Università di Genova
DIBRIS DIPARTIMENTO DI INFORMATICA, BIOINGEGNERIA, ROBOTICA E INGEGNERIA DEI SISTEMI

Augmented Reality

Introduction to SDKs for AR development

Manuela Chessa – manuela.chessa@unige.it
Fabio Solari – fabio.solari@unige.it

SDKs for AR development

The most used

Vuforia

ARCore

ARKit

Others...

8thWall

EasyAR

(the old) ARToolKit

Vuforia

Vuforia

https://developer.vuforia.com/home

Vuforia is an augmented reality SDK developed by PTC

It enables developers to create AR experiences for mobile devices and smart glasses.

It’s particularly known for image and object recognition

A go-to for many enterprise and industrial applications

Vuforia

Maintained and updated SDK

March 26, 2025

Vuforia Engine 11.1 is Available!

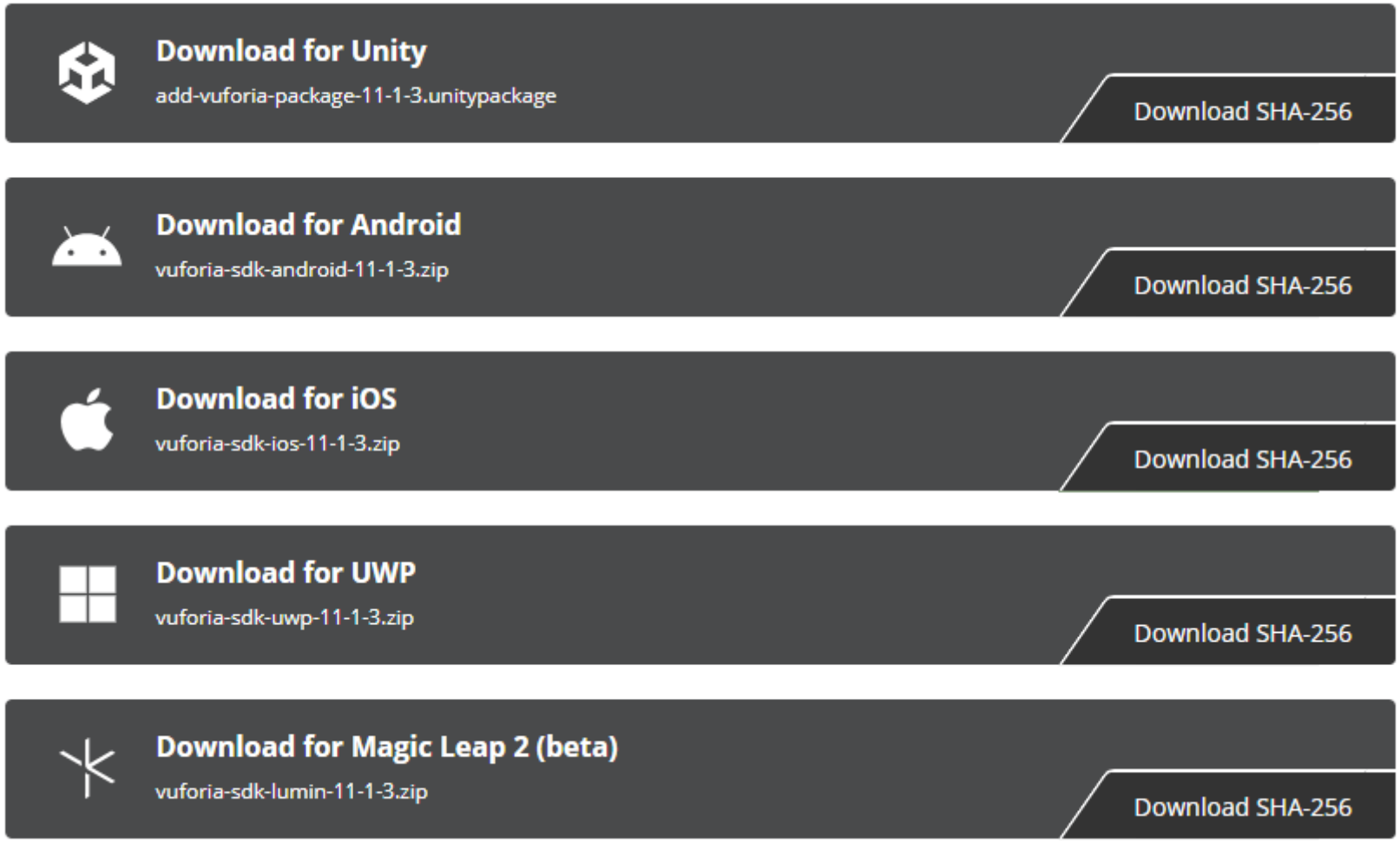
The Vuforia Engine team is happy to announce our newest version. Below are the key updates in this release. Please be sure to check out the release notes for the full list.

In this Release:

- **On-Prem Advanced Model Targets:** Some pre-processing has been shifted to generation time, meaning the first time an app uses a target, the target can start tracking much faster.
- **On-Prem Step Check:** Android is now a supported platform, with the best performance on devices with more powerful CPUs.
- **Bug fixes and performance improvements**

Thanks,
Vuforia Engine Team

Vuforia- supported platforms



Vuforia – Image Targets (marker tracking)

Image Targets represent images that Vuforia Engine can detect and track. The image is tracked by comparing extracted natural features from the camera image against a known target resource database. Once the Image Target is detected, Vuforia Engine will track the image and augment your content seamlessly using the best image-tracking technology in the market.

Vuforia – Image Targets

1. **Preparing and Designing Images** following the guidelines (given by how feature detection and camera pose estimation work)
2. **Creating the Image Targets**
    1. Upload the images to the Target Manager for evaluation and processing. The Image Targets can thereafter be downloaded as a package suitable for integration in both native and Unity
    2. Image Targets can also be created at runtime in both native IDEs and in the Unity Editor, which does not require you to upload the images.
    3. For use cases with thousands of images or a constantly updated set of images, such as product labels, newspapers, or magazines, Vuforia Engine also offers powerful cloud recognition technology

Vuforia – Image Targets

Preparing and Designing Images

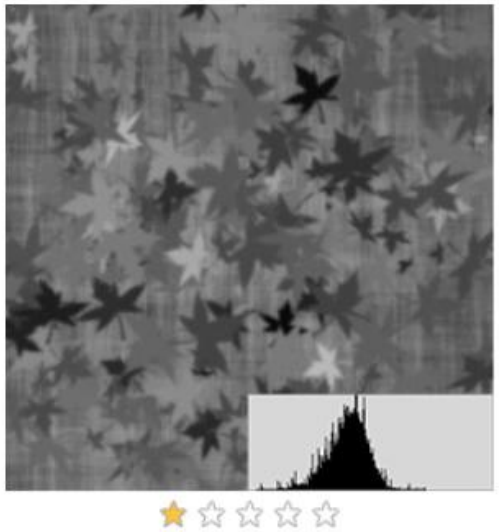
Vuforia Engine uses the grayscale version of your target image to identify features that can be used for recognition and tracking.

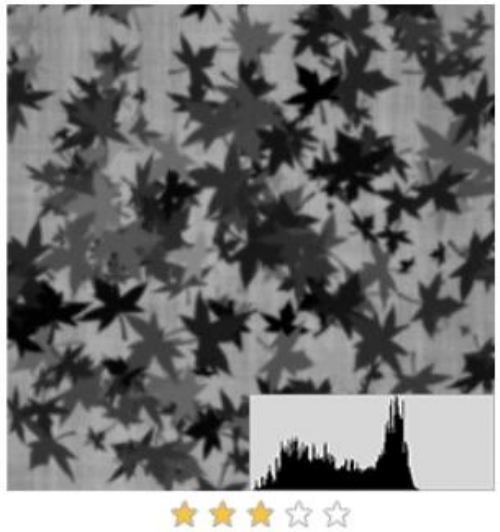
You can use the grayscale histogram of your image to evaluate its suitability as a target image.

If the histogram is wide and flat, this is a good first indication that the image contains a good distribution of useful features.

Vuforia – Image Targets

Preparing and Designing Images



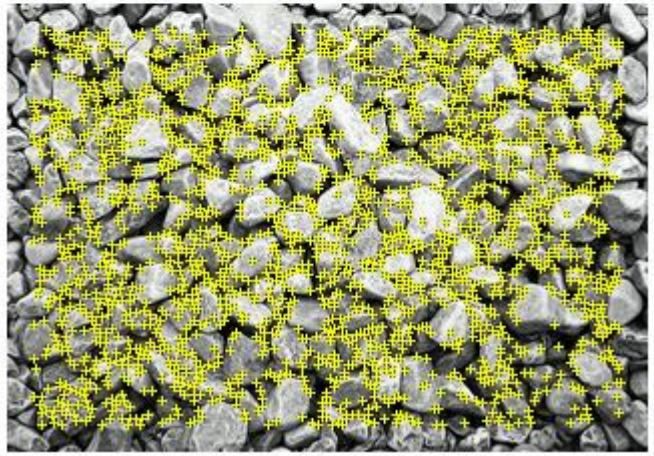


Vuforia – Image Targets

Preparing and Designing Images

Rich in detail

Street scene, group of people, collages and mixtures of items, and sport scenes are good examples.



Vuforia – Image Targets

Preparing and Designing Images

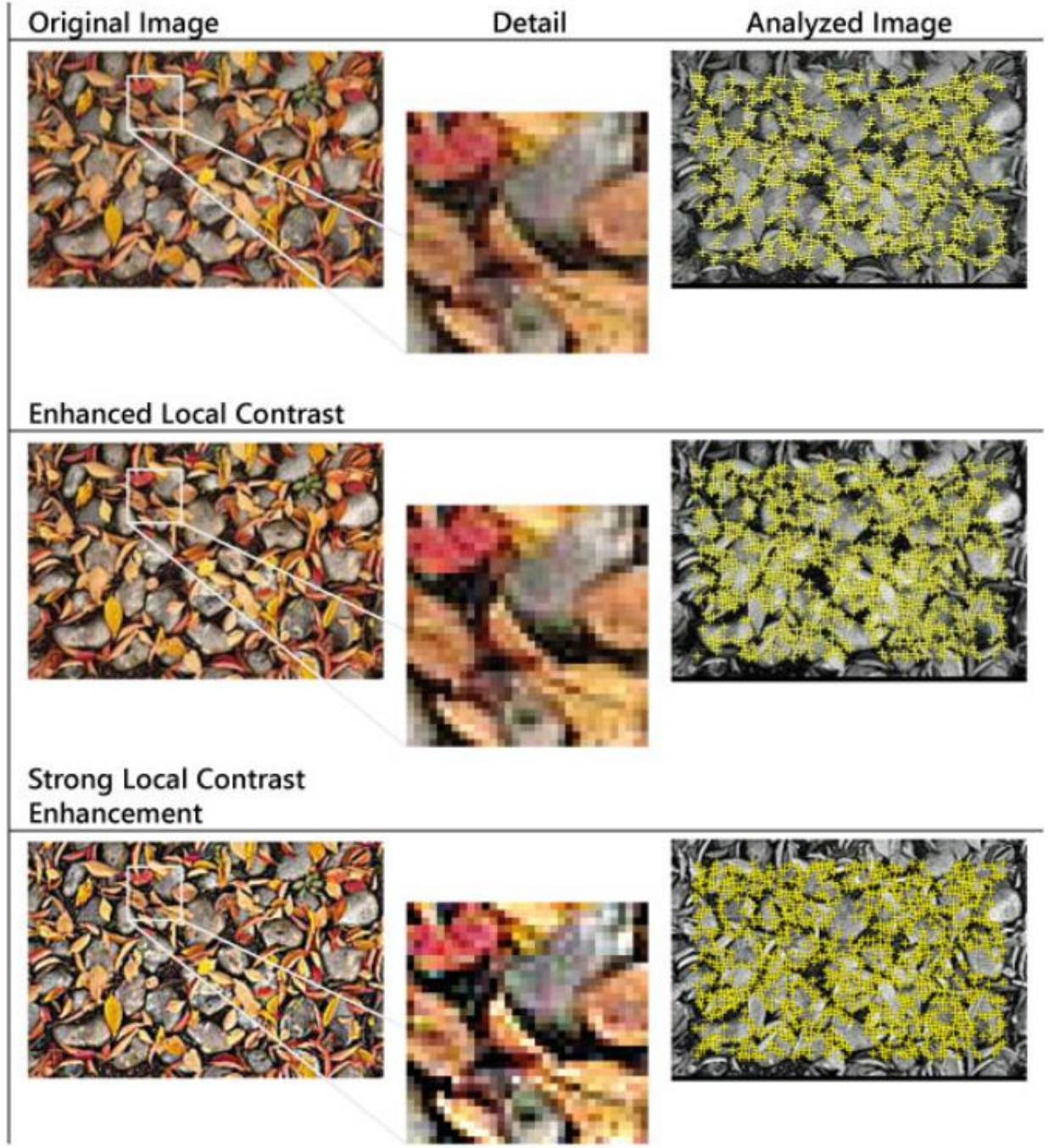
Good Contrast

Images with bright and dark regions and well-lit areas work well.

Image processing to improve targets

Vuforia – Image Targets

Good or bad local contrast is often difficult to detect with your eye. You can improve the contrast of the image by enhancing the features' edges as demonstrated in the example below. Other general features such as organic shapes, round details, blurred, or highly compressed images often do not provide enough richness and detail to be detected and tracked properly.

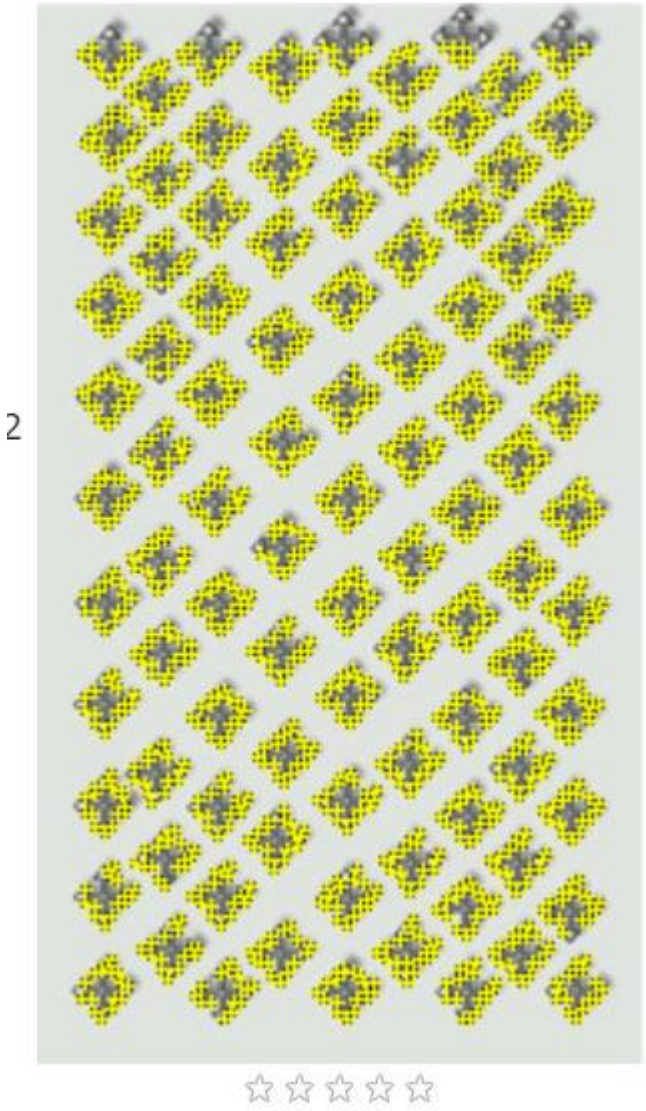


Vuforia – Image Targets

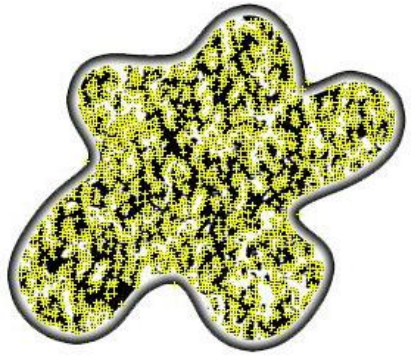
Preparing and Designing Images

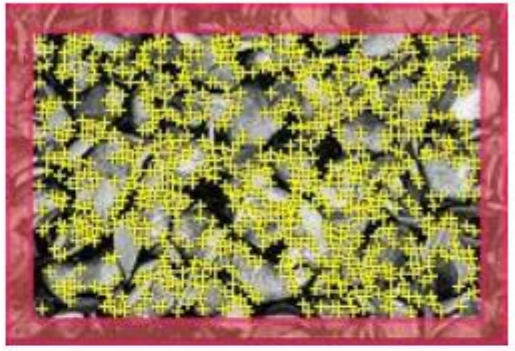
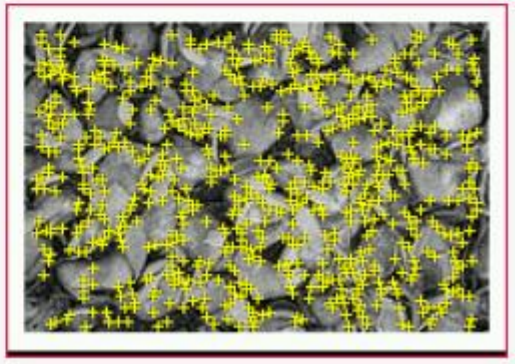
No repetitive patterns

Employ unique features and distinct graphics covering as much of the target as possible to avoid symmetry, repeated patterns, and feature-less areas.



Vuforia – Image Targets



	Uploaded Image	Analyzed Image (Red Marking)
Original Image Target		
Image Target with border		

Vuforia – Cylinder Targets (marker tracking)

Cylinder Targets enable you to detect and track images wrapped into cylindrical and conical shapes. Vuforia Engine can track the sides, flat top, and bottom of the Cylinder Target. Cylindrical shapes are widely used for consumer goods and often have unique labels ideal for creating an accompanying augmented reality experience.

Vuforia – Cylinder Targets

Preparing and Designing Cylinder Targets

Same rules as Images

Cylinders are widely used (e.g. cans) but many objects have slightly different shapes (bottles, cups)

Mathematical rules

https://developer.vuforia.com/library/vuforia-engine/images-and-objects/cylinder-targets/recommendations-designing-cylinder-targets/

Vuforia – Multi Targets (marker tracking)

A Multi Target is a collection of multiple Image Targets combined into a defined geometric arrangement such as boxes. This allows tracking and detection from all sides and can serve numerous use cases in, for example, marketing, packaging, and in instructional contexts. Start by creating your Multi Targets in the Vuforia Target Manager and upload your images fitting the dimensions of your Multi Targets.

Vuforia – Multi Targets

Preparing and Designing Multi Targets

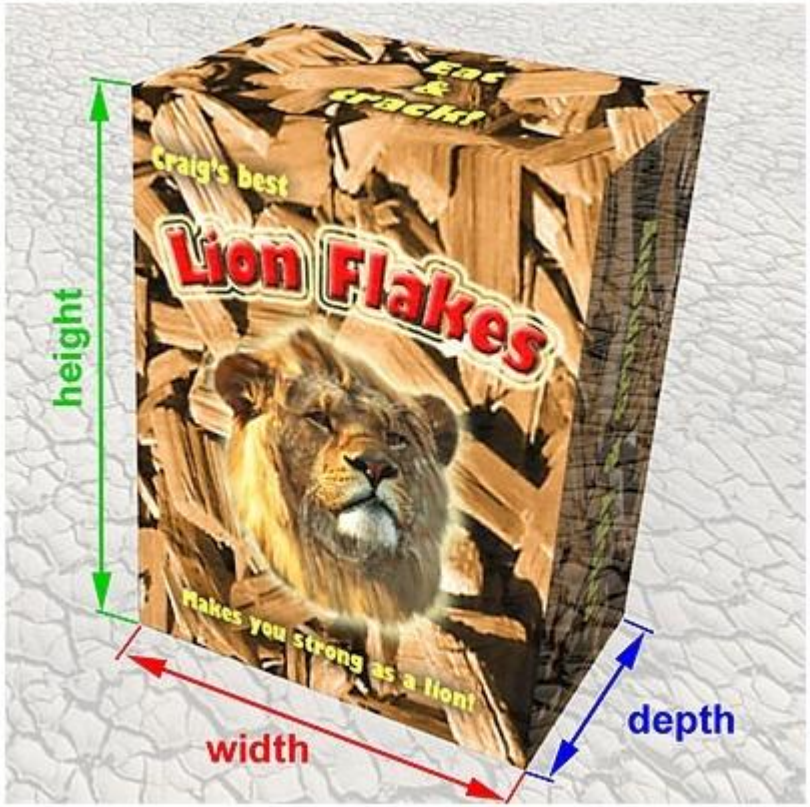
Same rules as Images

But Multi Targets are tracked as a single trackable item, so performance is substantially improved (compared to tracking multiple single-Image Targets at the same time).

The factors that differ from an Image Target are the dimensional parameters of a Multi Target.

We recommend the depth of the Multi Target be at least half the width of the front side.

https://developer.vuforia.com/library/vuforia-engine/images-and-objects/multi-targets/recommendations-designing-multi-targets/



Vuforia – Model Targets (marker tracking)

Model Targets enable apps built using Vuforia Engine to recognize and track particular objects in the real world based on the shape of the object.

A wide variety of objects can be used as Model Targets, from home appliances and toys, to vehicles, to large-scale industrial equipment and even architectural landmarks.

Vuforia – Model Targets

To make a Model Target for a particular object you need to have access to 3D model data of the object, such as a 3D CAD model or a 3D scan of the object that you created or obtained from a 3rd party source or application.

The object must:

Be geometrically rigid (i.e. it cannot be deformable or malleable).

Present stable surface features (shiny surfaces are not supported).

Vuforia – Model Targets

The Model Target Generator generates Model Targets by taking a 3D model representing the object you want to track as input,

checks it for suitability,

and lets you configure it for optimal tracking with Guide Views and Advanced Views.

The MTG generates a Vuforia Database which you can use with Vuforia Engine's Unity integration, or in your own native application, in order to track the object.

Vuforia – Model Targets

Model Target Generator

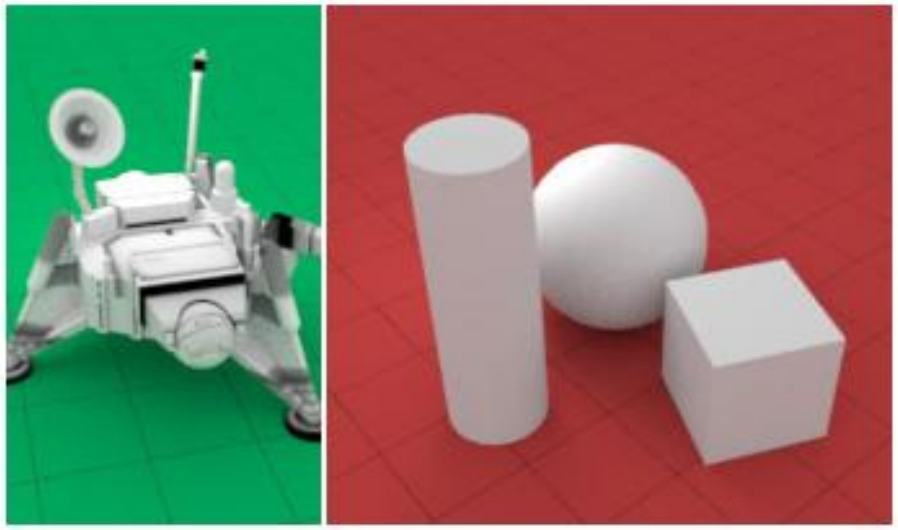
https://developer.vuforia.com/library/vuforia-engine/images-and-objects/model-targets/model-target-generator/model-target-generator-user-guide/

Vuforia – Model Targets

Preparing and Designing Model Targets

Sufficient Geometric Detail - Complex Enough Model

It is recommended to avoid symmetric objects as the Vuforia Engine tracking technology won't be able to tell its sides apart. Additionally, repeated parts and patterns, such as identical extrusions on a surface, can further cause confusion for detection and tracking.

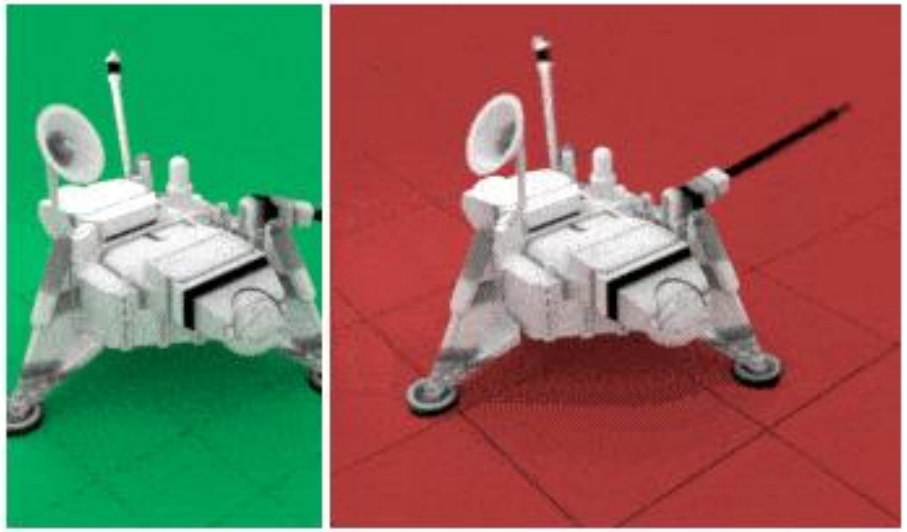


Vuforia – Model Targets

Preparing and Designing Model Targets

Non-flexible and Rigid

As a best practice, remove parts from the CAD model that are not always present on the physical object; e.g., variants of a product that have some small attachment that is not present on every object, or parts that are known to move.

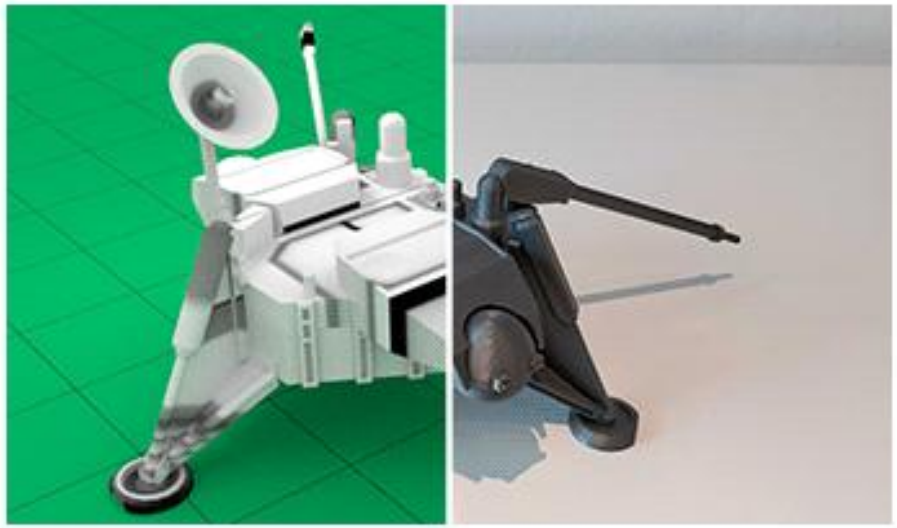


Vuforia – Model Targets

Preparing and Designing Model Targets

Matching CAD-model

Physical objects should have the exact same shape and size as their CAD model used for target generation.

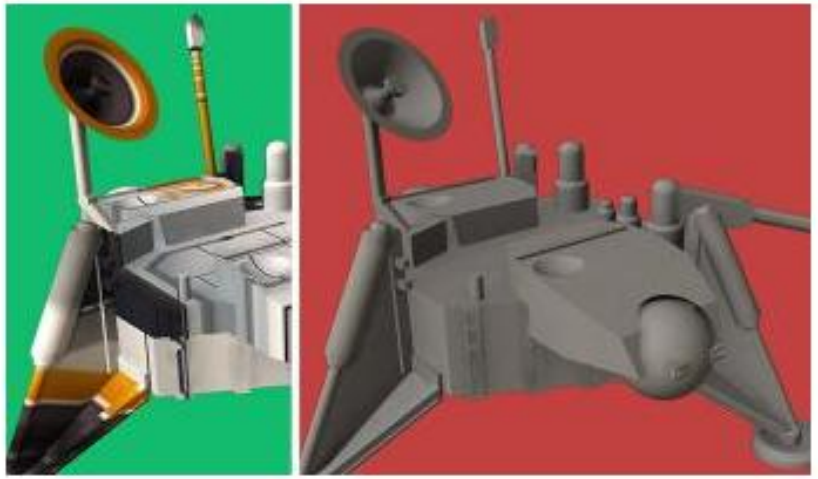


Vuforia – Model Targets

Preparing and Designing Model Targets

Textures

It can be helpful to include textures for your model if these provide visual fidelity and resembles the appearance of the physical object. The textures can be surface patterns, labels, prints, or flat elements - such as gauge-backplates.



Vuforia – Model Targets

Preparing and Designing Model Targets

Large Holes

Incorrect Normals

Missing parts

https://developer.vuforia.com/library/vuforia-engine/images-and-objects/model-targets/best-practices/model-targets-supported-objects-cad-model-best-practices/

Vuforia – Bar Code Scanner (marker tracking)

The Vuforia Barcode Scanner lets you detect and read a range of barcode and QR-code types with handheld devices and eyewear devices. Scan and automatically read multiple barcodes at the same time and make product identification fast and easy. Bring together the digital and physical with Barcode Scanning.

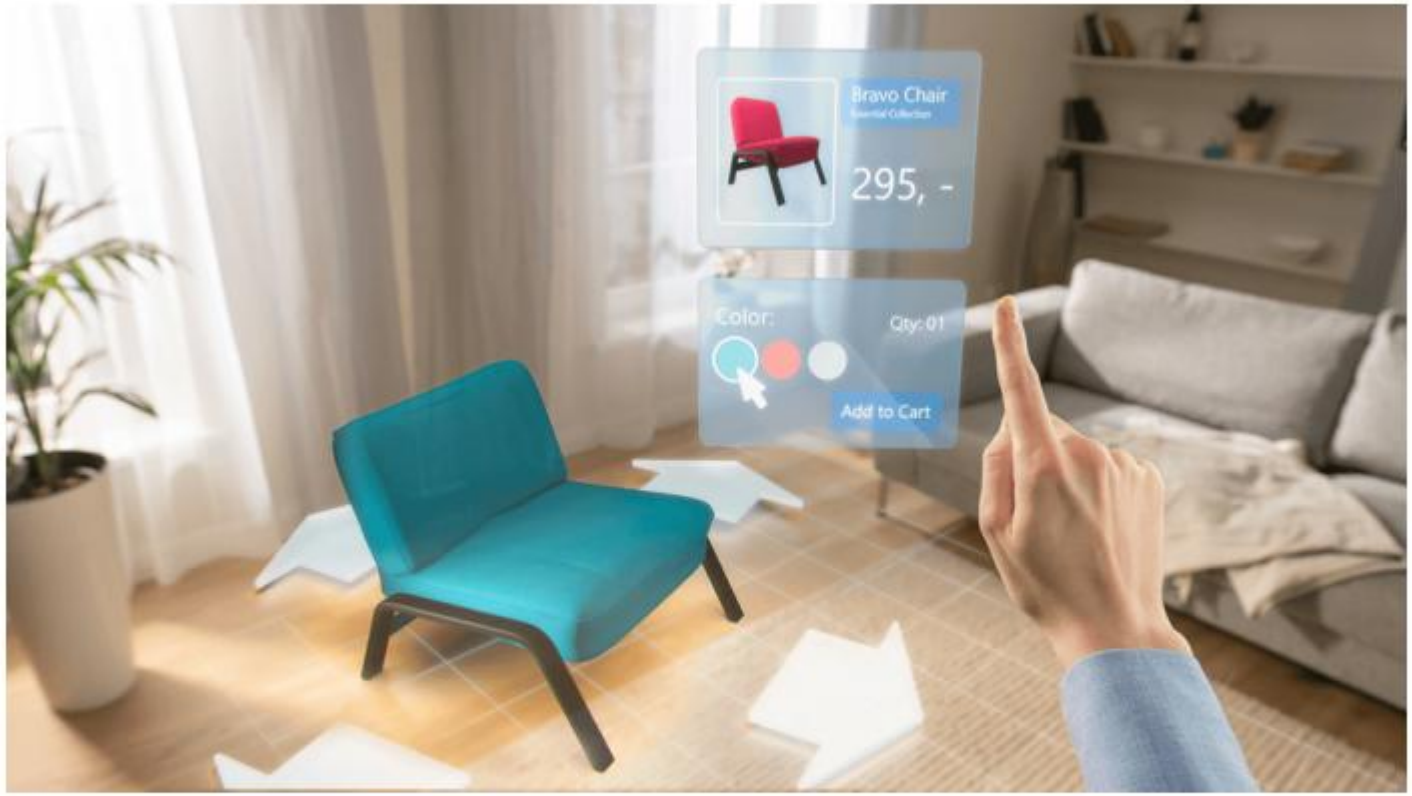
Vuforia – VuMarks (marker tracking)

VuMarks are the next-generation bar code. They allows the freedom for a customized and brand-conscious design while simultaneously encoding data and acting as a trackable AR target. VuMark designs are completely customizable, so you can have a unique VuMark for every unique object.

https://developer.vuforia.com/library/vuforia-engine/images-and-objects/vumarks/design-guide/vumark-design-guide/

Vuforia – Ground Plane (markerless tracking)

- It is based on ARKit and ARCore (later in the course)
- Same prerequisites (in terms of hardware)



Vuforia Ground Plane enables digital content to be placed on horizontal surfaces in your environment, such as floors and tabletops. It supports the detection and tracking of horizontal surfaces, and also enables you to place content in mid-air using Anchor Points.

Vuforia – Area Targets (marker tracking)

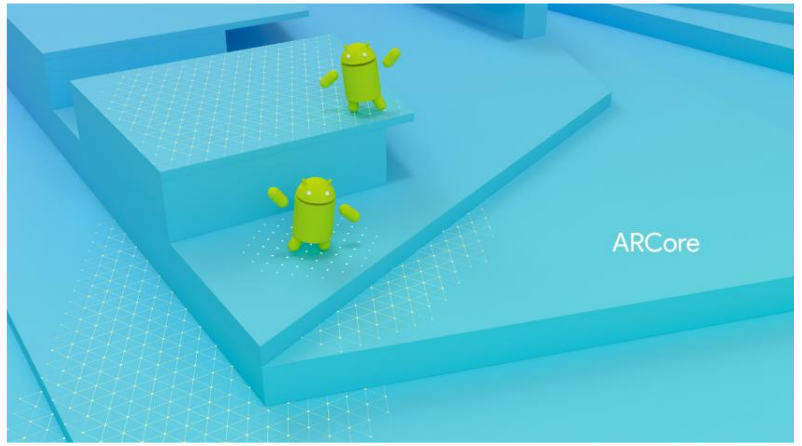
Area Targets is a Vuforia powered environment tracking feature that enables you to track and augment areas and spaces. By using a 3D scan as an accurate model of the space to create an Area Target Device Database, you can easily deliver augmentations to stationary objects in the scanned environment. This enables creating games, navigation applications, and spatial instructions that are all using the surroundings as interactive elements to be explored. Offices, factory floors, apartments, public spaces, museums, and many more areas are ideal locations for Area Targets.

Università di Genova
DIBRIS DIPARTIMENTO
DI INFORMATICA, BIOINGEGNERIA,
ROBOTICA E INGEGNERIA DEI SISTEMI

Google ARCore

ARCore

ARCore is Google's platform for building augmented reality experiences.



ARCore mainly uses **markerless tracking**:

- No need of pre-defined targets
- Features are found in the environment
- SLAM technique
- The relative pose between the image and the camera is computed
- The reference frames of the camera and the world are aligned

ARCore

ARCore provides SDKs for many of the most popular development environments. These SDKs provide native APIs for all of the essential AR features like motion tracking, environmental understanding, and light estimation. With these capabilities you can build entirely new AR experiences or enhance existing apps with AR features.

Android

Android NDK

Unity (AR Foundation)

iOS

Unreal

Web

ARCore

https://developers.google.com/ar/develop

- Using different APIs, ARCore enables your **phone** to sense its environment, understand the world and interact with information. Some of the APIs are available across Android and iOS to enable **shared AR experiences**.

- ARCore uses three key capabilities to **integrate virtual** content with the **real** world as seen through your phone's camera:
  - **Motion tracking** allows the phone to understand and track its position relative to the world.
  - **Environmental understanding** allows the phone to detect the size and location of all type of surfaces: horizontal, vertical and angled surfaces like the ground, a coffee table or walls.
  - **Light estimation** allows the phone to estimate the environment's current lighting conditions.

ARCore

- Fundamentally, ARCore is doing two things: **tracking** the position of the mobile device as it moves, and **building** its own understanding of the real world.

- ARCore's **motion tracking** technology uses the phone's camera to identify interesting points, called **features**, and tracks how those points move over time. With a combination of the movement of these points and readings from the phone's **inertial sensors**, ARCore determines both the **position** and **orientation** of the **phone** as it moves through space.

- In addition to identifying key points, ARCore can detect **flat surfaces**, like a table or the floor, and can also estimate the average **lighting** in the area around it. These capabilities combine to enable ARCore to build its own understanding of the world around it.

- ARCore's understanding of the real world lets you place objects, annotations, or other information in a way that **integrates seamlessly** with the real world. Even if you turn around and leave the room, when you come back, **the augmentations will be right where you left it**.

ARCore

https://developers.google.com/ar/develop/fundamentals

Motion tracking

- As your phone moves through the world, ARCore uses the **simultaneous localization and mapping**, or SLAM, to understand where the phone is relative to the world around it. The visual information is combined with **inertial measurements** from the device's IMU to estimate the **pose** (position and orientation) of the camera relative to the world over time.

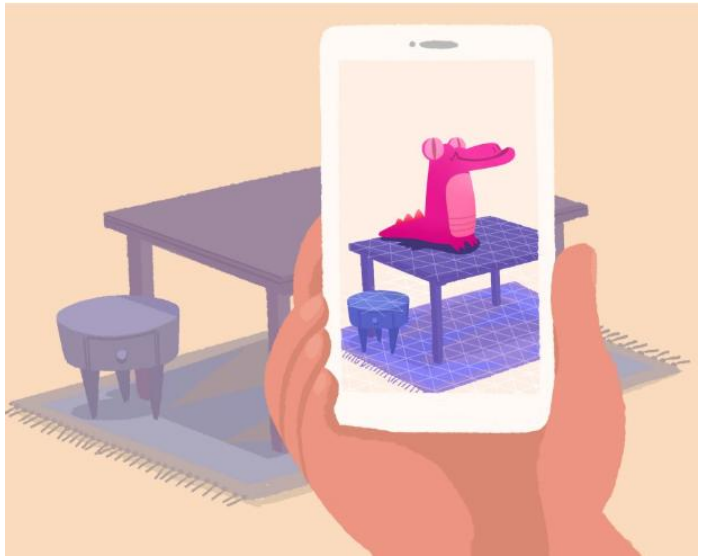
- By **aligning** the pose of the **virtual camera** that renders your 3D content with the pose of the device's camera provided by ARCore, developers are able to render virtual content from the **correct perspective**.

ARCore

Environmental understanding

- ARCore is constantly improving its understanding of the real world environment by **detecting feature points** and **planes**.

- ARCore looks for **clusters of feature points** that appear to lie on common horizontal or vertical surfaces, like tables or walls, and makes these surfaces available to your app as **geometric planes**. You can use this information to place virtual objects resting on flat surfaces.
- *Because ARCore uses feature points to detect planes, flat surfaces without texture, such as a white wall, may not be detected properly.*



ARCore

Depth understanding

- ARCore can create **depth maps**, using the main RGB camera (by handling **occlusions** between real and virtual objects).

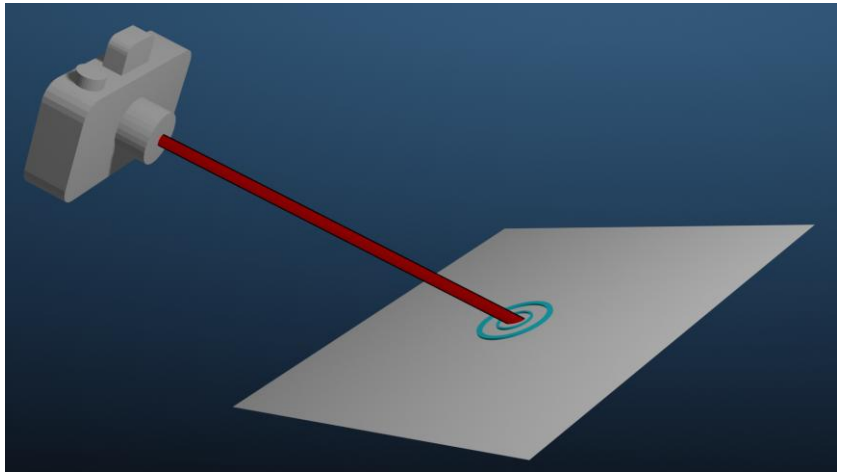
Light estimation

- ARCore can detect information about the lighting of its environment, thus lighting virtual objects under the same conditions as the environment around them, increasing the sense of realism.

ARCore

User interaction

- ARCore uses **hit testing** to take an (x,y) coordinate corresponding to the phone's screen (provided by a tap) and projects a **ray** into the camera's view of the world, returning any geometric planes or feature points that the ray intersects, along with the **pose of that intersection** in world space. This allows users to **interact with objects** in the environment.



ARCore

Anchors

- When you want to place a virtual object, you need to define an anchor to ensure that **ARCore tracks** the object's **position** over time. Often times you create an anchor based on the pose returned by a hit test.

ARCore (marker based functionalities)

Augmented Images

- Augmented Images is a feature that allows you to build **AR apps** that can **respond** to **specific 2D images**. Images can be compiled offline to create an **image database**, or individual images can be added in real time from the device. Once registered, ARCore will detect these images, and return a corresponding pose.

ARCore – Augmented Faces (marker based functionalities)

The Augmented Faces API allows you to render assets on top of human faces without using specialized hardware. It provides feature points that enable your app to automatically identify different regions of a detected face. Your app can then use those regions to overlay assets in a way that properly matches the contours of an individual face.

Unity AR Foundation

AR Foudation

Framework provided by Unity that allows to build AR applications once and deploy on different platforms.

The AR Foundation package contains interfaces for AR features, but does not implement any features itself. To use AR Foundation on a target platform, you also need a separate provider plug-in package for that platform.

https://docs.unity3d.com/Packages/com.unity.xr.arfoundation@6.1/manual/index.html

AR Foundation

Features

AR Foundation supports the following features:

Feature	Description
Session	Enable, disable, and configure AR on the target platform.
Device tracking	Track the device's position and rotation in physical space.
Camera	Render images from device cameras and perform light estimation.
Plane detection	Detect and track flat surfaces.
Bounding Box detection	Detect and track bounding boxes of 3D objects.
Image tracking	Detect and track 2D images.
Object tracking	Detect and track 3D objects.
Face tracking	Detect and track human faces.
Body tracking	Detect and track a human body.
Point clouds	Detect and track feature points.
Ray casts	Cast rays against tracked items.
Anchors	Track arbitrary points in space.
Meshing	Generate meshes of the environment.
Environment probes	Generate cubemaps of the environment.
Occlusion	Occlude AR content with physical objects and perform human segmentation.
Participants	Track other devices in a shared AR session.

AR Foundation

AR Foundation provider plug-ins rely on platform implementations of AR features, such as Google's ARCore on Android and Apple's ARKit on iOS. Not all features are available on all platforms.

	ARCore	ARKit		OpenXR			XR Simulation
Feature	**Android**	**iOS**	**visionOS**	**Microsoft HoloLens**	**Meta Quest**	**Android XR**	**Unity Editor**
Session	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Device tracking	Yes	Yes	Yes	Yes	Yes		Yes
Camera	Yes	Yes			Yes	Yes	Yes
Plane detection	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bounding Box detection					Yes		Yes
Image tracking	Yes	Yes	Yes				Yes
Object tracking		Yes					
Face tracking	Yes	Yes				Yes	
Body tracking		Yes					
Point clouds	Yes	Yes					Yes
Ray casts	Yes	Yes		Yes	Yes	Yes	Yes
Anchors	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Meshing		Yes	Yes	Yes	Yes		Yes
Environment probes	Yes	Yes	Yes				Yes
Occlusion	Yes	Yes				Yes	Yes
Participants		Yes					