WebSocketSession session, TextMessage message)
 throws Exception {
  JsonObject jsonMessage = gson.fromJson(message.getPayload(),
   JsonObject.class);

  log.debug("Incoming message: {}", jsonMessage);

  switch (jsonMessage.get("id").getAsString()) {
   case "start":
    start(session, jsonMessage);
    break;
   case "show_noses":
    setVisualization(session, jsonMessage);
    break;
   case "scale_factor":
    log.debug("Case scale factor");
    setScaleFactor(session, jsonMessage);
    break;
   case "process_num_frames":
    log.debug("Case process num frames");
    setProcessNumberFrames(session, jsonMessage);
    break;
   case "width_to_process":
    log.debug("Case width to process");
    setWidthToProcess(session, jsonMessage);
```

```
    break;

   case "stop":
    {
     UserSession user = users.remove(session.getId());
     if (user != null) {
      user.release();
     }
     break;
    }
   case "onIceCandidate":
    {
     JsonObject candidate = jsonMessage.get("candidate")
     .getAsJsonObject();

     UserSession user = users.get(session.getId());
     if (user != null) {
      IceCandidate cand = new IceCandidate(candidate.get("candidate")
       .getAsString(), candidate.get("sdpMid").getAsString(),
       candidate.get("sdpMLineIndex").getAsInt());
      user.addCandidate(cand);
     }
     break;
    }

   default:
    sendError(session,
     "Invalid message with id " + jsonMessage.get("id").getAsString());
    break;
  }
 }

 private void start(WebSocketSession session, JsonObject jsonMessage) {
  ...
 }

 private void sendError(WebSocketSession session, String message) {
   ...
  }
  ...
}
```

In the following snippet, we can see the start method. It handles the ICE candidates gathering, creates a Media Pipeline, creates the Media Elements (WebRtcEndpoint and NuboNoseDetectorFilter) and make the connections among them. A startResponse message is sent back to the client with the SDP answer.

```
private void start(final WebSocketSession session, JsonObject jsonMessage) {
 try {
  // Media Logic (Media Pipeline and Elements)
  UserSession user = new UserSession();
  MediaPipeline pipeline = kurento.createMediaPipeline();
  user.setMediaPipeline(pipeline);
  webRtcEndpoint = new WebRtcEndpoint.Builder(pipeline).build();
  user.setWebRtcEndpoint(webRtcEndpoint);
  users.put(session.getId(), user);

  webRtcEndpoint
   .addOnIceCandidateListener(new EventListener < OnIceCandidateEvent > () {
```

```
    @Override
    public void onEvent(OnIceCandidateEvent event) {
     JsonObject response = new JsonObject();
     response.addProperty("id", "iceCandidate");
     response.add("candidate", JsonUtils
      .toJsonObject(event.getCandidate()));
     try {
      synchronized(session) {
       session.sendMessage(new TextMessage(
        response.toString()));
      }
     } catch (IOException e) {
      log.debug(e.getMessage());
     }
    }
   });

  nose = new NuboNoseDetector.Builder(pipeline).build();
  webRtcEndpoint.connect(nose);
  nose.connect(webRtcEndpoint);

  // SDP negotiation (offer and answer)
  String sdpOffer = jsonMessage.get("sdpOffer").getAsString();
  String sdpAnswer = webRtcEndpoint.processOffer(sdpOffer);

  // Sending response back to client
  JsonObject response = new JsonObject();
  response.addProperty("id", "startResponse");
  response.addProperty("sdpAnswer", sdpAnswer);

  synchronized(session) {
   session.sendMessage(new TextMessage(response.toString()));
  }
  webRtcEndpoint.gatherCandidates();

 } catch (Throwable t) {
  sendError(session, t.getMessage());
 }
}
```

The sendError method is quite simple: it sends an error message to the client when an exception is caught in the server-side.

```
private void sendError(WebSocketSession session, String message) {
 try {
  JsonObject response = new JsonObject();
  response.addProperty("id", "error");
  response.addProperty("message", message);
  session.sendMessage(new TextMessage(response.toString()));
 } catch (IOException e) {
  log.error("Exception sending message", e);
 }
}
```

Application Client Side

Let's move now to the client-side of the application. To call the previously created WebSocket service in the server-side, we use the JavaScript class WebSocket. We use an specific JavaScript library called kurento-utils.js to simplify the WebRTC interaction with the server. This library depends on adapter.js, which is a JavaScript WebRTC utility maintained by Google that abstracts away browser differences. Finally jquery.js is also needed in this application.

These libraries are linked in the index.html web page, and are used in the index.js. In the following snippet we can see the creation of the WebSocket (variable ws) in the path /nubonosedetector. Then, the onmessage listener of the WebSocket is used to implement the JSON signaling protocol in the client-side. Notice that there are three incoming messages to client: startResponse, error, and iceCandidate. Convenient actions are taken to implement each step in the communication. For example, in functions start the function WebRtcPeer.WebRtcPeerSendrecv of kurento-utils.js is used to start a WebRTC communication.

```
var ws = new WebSocket('ws://' + location.host + '/nubonosedetector');

ws.onmessage = function(message) {
 var parsedMessage = JSON.parse(message.data);
 console.info('Received message: ' + message.data);

 switch (parsedMessage.id) {
  case 'startResponse':
   startResponse(parsedMessage);
   break;

  case 'iceCandidate':
   webRtcPeer.addIceCandidate(parsedMessage.candidate, function(error) {
    if (!error) return;
    console.error("Error adding candidate: " + error);
   });
   break;

  case 'error':
   if (state == I_AM_STARTING) {
    setState(I_CAN_START);
   }
   onError("Error message from server: " + parsedMessage.message);
   break;
  default:
   if (state == I_AM_STARTING) {
    setState(I_CAN_START);
   }
   onError('Unrecognized message', parsedMessage);
 }
}

function start() {
 console.log("Starting video call ...")
  // Disable start button
 setState(I_AM_STARTING);
 showSpinner(videoInput, videoOutput);

 console.log("Creating WebRtcPeer and generating local sdp offer ...");
 var options = {
  localVideo: videoInput,
  remoteVideo: videoOutput,
  onicecandidate: onIceCandidate
 }
```

```
 webRtcPeer = new kurentoUtils.WebRtcPeer.WebRtcPeerSendrecv(options,
  function(error) {
   if (error) {
    return console.error(error);
   }
   webRtcPeer.generateOffer(onOffer);
  });
}

function onOffer(error, offerSdp) {
 if (error) return console.error("Error generating the offer");
 console.info('Invoking SDP offer callback function ' + location.host);
 var message = {
  id: 'start',
  sdpOffer: offerSdp
 }
 sendMessage(message);
}


function onIceCandidate(candidate) {
 console.log("Local candidate" + JSON.stringify(candidate));

 var message = {
  id: 'onIceCandidate',
  candidate: candidate
 };
 sendMessage(message);
}
```

Dependencies

This Java Spring application is implemented using Maven. The relevant part of the pom.xml is where NUBOMEDIA dependencies are declared. we need two dependencies: the Client Java dependency (kurento-client) and the JavaScript Kurento utility library (kurento-utils) for the client-side. Browser dependencies (i.e. *bootstrap*, *ekko-lightbox*, and *adapter.js*) are handled with Webjars.

```
<dependencies>
   <dependency>
      <groupId>org.kurento</groupId>
      <artifactId>kurento-client</artifactId>
   </dependency>
   <dependency>
      <groupId>org.kurento</groupId>
      <artifactId>kurento-utils-js</artifactId>
   </dependency>
</dependencies>
```

Note: We are in active development. You can find the latest version of Kurento Java Client at Maven Central.

1.4.7 Tracker

This web application consists on a WebRTC video communication with a tracker detector filter (loopback, the media stream going from client to the media server and back to client).

Compiling & Running

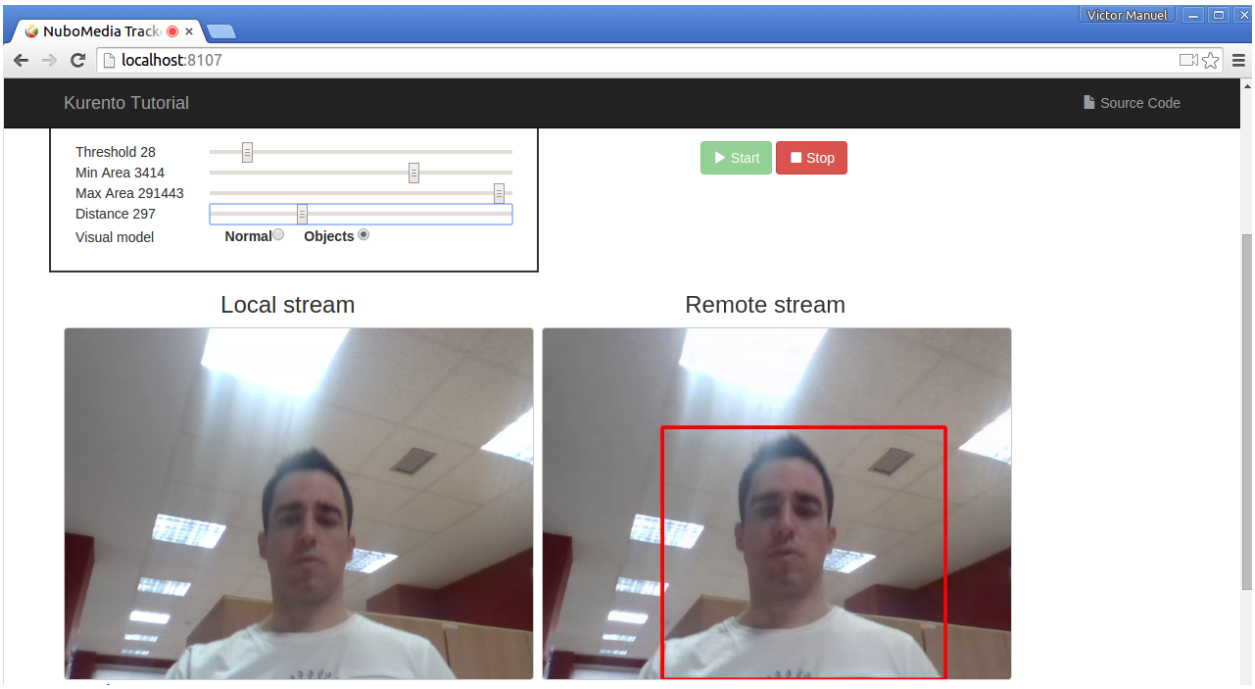
This section explain how to compile and run this tutorial in a local environment. To install the necessary software please see the installation guide. To compile and run this tutorial from the source code you can use the following commands:

```
git clone https://github.com/nubomedia/nubomedia-vca-tracker-tutorial
cd nubomedia-vca-tracker-tutorial
mvn spring-boot:run
```

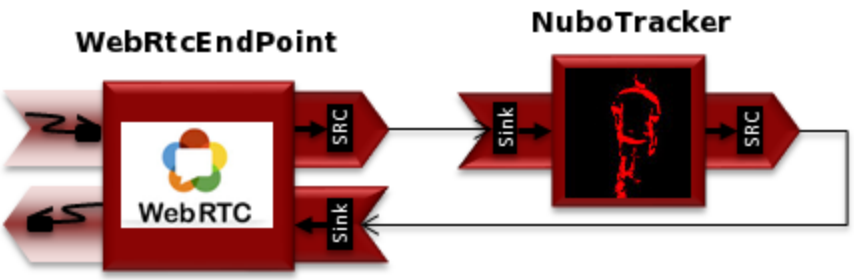
At this point we can test the application accessing the following URL: https://localhost:8443/.

Understanding this example

The following figure shows a screenshoot of this demo running.



The interface of the application (an HTML web page) is composed by two HTML5 video tags: one showing the local stream (as captured by the device webcam) and the other showing the remote stream sent by the media server back to the client. The video camera stream is sent to Kurento Media Server, which processes and sends it back to the client as a remote stream. To implement this, we need to create a Media Pipeline composed by the following Media Elements:

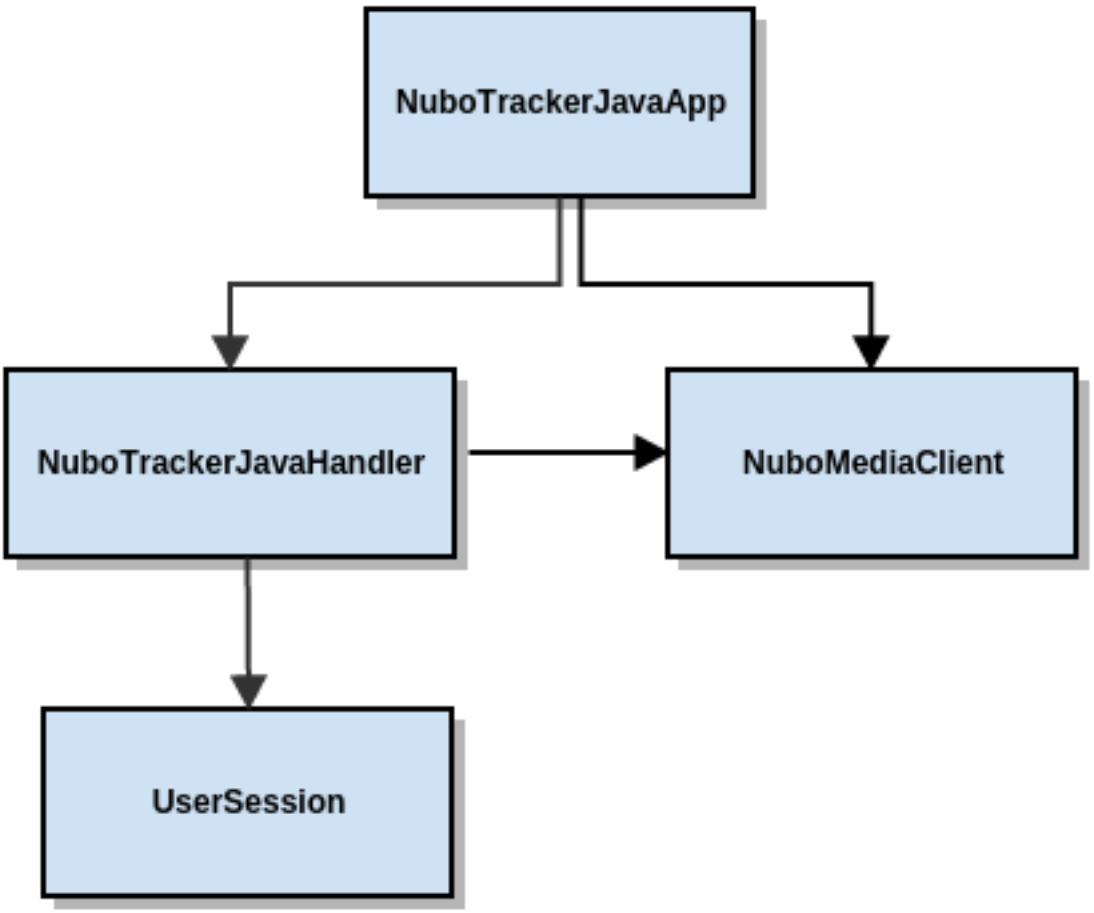


This is a web application, and therefore it follows a client-server architecture. At the client-side, the logic is implemented in JavaScript. At the server-side we use a Java EE application server consuming a Client API to control the Media Server capabilities. To communicate these entities, two WebSockets are used. First, a WebSocket is created between client and application server to implement a custom signaling protocol. Second, another WebSocket is used to perform the communication between the Java Client and the Media Server. To communicate the client with the Java EE application server the platform uses a simple signaling protocol based on JSON messages over WebSocket's. SDP and ICE candidates needs to be exchanged between client and server to establish the WebRtc session. If you are interested on knowing more about the messages exchanged between them, have a look to this example .

Application Server Side

This demo has been developed using a Java EE application server based on the Spring Boot framework. This technology can be used to embed the Tomcat web server in the application and thus simplify the development process.

In the following figure you can see a class diagram of the server side code:



The main class of this demo is named NuboTrackerJavaApp. As you can see, the NuboMediaClient is instantiated in this class as a Spring Bean. This bean is used to create Media Pipelines, which are used to add media capabilities to your applications. In this instantiation we see that we need to specify to the client library the location of the Kurento Media Server. In this example, we assume it's located at localhost listening in port 8888. If you reproduce this tutorial you'll need to insert the specific location of your Kurento Media Server instance there.

```
@Configuration
@EnableWebSocket
@EnableAutoConfiguration
public class NuboTrackerJavaApp implements WebSocketConfigurer {

 final static String DEFAULT_KMS_WS_URI = "ws://localhost:8888/kurento";

 @Bean
 public NuboTrackerJavaHandler handler() {
  return new NuboTrackerJavaHandler();
 }

 @Bean
 public KurentoClient kurentoClient() {
  return KurentoClient.create(System.getProperty("kms.ws.uri",
   DEFAULT_KMS_WS_URI));
 }

 @Override
 public void registerWebSocketHandlers(WebSocketHandlerRegistry registry) {
```

```
  registry.addHandler(handler(), "/nubotrackerdetector");
 }

 public static void main(String[] args) throws Exception {
  new SpringApplication(NuboTrackerJavaApp.class).run(args);
 }
}
```

This web application follows Single Page Application architecture and uses a WebSocket to communicate client with application server by means of requests and responses. Specifically, the main app class implements the interface WebSocketConfigurer to register a WebSocketHanlder to process WebSocket requests in the path /nubotrackerdetector.

NuboTrackerJavaHandler class implements TextWebSocketHandler to handle text WebSocket requests. The central piece of this class is the method handleTextMessage. This method implements the actions for requests, returning responses through the WebSocket. In other words, it implements the server part of the signaling protocol depicted.

In the designed protocol there are three different kinds of incoming messages to the Server: start, threshold, min_area, max_area, distance, visual_mode, stop and onIceCandidates. These messages are treated in the switch clause, taking the proper steps in each case.

```
public class NuboTrackerJavaHandler extends TextWebSocketHandler {

 @Override
 public void handleTextMessage(WebSocketSession session, TextMessage message)
 throws Exception {
  JsonObject jsonMessage = gson.fromJson(message.getPayload(),
   JsonObject.class);

  log.debug("Incoming message: {}", jsonMessage);

  switch (jsonMessage.get("id").getAsString()) {
   case "start":
    start(session, jsonMessage);
    break;

   case "threshold":
    setThreshold(session, jsonMessage);
    break;

   case "min_area":
    setMinArea(session, jsonMessage);
    break;

   case "max_area":
    setMaxArea(session, jsonMessage);
    break;

   case "distance":
    setDistance(session, jsonMessage);
    break;

   case "visual_mode":
    setVisualMode(session, jsonMessage);
    break;
   case "stop":
    {
     UserSession user = users.remove(session.getId());
     if (user != null) {
      user.release();
```

```
      }
      break;

      case "stop":
       {
        UserSession user = users.remove(session.getId());
        if (user != null) {
         user.release();
        }
        break;
       }
      case "onIceCandidate":
       {
        JsonObject candidate = jsonMessage.get("candidate")
        .getAsJsonObject();

        UserSession user = users.get(session.getId());
        if (user != null) {
         IceCandidate cand = new IceCandidate(candidate.get("candidate")
          .getAsString(), candidate.get("sdpMid").getAsString(),
          candidate.get("sdpMLineIndex").getAsInt());
         user.addCandidate(cand);
        }
        break;
       }

       default: sendError(session,
        "Invalid message with id " + jsonMessage.get("id").getAsString());
       break;
     }
   }

  private void start(WebSocketSession session, JsonObject jsonMessage) {
    ...
   }

  private void sendError(WebSocketSession session, String message) {
     ...
    }
    ...
 }
}
```

In the following snippet, we can see the start method. It handles the ICE candidates gathering, creates a Media Pipeline, creates the Media Elements (WebRtcEndpoint and NuboTrackerFilter) and make the connections among them. A startResponse message is sent back to the client with the SDP answer.

```
private void start(final WebSocketSession session, JsonObject jsonMessage) {
 try {
  // Media Logic (Media Pipeline and Elements)
  UserSession user = new UserSession();
  MediaPipeline pipeline = kurento.createMediaPipeline();
  user.setMediaPipeline(pipeline);
  webRtcEndpoint = new WebRtcEndpoint.Builder(pipeline).build();
  user.setWebRtcEndpoint(webRtcEndpoint);
  users.put(session.getId(), user);

  webRtcEndpoint
```

```
    .addOnIceCandidateListener(new EventListener < OnIceCandidateEvent > () {

     @Override
     public void onEvent(OnIceCandidateEvent event) {
      JsonObject response = new JsonObject();
      response.addProperty("id", "iceCandidate");
      response.add("candidate", JsonUtils
       .toJsonObject(event.getCandidate()));
      try {
       synchronized(session) {
        session.sendMessage(new TextMessage(
         response.toString()));
       }
      } catch (IOException e) {
       log.debug(e.getMessage());
      }
     }
    });

   tracker = new NuboTracker.Builder(pipeline).build();
   webRtcEndpoint.connect(tracker);
   tracker.connect(webRtcEndpoint);

   // SDP negotiation (offer and answer)
   String sdpOffer = jsonMessage.get("sdpOffer").getAsString();
   String sdpAnswer = webRtcEndpoint.processOffer(sdpOffer);

   // Sending response back to client
   JsonObject response = new JsonObject();
   response.addProperty("id", "startResponse");
   response.addProperty("sdpAnswer", sdpAnswer);

   synchronized(session) {
    session.sendMessage(new TextMessage(response.toString()));
   }
   webRtcEndpoint.gatherCandidates();

  } catch (Throwable t) {
   sendError(session, t.getMessage());
  }
 }
```

The sendError method is quite simple: it sends an error message to the client when an exception is caught in the server-side.

```
private void sendError(WebSocketSession session, String message) {
 try {
  JsonObject response = new JsonObject();
  response.addProperty("id", "error");
  response.addProperty("message", message);
  session.sendMessage(new TextMessage(response.toString()));
 } catch (IOException e) {
  log.error("Exception sending message", e);
 }
}
```

Application Client Side

Let's move now to the client-side of the application. To call the previously created WebSocket service in the server-side, we use the JavaScript class WebSocket. We use an specific JavaScript library called kurento-utils.js to simplify the WebRTC interaction with the server. This library depends on adapter.js, which is a JavaScript WebRTC utility maintained by Google that abstracts away browser differences. Finally jquery.js is also needed in this application.

These libraries are linked in the index.html web page, and are used in the index.js. In the following snippet we can see the creation of the WebSocket (variable ws) in the path /nubotrackerdetector. Then, the onmessage listener of the WebSocket is used to implement the JSON signaling protocol in the client-side. Notice that there are three incoming messages to client: startResponse, error, and iceCandidate. Convenient actions are taken to implement each step in the communication. For example, in functions start the function WebRtcPeer.WebRtcPeerSendrecv of kurento-utils.js is used to start a WebRTC communication.

```
var ws = new WebSocket('ws://' + location.host + '/nubotrackerdetector');

ws.onmessage = function(message) {
 var parsedMessage = JSON.parse(message.data);
 console.info('Received message: ' + message.data);

 switch (parsedMessage.id) {
  case 'startResponse':
   startResponse(parsedMessage);
   break;

  case 'iceCandidate':
   webRtcPeer.addIceCandidate(parsedMessage.candidate, function(error) {
    if (!error) return;
    console.error("Error adding candidate: " + error);
   });
   break;

  case 'error':
   if (state == I_AM_STARTING) {
    setState(I_CAN_START);
   }
   onError("Error message from server: " + parsedMessage.message);
   break;
  default:
   if (state == I_AM_STARTING) {
    setState(I_CAN_START);
   }
   onError('Unrecognized message', parsedMessage);
 }
}

function start() {
 console.log("Starting video call ...")
  // Disable start button
 setState(I_AM_STARTING);
 showSpinner(videoInput, videoOutput);

 console.log("Creating WebRtcPeer and generating local sdp offer ...");
 var options = {
  localVideo: videoInput,
  remoteVideo: videoOutput,
  onicecandidate: onIceCandidate
 }
```

```
 webRtcPeer = new kurentoUtils.WebRtcPeer.WebRtcPeerSendrecv(options,
  function(error) {
   if (error) {
    return console.error(error);
   }
   webRtcPeer.generateOffer(onOffer);
  });
}

function onOffer(error, offerSdp) {
 if (error) return console.error("Error generating the offer");
 console.info('Invoking SDP offer callback function ' + location.host);
 var message = {
  id: 'start',
  sdpOffer: offerSdp
 }
 sendMessage(message);
}

function onIceCandidate(candidate) {
 console.log("Local candidate" + JSON.stringify(candidate));

 var message = {
  id: 'onIceCandidate',
  candidate: candidate
 };
 sendMessage(message);
}
```

Dependencies

This Java Spring application is implemented using Maven. The relevant part of the pom.xml is where NUBOMEDIA dependencies are declared. we need two dependencies: the Client Java dependency (kurento-client) and the JavaScript Kurento utility library (kurento-utils) for the client-side. Browser dependencies (i.e. *bootstrap*, *ekko-lightbox*, and *adapter.js*) are handled with Webjars.

```
<dependencies>
   <dependency>
      <groupId>org.kurento</groupId>
      <artifactId>kurento-client</artifactId>
   </dependency>
   <dependency>
      <groupId>org.kurento</groupId>
      <artifactId>kurento-utils-js</artifactId>
   </dependency>
</dependencies>
```

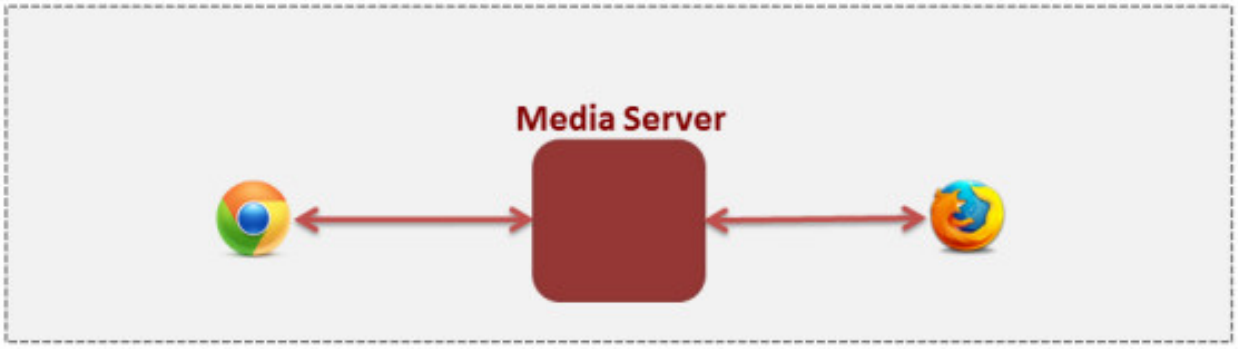
Note: We are in active development. You can find the latest version of Kurento Java Client at Maven Central.

1.5 Advanced guide

On this section, we give an overview of the NUBOMEDIA architecture, with special emphasis on the part of computer vision. Let's start with a simple explanation of what NUBOMEDIA is. Imagine a media communication using Skype. But instead of using Skype, this time we use web browsers, through a PC, table or mobile phone. Now, in the middle of this communication We can introduce different boxes or filters. This boxes or filters have a specific functionality. In particular, such funcionality is related to media capabilities such as encryption, transcoding, computer vision and augmented reality.

At this point, we can differentiate two parts the client part which runs in the browser and the cloud part running over OpenStack which has the logic of the application and is capable of creating the different filters (multimedia capabilities) in the cloud with the specific functionalities and establish the corresponding communications among the filters. Therefore we can distinguish three different modules:

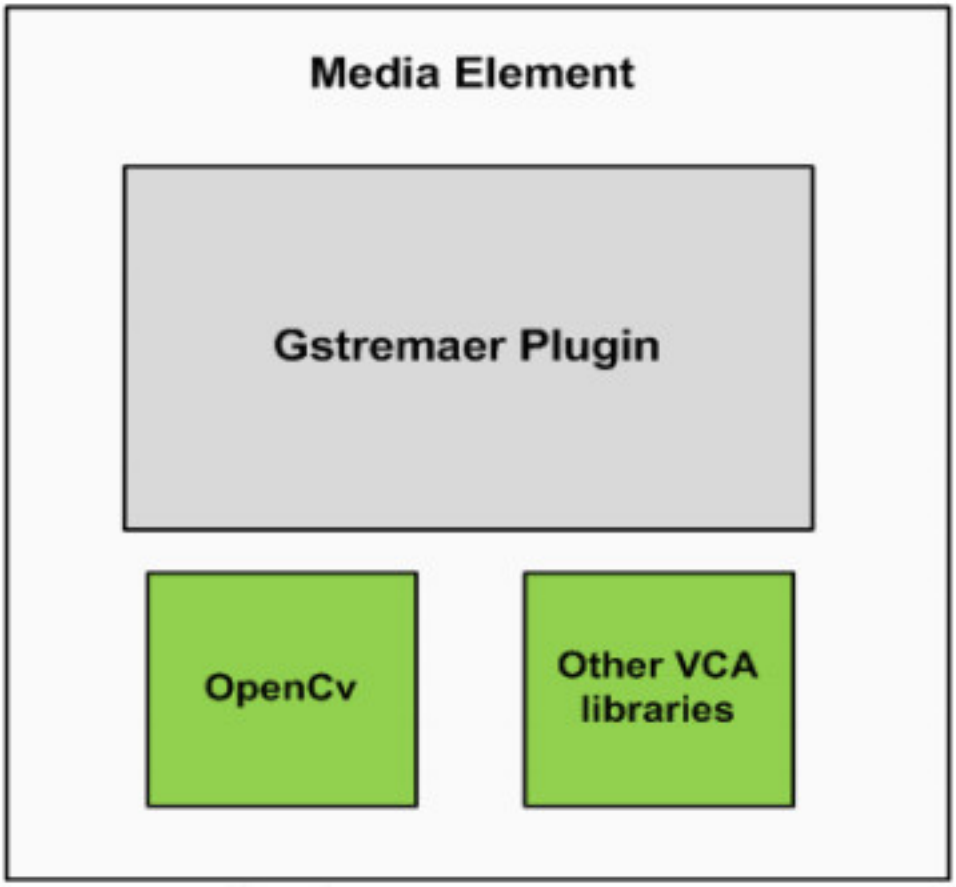
- **Client Application**: which involves the native multimedia capabilities of the browser plus the specific client-side application logic.
- **Application Server (AS)**: which runs on the cloud and contains the server-side application logic.
- **Media Server (MS)**: which runs on the cloud and is responsible for receiving commands for creating specific filters.



The main technologies used for this architecture are: OpenStack, Kurento and different techniques that make it possible to develop the different features of the filters.

From now on, we will focus on the part of computer vision. The different computer vision filters are integrated in NUBOMEDIA through the **Media Elements (ME)**. These media elements are created by the Media Server (MS). The media elements are monolithic and abstractions elements which send and receive media streams and data through different protocols. The goal of these elements is to carry out specific processing of the media stream or the data. Specifically, the VCA media elements are focused on applying VCA algorithms in order to extract valuable semantic information.

Now, we are going to see how to integrate these algorithms and how to process the video and data. The Media Elements offer the possibility to develop a specific algorithm through a GStreamer plugin. These plugins offer to the developers the video, frame by frame in a specific function. Therefore, the user can perform the processing of the frame in this function. With the aim to process every frame the developers can use different libraries. On this project a high percentage of the algorithms are going to be developed using the **OpenCV** library. On the other hand, an important percentage of the algorithms are going to be developed using other libraries. In the following figure we can see the different modules used to develop VCA filters contained on the media elements.



Finally, once the algorithm has been developed and installed, the developers can use the filter using the Java or JavaScript API.