Welcome to the ARCore & Sceneform Workshop

- Before we get started...
- Clone **github.com/ramonaharrison/ar-workshop**
- Make sure Android Studio is updated to 3.1 or higher
- Set up an ARCore supported device
- Or an ARCore supported emulator

About this workshop

- We are Ramona Harrison & David Morant
- We work on Android @ The New York Times

About this workshop

- We're going to build an AR Stickers app using ARCore and Sceneform.
- We'll cover AR fundamentals, drawing 3D shapes, importing and editing 3D models, user interactions, augmented faces, and cloud anchors.

About this workshop

- These slides are linked from the README (slides.pdf)
- There's also a raw version where you can grab code snippets (slides.md)

About ARCore

- Google released ARCore in February 2018.
- ARCore helps devs build apps that can understand the environment around a device and place objects and information in it.

About Sceneform

- Google followed up with Sceneform at I/O 2018.
- Sceneform helps devs render 3D scenes on Android without needing to learn OpenGL.

Drawing a 3D cube Before Sceneform

```
public class Cube {
    private static final float VERTICES[] = { -0.5f, -0.5f, -0.5f, 0.5f, -0.5f, -0.5f, 0.5f, 0.5f, -0.5f, -0.5f, 0.5f, -0.5f, -0.5f, -0.5f, 0.5f, 0.5f, -0.5f, 0.5f, 0.5f, 0.5f, 0.5f, -0.5f, 0.5f, 0.5f};
    private static final float COLORS[] = { 0.0f, 1.0f, 1.0f, 1.0f, 1.0f, 0.0f, 0.0f, 1.0f, 1.0f, 1.0f, 0.0f, 1.0f, 0.0f, 1.0f, 0.0f, 1.0f, 0.0f, 0.0f, 1.0f, 1.0f, 1.0f, 0.0f, 1.0f, 1.0f, 1.0f, 1.0f, 1.0f, 0.0f, 1.0f, 1.0f, 1.0f};
    private static final byte INDICES[] = { 0, 1, 3, 3, 1, 2, 0, 1, 4, 4, 5, 1, 1, 2, 5, 5, 6, 2, 2, 3, 6, 6, 7, 3, 3, 7, 4, 4, 3, 0, 4, 5, 7, 7, 6, 5};
    private static final int COORDS_PER_VERTEX = 3;
    private static final int VALUES_PER_COLOR = 4;
    private final int VERTEX_STRIDE = COORDS_PER_VERTEX * 4;
    private final int COLOR_STRIDE = VALUES_PER_COLOR * 4;
    private static final String VERTEX_SHADER_CODE = "uniform mat4 uMVPMatrix;attribute vec4 vPosition;attribute vec4 vColor;varying vec4 _vColor;void main() {  _vColor = vColor;  gl_Position = uMVPMatrix * vPosition;}";
    private static final String FRAGMENT_SHADER_CODE = "precision mediump float;varying vec4 _vColor;void main() {  gl_FragColor = _vColor;}";
    private final FloatBuffer mVertexBuffer;
    private final FloatBuffer mColorBuffer;
    private final ByteBuffer mIndexBuffer;
    private final int mProgram;
    private final int mPositionHandle;
    private final int mColorHandle;
    private final int mMVPMatrixHandle;

    public Cube() {
        ByteBuffer byteBuffer = ByteBuffer.allocateDirect(VERTICES.length * 4);
        byteBuffer.order(ByteOrder.nativeOrder());
        mVertexBuffer = byteBuffer.asFloatBuffer();
        mVertexBuffer.put(VERTICES);
        mVertexBuffer.position(0);
        byteBuffer = ByteBuffer.allocateDirect(COLORS.length * 4);
        byteBuffer.order(ByteOrder.nativeOrder());
        mColorBuffer = byteBuffer.asFloatBuffer();
        mColorBuffer.put(COLORS);
        mColorBuffer.position(0);
        mIndexBuffer = ByteBuffer.allocateDirect(INDICES.length);
        mIndexBuffer.put(INDICES);
        mIndexBuffer.position(0);
        mProgram = GLES20.glCreateProgram();
        GLES20.glAttachShader(mProgram, loadShader(GLES20.GL_VERTEX_SHADER, VERTEX_SHADER_CODE));
        GLES20.glAttachShader(
                mProgram, loadShader(GLES20.GL_FRAGMENT_SHADER, FRAGMENT_SHADER_CODE));
        GLES20.glLinkProgram(mProgram);
        mPositionHandle = GLES20.glGetAttribLocation(mProgram, "vPosition");
        mColorHandle = GLES20.glGetAttribLocation(mProgram, "vColor");
        mMVPMatrixHandle = GLES20.glGetUniformLocation(mProgram, "uMVPMatrix");
    }

    public void draw(float[] mvpMatrix) {
        GLES20.glUseProgram(mProgram);
        GLES20.glEnableVertexAttribArray(mPositionHandle);
        GLES20.glVertexAttribPointer(
                mPositionHandle, 3, GLES20.GL_FLOAT, false, VERTEX_STRIDE, mVertexBuffer);
        GLES20.glEnableVertexAttribArray(mColorHandle);
        GLES20.glVertexAttribPointer(
                mColorHandle, 4, GLES20.GL_FLOAT, false, COLOR_STRIDE, mColorBuffer);
        GLES20.glUniformMatrix4fv(mMVPMatrixHandle, 1, false, mvpMatrix, 0);
        GLES20.glDrawElements(
                GLES20.GL_TRIANGLES, INDICES.length, GLES20.GL_UNSIGNED_BYTE, mIndexBuffer);
        GLES20.glDisableVertexAttribArray(mPositionHandle);
        GLES20.glDisableVertexAttribArray(mColorHandle);
    }

    private static int loadShader(int type, String shaderCode){
        int shader = GLES20.glCreateShader(type);
        GLES20.glShaderSource(shader, shaderCode);
        GLES20.glCompileShader(shader);
        return shader;
    }
}
```

Drawing a 3D cube before Sceneform

```
public void draw(float[] mvpMatrix) {
    GLES20.glUseProgram(mProgram);
    GLES20.glEnableVertexAttribArray(mPositionHandle);
    GLES20.glVertexAttribPointer(
            mPositionHandle, 3, GLES20.GL_FLOAT, false, VERTEX_STRIDE, mVertexBuffer);
    GLES20.glEnableVertexAttribArray(mColorHandle);
    GLES20.glVertexAttribPointer(
            mColorHandle, 4, GLES20.GL_FLOAT, false, COLOR_STRIDE, mColorBuffer);
    GLES20.glUniformMatrix4fv(mMVPMatrixHandle, 1, false, mvpMatrix, 0);
    GLES20.glDrawElements(
            GLES20.GL_TRIANGLES, INDICES.length, GLES20.GL_UNSIGNED_BYTE, mIndexBuffer);
    GLES20.glDisableVertexAttribArray(mPositionHandle);
    GLES20.glDisableVertexAttribArray(mColorHandle);
}
```

Drawing a 3D cube with Sceneform

```
val size = Vector3(1.0f, 1.0f, 1.0f)
val position = Vector3(0.0f, 0.0f, 0.0f)

MaterialFactory.makeOpaqueWithColor(this, Color(Color.RED))
    .thenAccept(material -> ShapeFactory.makeCube(size, position, material))
```

Let's get started

Add the dependency

In `app/build.gradle`

```
dependencies {
    // ...

    implementation "com.google.ar.sceneform.ux:sceneform-ux:1.8.0"
}
```

Configure the manifest

Setup camera in the `<manifest>` section

```
<uses-permission android:name="android.permission.CAMERA" />
<uses-feature android:name="android.hardware.camera.ar" android:required="true" />
```

In the `<application>` section, add a Play Store filter for users on devices that are not supported by ARCore.

```
<meta-data android:name="com.google.ar.core" android:value="required" />
```

Add the ARFragment

In `content_main.xml`

```
<fragment
    android:id="@+id/fragment"
    android:name="com.google.ar.sceneform.ux.ArFragment"
    android:layout_width="match_parent"
    android:layout_height="match_parent" />
```

Run it!

Emulator troubleshooting

- Check that your Android Emulator is updated to 27.2.9 or later.
- Follow the instructions linked in the README.

AR Fundamentals

Feature points

feature points are visually distinct features that ARCore detects in each captured camera image (e.g. the corner of a table, a mark on a wall)

Motion Tracking

ARCore detects visually distinct **feature points** in each captured camera image and uses these points to compute a device's change in location over time.

Motion tracking

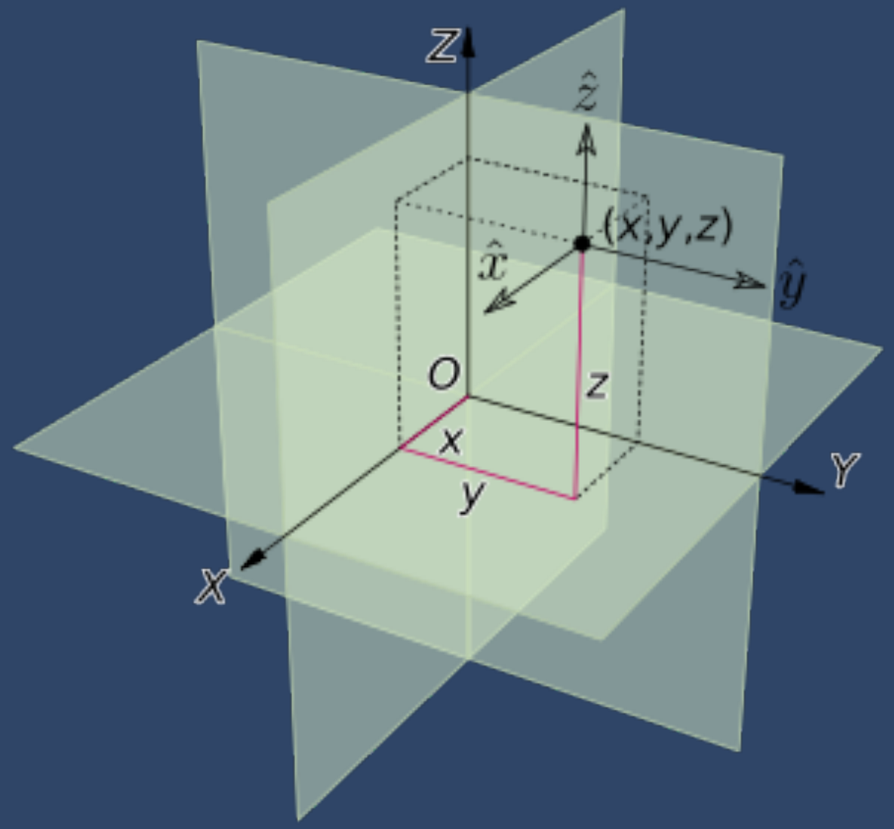
Visual feature point information is combined with measurements from the device's Inertial Measurement Unit (IMU).

Motion tracking

This combined data is used to estimate the **pose**, defined by **position** and **orientation**, of the device camera relative to the world over time.

World space

- World space is the 3D coordinate space in which the camera and other objects are positioned.
- Three fixed axes: x, y, z.
- The positions of the camera and other objects are updated from frame to frame as they move within the space.



Pose

Everything in an AR scene has a **pose** within the world space.

Each **pose** is composed of:

- x-axis translation
- y-axis translation
- z-axis translation
- rotation

Pose

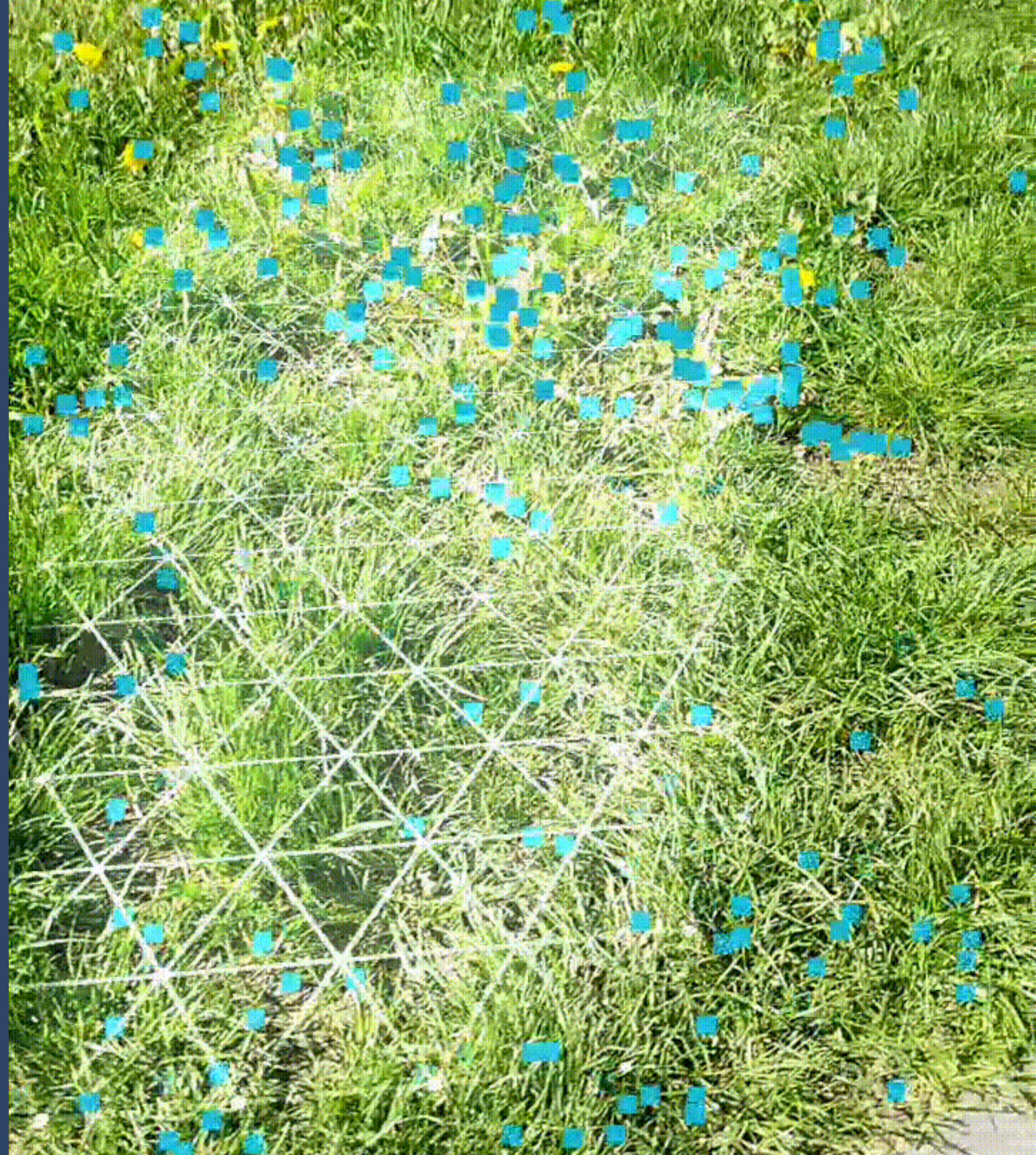
Sceneform aligns the pose of the **virtual camera** that renders your 3D content with the pose of the device's camera provided by ARCore.

Pose

Because the rendered virtual content is overlaid and aligned on top of the camera image, it appears as if your virtual content is part of the real world.

Plane detection

ARCore looks for clusters of feature points that appear to lie on common horizontal or vertical surfaces and provides this data to Sceneform as **planes**.



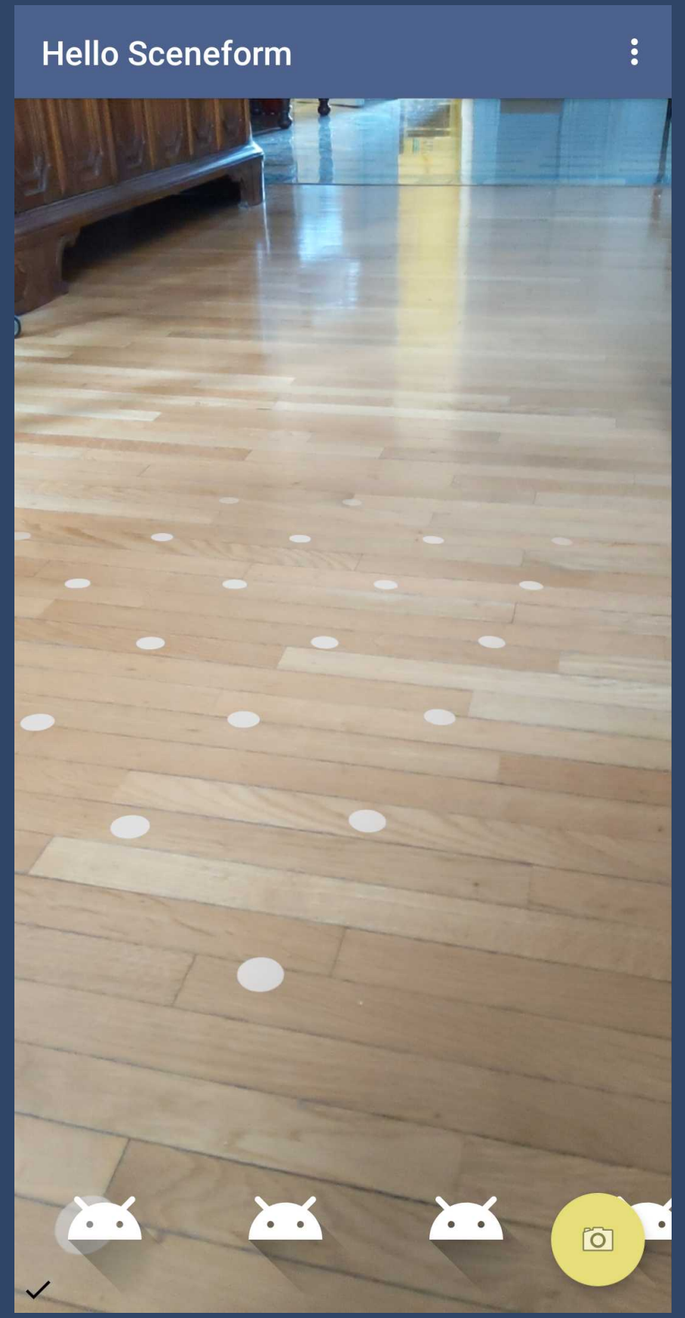
Plane detection

A **plane** is composed of:

- A center **pose**
- An **extent** along each axis
- A **polygon**, a collection of 2D vertices approximating the detected plane.

Plane detection

The Sceneform fragment renders a plane-grid to indicate via the UI where these planes exist.



Goal:

When a user taps a point on the screen that intersects with a plane, we want to place an object at that point.

Hit test

We want to determine if a **ray** extending from the **x, y** coordinate of our tap intersects a plane.

If it does, we'll place an **anchor** at the **pose of the intersection**.

Hit test

In `MainActivity.kt`, set up the `ArFragment` with an `OnTapArPlaneListener`.

```
private lateinit var arFragment: ArFragment

override fun onCreate(savedInstanceState: Bundle?) {
    //...
    arFragment = fragment as ArFragment
    arFragment.setOnTapArPlaneListener { hitResult, plane, motionEvent ->
        // We've hit a plane!
    }
}
```

Hit Result

Represents *an intersection between a **ray** and estimated real-world **geometry*** (e.g. a `Node` or a `Plane`).

We can use a `HitResult` to determine the `Pose` of the intersection, the distance from the camera,
or to create a new `Anchor` at the pose of intersection.

Shapes

Let's start out by adding a sphere at that pose.

We can use Sceneform's `ShapeFactory` API to create renderable shapes: cubes, cylinders, and spheres to which we can apply materials such as surface colors or textures.

Shapes

Create a new function in `MainActivity.kt`:

```
private fun addSphere(color: Int, anchor: Anchor, radius: Float, centerX : Float, centerY: Float, centerZ : Float) {
    MaterialFactory.makeOpaqueWithColor(this, com.google.ar.sceneform.rendering.Color(color))
        .thenAccept { material ->
            val shape = ShapeFactory.makeSphere(radius, Vector3(centerX, centerY, centerZ), material)
            addNodeToScene(anchor, shape)
        }
}
```

Nodes

All of the virtual content in a AR experience is organized as a **scene graph**.

A **scene graph** is basically an n-tree, made up of **nodes** which can each have 0...n children.

Nodes

We need a way to add our sphere to the **scene**. We'll do that by creating a `Node`, attached to an `Anchor` at the point of intersection.

Nodes

Create a new function in `MainActivity.kt`:

```
    private fun addNodeToScene(anchor: Anchor, renderable: Renderable) {
        val anchorNode = AnchorNode(anchor)
        val node = TransformableNode(arFragment.transformationSystem)
        node.renderable = renderable
        node.setParent(anchorNode)
        arFragment.arSceneView.scene.addChild(anchorNode)
    }
```

Anchors

Now we want to create an **anchor** based on the **hit result**, so that we can anchor our node to the pose on the plane we tap.

Anchors

Create an anchor based on the `HitResult`, and use it to add a sphere to the scene.

```
arFragment.setOnTapArPlaneListener { hitResult, plane, motionEvent ->
    val anchor = hitResult.createAnchor()
    addSphere(Color.RED, anchor, 0.1f, 0.0f, 0.15f, 0.0f)
}
```

Run it!

Sceneform plugin

Sceneform has an Android Studio plugin for importing, editing, and previewing 3D models.

Sceneform plugin: installation

Android Studio > Preferences > Plugins > browse repositories
Google Sceneform Tools (Beta)

Supported formats

Look in `app/sampledata/models`. We've provided some models.

- `.obj` - encodes the 3D geometry of the model (e.g. vertices, polygon faces)
- `.mtl` - material referenced by the `.obj`, describes the surface of the model (e.g. color, texture, reflection)
- `.png` - optional visual texture referenced by the `.mtl` to be mapped onto the surface of the model

Supported formats

In addition to Wavefront `obj`, Sceneform also supports importing:

- FBX, with or without animations
- glTF (animations not supported)

Sceneform assets

1. Select `app/sampledata/models/coffee.obj` and then right mouse click to get the menu.
2. Pick `New > Sceneform asset`.
3. Click `Finish`.

Sceneform assets

We've now converted into Sceneform's `.sfa` and `.sfb` formats.

- `.sfb` - Sceneform Binary, points to the models, material definitions, and textures in the source asset.
- `.sfa` - Sceneform Asset Definition, a human-readable description of the `.sfb`

Import the rest of the models

Take a few minutes to import the three remaining models: `pasta.obj`, `pizza.obj`, and `tiramisu.obj`

Goal: When a user taps, we want to place the selected object from the gallery at that point.

Renderables

A *renderable* is an object that can be attached to a *node* to render in 3D space.

Loading renderables from model assets

Make a new function in `MainActivity.kt` to load the renderable from it's URI and attach it at the anchor.

```
private fun placeObject(anchor: Anchor, model: Uri) {
    ModelRenderable.builder()
        .setSource(fragment.context, model)
        .build()
        .thenAccept { renderable -> addNodeToScene(anchor, renderable) }
        .exceptionally { throwable ->
            Toast.makeText(this@MainActivity, "Something went wrong!", Toast.LENGTH_SHORT).show()
            null
        }
}
```

Update the tap listener

Get the URI from the selected gallery item and pass it, along with the anchor, to `placeObject`.

```
arFragment.setOnTapArPlaneListener { hitResult, plane, motionEvent ->
    val anchor = hitResult.createAnchor()
    val uri = galleryAdapter.getSelected().getUri()
    placeObject(anchor, uri)
}
```

Run it!

Google Poly

Thousands of open source 3D models can be found at poly.google.com

Adjusting Scale

In `coffee.sfa`

```
model: {
    attributes: [
      'Position',
      'Orientation',
    ],
    collision: {},
    file: 'sampledata/models/coffee.obj',
    name: 'coffee',
    recenter: 'root',
    scale: 0.50,
  },
```

Run it!

Snap a photo

We can take a photo of our AR scene, including the virtual content, by capturing the `SurfaceView` (the class that `ArSceneView` descends from).

Snap a photo

The app already includes a `CameraHelper.kt` class. Let's wire it up so that when the button is clicked, we take a photo.

```
private lateinit var camera: CameraHelper

override fun onCreate(savedInstanceState: Bundle?) {
    // ...

    if (ActivityCompat.checkSelfPermission(this, Manifest.permission.WRITE_EXTERNAL_STORAGE) != PackageManager.PERMISSION_GRANTED) {
        ActivityCompat.requestPermissions(this, arrayOf(Manifest.permission.WRITE_EXTERNAL_STORAGE), 0)
    }

    camera = CameraHelper(this, arFragment.arSceneView)
    fab.setOnClickListener { camera.snap() }
}
```

Run it!

Now for the fun stuff...

Augmented Faces

Augmented Faces

Let's extend our stickers app to experiment with Sceneform's `AugmentedFaces` API.

Augmented Faces

Augmented Faces helps you to identify different regions of a detected face, and use those regions to anchor nodes and renderables so that they align, contour and move with the face.

Augmented Faces

ARCore provides detected regions and an augmented face mesh. This mesh is a virtual representation of the face, and consists of the vertices, facial regions, and the center of the user's head.

Augmented Faces

When a user's face is detected by the camera, ARCore detects:

- The **center pose**: the physical center point of the user's head, inside the skull directly behind the nose.
- The **face mesh**: the hundreds of vertices that make up the face, defined relative to the center pose.
- The **face regions**: three distinct poses on the user's face (left forehead, right forehead, nose tip)

Augmented Faces

These elements are used by AugmentedFace APIs as feature points to align 3D assets to the face.

Extend the ArFragment

Create a new class, `FaceArFragment.kt`. Override `getSessionConfiguration` to enable augmented face mode.

```
class FaceArFragment : ArFragment() {

    override fun getSessionConfiguration(session: Session): Config {
        val config = Config(session)
        config.augmentedFaceMode = Config.AugmentedFaceMode.MESH3D
        return config
    }

}
```

Extend the ArFragment

Configure the session to use the front-facing camera. Turn off the plane discovery controller, since plane detection doesn't work with the front-facing camera.

In `FaceArFragment`:

```
override fun getSessionFeatures() = EnumSet.of<Session.Feature>(Session.Feature.FRONT_CAMERA)

override fun onCreateView(inflater: LayoutInflater,
                         @Nullable container: ViewGroup?,
                         @Nullable savedInstanceState: Bundle?): View? {
    val frameLayout = super.onCreateView(inflater, container, savedInstanceState) as FrameLayout?

    planeDiscoveryController.hide()
    planeDiscoveryController.setInstructionView(null)

    return frameLayout
}
```

Add the fragment to the layout

In `content_faces.xml`

```
<fragment
        android:id="@+id/fragment"
        android:name="com.nytimes.android.ramonaharrison.FaceArFragment"
        android:layout_width="match_parent"
        android:layout_height="match_parent" />
```

Import the face model

From the `sampledata` directory, import `fox_face.fbx` as a Sceneform asset.

Load the face model as a renderable

In `FacesActivity.kt`, create a function to load the imported asset as a renderable.

```
class FacesActivity : AppCompatActivity() {

    var faceRegionsRenderable: ModelRenderable? = null

    override fun onCreate(savedInstanceState: Bundle?) {
        // ...

        loadFaceRenderable()
    }

    private fun loadFaceRenderable() {
        ModelRenderable.builder()
            .setSource(this, R.raw.fox_face)
            .build()
            .thenAccept { modelRenderable: ModelRenderable ->
                modelRenderable.isShadowCaster = false
                modelRenderable.isShadowReceiver = false
                faceRegionsRenderable = modelRenderable
            }
    }
}
```

Load the face texture

The project also include a texture that we'll superimpose over the entire face. Create another method in `FaceActivity` to load this texture.

```
var faceMeshTexture: Texture? = null

override fun onCreate(savedInstanceState: Bundle?) {
    // ..
    loadFaceRenderable()
    loadFaceTexture()
}

private fun loadFaceTexture() {
    Texture.builder()
        .setSource(this, R.drawable.fox_face_mesh_texture)
        .build()
        .thenAccept({ texture: Texture ->
            faceMeshTexture = texture
        })
}
```

Setup the scene

In `FacesActivity.kt`, set up the fragment and set up the camera stream to render first so that the face mesh occlusion works properly.

```
private lateinit var arFragment: ArFragment

override fun onCreate(savedInstanceState: Bundle?) {
    // ...

    arFragment = fragment as ArFragment
    val sceneView = arFragment.arSceneView
    sceneView.cameraStreamRenderPriority = Renderable.RENDER_PRIORITY_FIRST
}
```

Update loop

Add an `OnUpdateListener` to the scene. This listener has a callback that will be invoked on every frame, right before the scene gets updated.

Assuming our renderable and texture are loaded and ready, this is where we'll attach new nodes to faces that have become visible in the frame, and remove nodes from faces that aren't in the frame anymore.

```
val scene = sceneView.scene
scene.addOnUpdateListener { frameTime: FrameTime ->
    if (faceRegionsRenderable != null && faceMeshTexture != null) {
        // Attach nodes for tracked faces and remove untracked faces
    }
}
```

Handle tracked faces

In `FacesActivity`, create a `faceNodeMap` member variable. We'll use this map to keep track of the actively tracked faces that are detected by ARCore, and of the nodes that we associate with these faces.

```
class FacesActivity : AppCompatActivity() {

    val faceNodeMap = HashMap<AugmentedFace, AugmentedFaceNode>()

    // ...
}
```

Handle tracked faces

Create a function `handleTrackedFaces`. In this function, we'll get a list of faces from the session and iterate through them to attach an `AugmentedFaceNode` with our renderable and texture.

```
private fun handleTrackedFaces(sceneView: ArSceneView, scene: Scene) {
    val faceList = sceneView.session?.getAllTrackables(AugmentedFace::class.java) ?: emptyList()
    for (face in faceList) {
        if (!faceNodeMap.containsKey(face)) {
            val faceNode = AugmentedFaceNode(face)
            faceNode.setParent(scene)
            faceNode.faceRegionsRenderable = faceRegionsRenderable
            faceNode.faceMeshTexture = faceMeshTexture
            faceNodeMap[face] = faceNode
        }
    }
}
```

Handle untracked faces

We also want to remove any nodes associated with faces that we're no longer tracking -- these are faces that have disappeared from the current frame.

```
private fun handleUntrackedFaces() {
    val iterator = faceNodeMap.entries.iterator()
    while (iterator.hasNext()) {
        val entry = iterator.next()
        val face = entry.key
        if (face.trackingState == TrackingState.STOPPED) {
            val faceNode = entry.value
            faceNode.setParent(null)
            iterator.remove()
        }
    }
}
```

Update the update loop

Invoke these two new functions from the update loop.

```
val scene = sceneView.scene
scene.addOnUpdateListener { frameTime: FrameTime ->
    if (faceRegionsRenderable != null && faceMeshTexture != null) {
        handleTrackedFaces(sceneView, scene)
        handleUntrackedFaces()
    }
}
```

Run it!

Cloud anchors

Grazie!