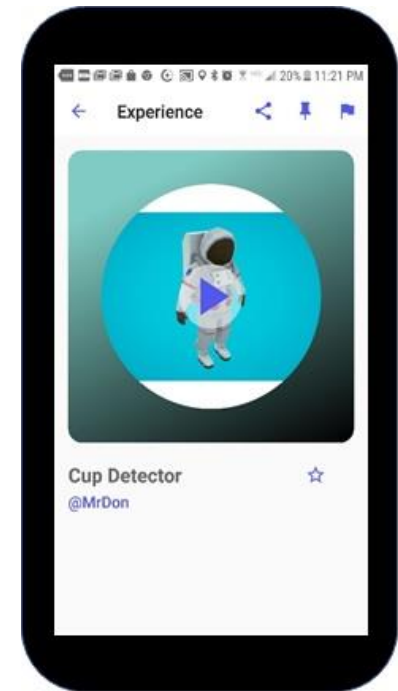
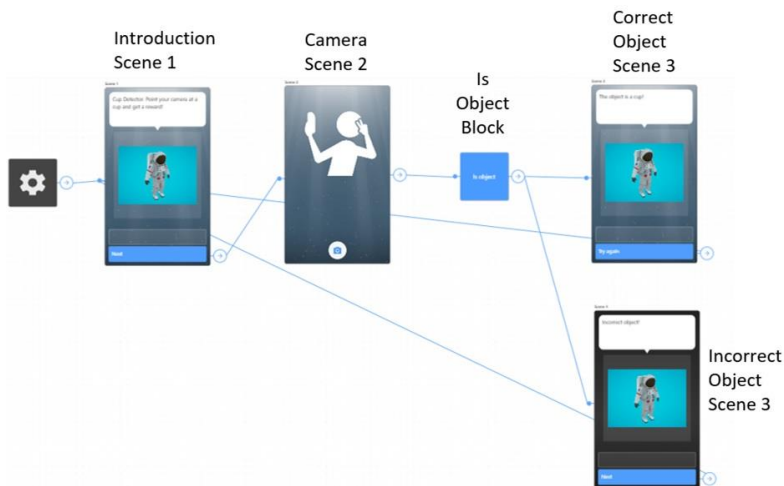


Exploring Vision Devices

Class 1: Embedded Vision Systems Research



August 26, 2019
Don Wilcher

Class 1: Embedded Vision Systems Research



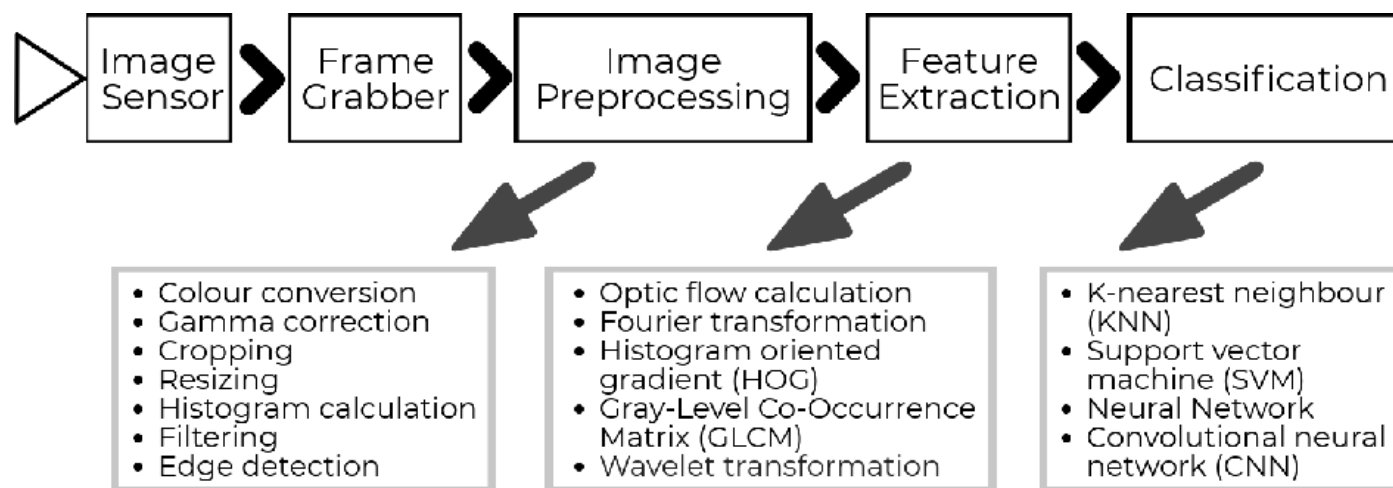
Agenda

- Application specific vision systems: Vision System Pipeline
- Image Sensor Simulator
- Lab Project: Build an Augmented Reality (AR) based smartphone vision device



Application specific vision systems

A common pipeline is used to show major functional characteristics of a typical embedded vision system (Bhowmik & Appiah, 2018).



Vision system pipeline

Bhowmik, D., & Appiah, K. (2018). *Embedded vision systems: A review of the literature*.

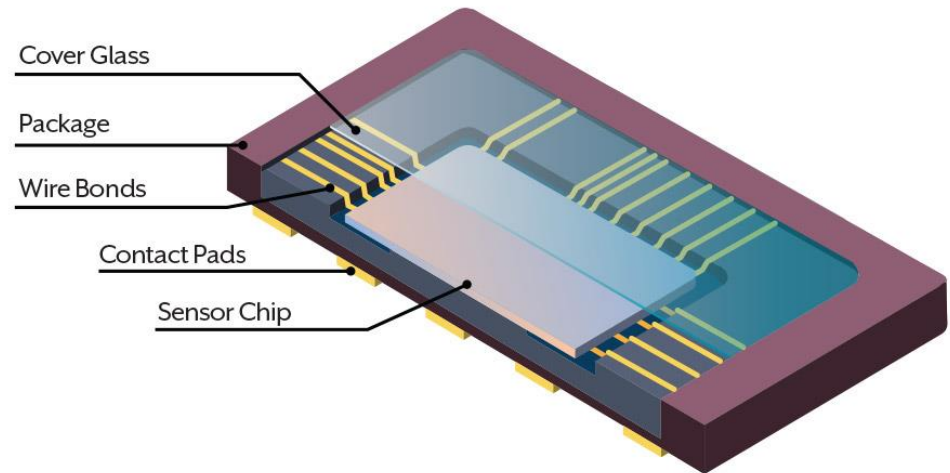
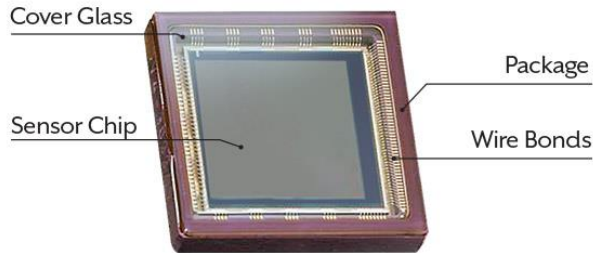
Retrieved from https://dspace.stir.ac.uk/retrieve/912d91dd-f3c6-44cc-96dc-a8c720167ace/Paper_73.pdf

Application specific vision systems...



The entry point of the Vision system pipeline is the image sensor. The image sensor consists of:

- a) pixels – built from light sensitive elements
- b) micro lenses
- c) micro electrical components



Typical image sensor

Application specific vision systems...



Frame Grabbers

The **frame grabber** takes the image sensors' signal and controls the frame synchronization and frame rate. Characteristics of frame grabber are:

- a) microcontroller based electronics pcb
- b) Attaches to a laptop internally
- c) uses a mini card slot for internally connection
- d) Captures individual digital still frames from an analog video or digital video stream
- d) software is used for frame synchronization and frame rate



Question 1:

What is the entry point to the Vision pipeline?

Application specific vision systems...



Frame Grabbers: Hardware Examples



PIXCI EB1miniG

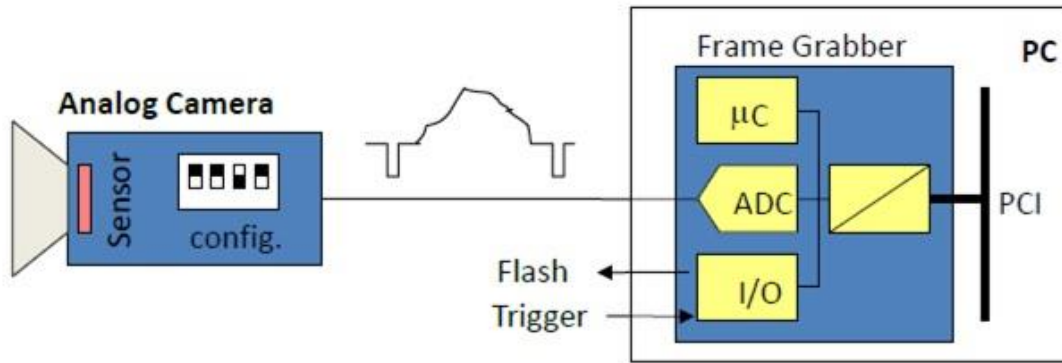


PIXCI EB1miniF

Application specific vision systems...

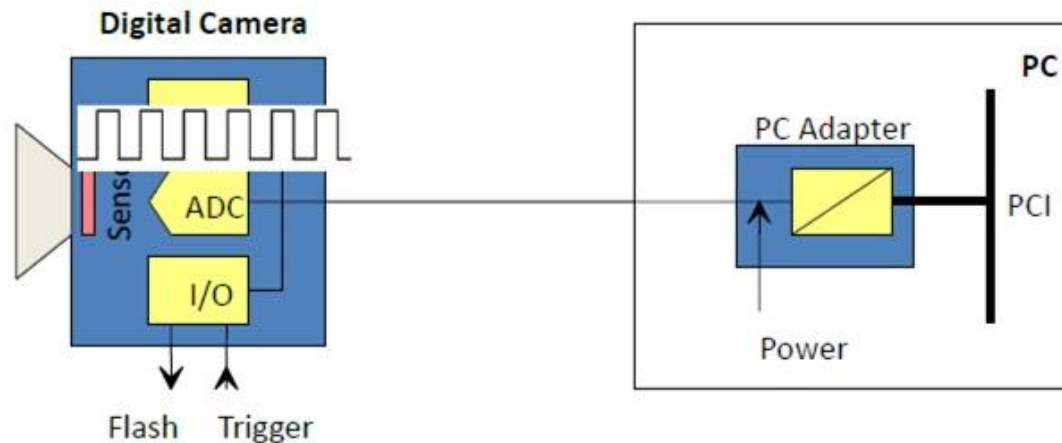


Frame Grabbers: Analog vs Digital Cameras



Analog problems:

- Pixel jitter
- Noise
- EMI Susceptibility
- Settings via dipswitch



Digital Solutions:

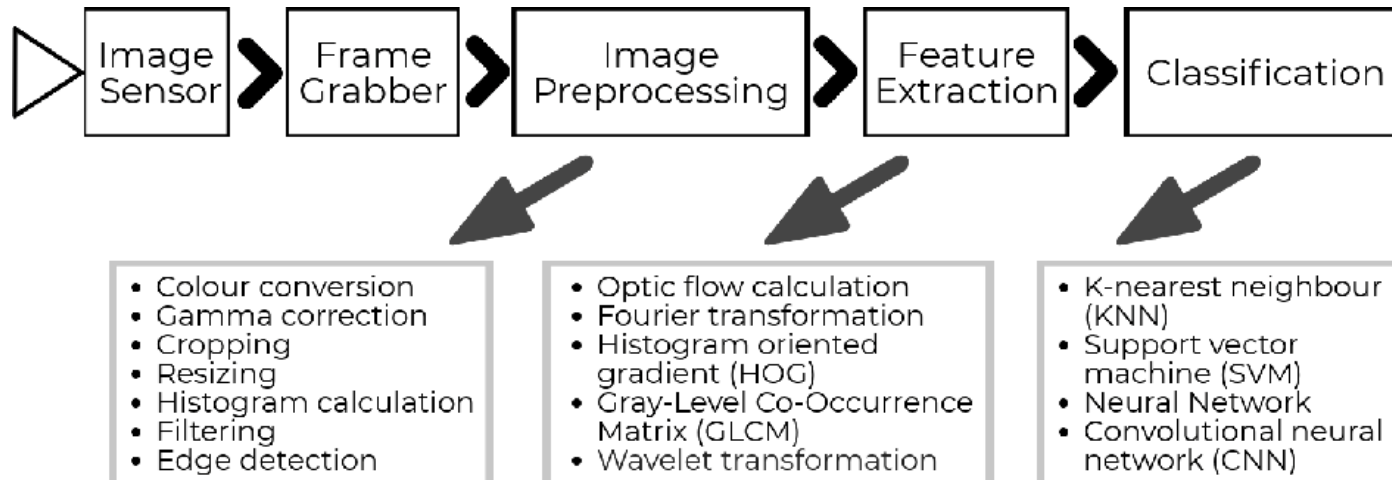
- Exact pixel readout
- No losses on the cable
- Settings via software

Application specific vision systems...



The raw pixels from the frame grabber are passed to

- a) Image pre-processing
- b) Feature extraction
- c) classification



Application specific vision systems...

Vision Processing



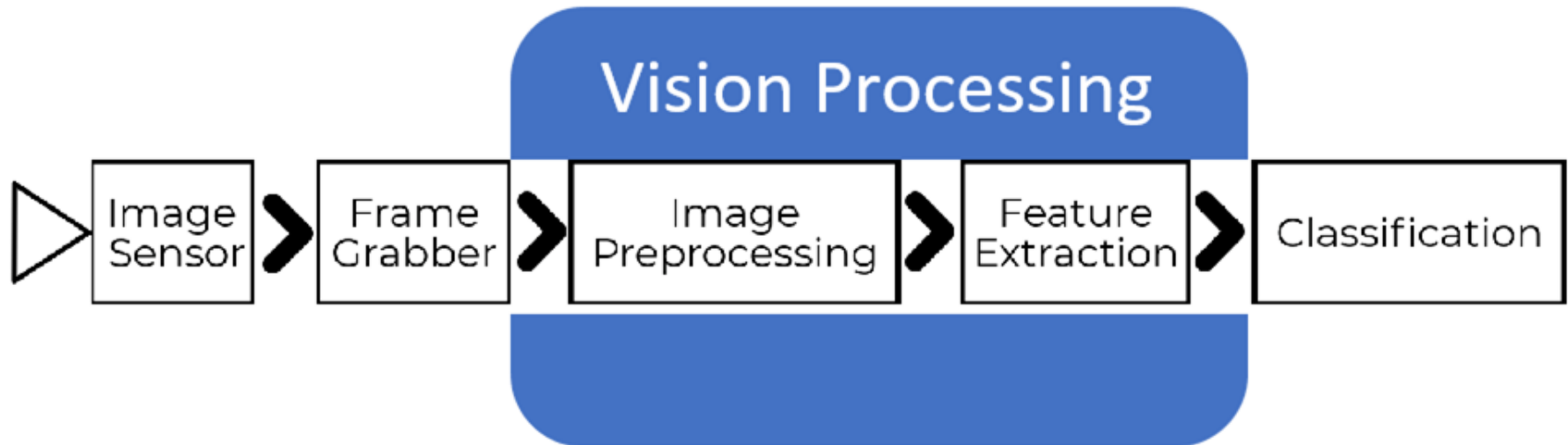
A mechanism used for :

- a) information extraction from a digital image
- b) software used to process digital image
- c) pre-processing used to optimize the image:
 - i. ensure features stand out
 - ii. runs measurements and compares them to specifications
 - iii. decision is made and final results presented

Application specific vision systems...



Vision Processing



Vision system pipeline modified

What is Classification?



Classification Models – Predicts the object membership based on characteristics grouping.

FAQs:

- The focus is on binary decision making.
- Prediction based on a true or false, yes or no 1 or 0 hierarchical format.
- Assigning a task of assigned objects from several predefined categories (Tan, Steinbach et al., 2016).
- Classifications uses Decision Trees to aid in attribute or event predictions.

Source:

Tan, P.N., Steinbach, M., & Kumar, V. (2016). *Introduction to data mining*. Retrieved from <https://www-users.cs.umn.edu/~kumar001/dmbook/ch4.pdf>

Question 2:



**What are the five components
for the Vision pipeline?**

Image Sensor Simulator



Image Sensor Simulator – an instructional tool that allows the following analysis:

- noise components.
- image quality.
- lighting conditions.
- digital image formulation process.

Image Sensor Simulator...



Camera/Image Sensor Noise Component Basics

Types of Noise Components:

- **Temporal** – Anything besides light that causes a pixel 1's value to change overtime (sources: temperature, ADC errors, etc)
 - a) **Shot Noise/Photon Noise:**
 - b) **Best Results:** Brighter/Better Light – less shot noise
- **Dark Current Noise** – The rate at which electrons are produced due to thermal effects.
 - a) **Every 8°C – Dark Noise Doubles:**
 - b) **Best Results:** Cooler Camera – less dark noise

Image Sensor Simulator...



Camera/Image Sensor Noise Component Basics

Types of Noise Components:

- **Quantization Noise** – Errors coming from the A/D conversion process. **Best Results: Use a better ADC** – less quantization noise

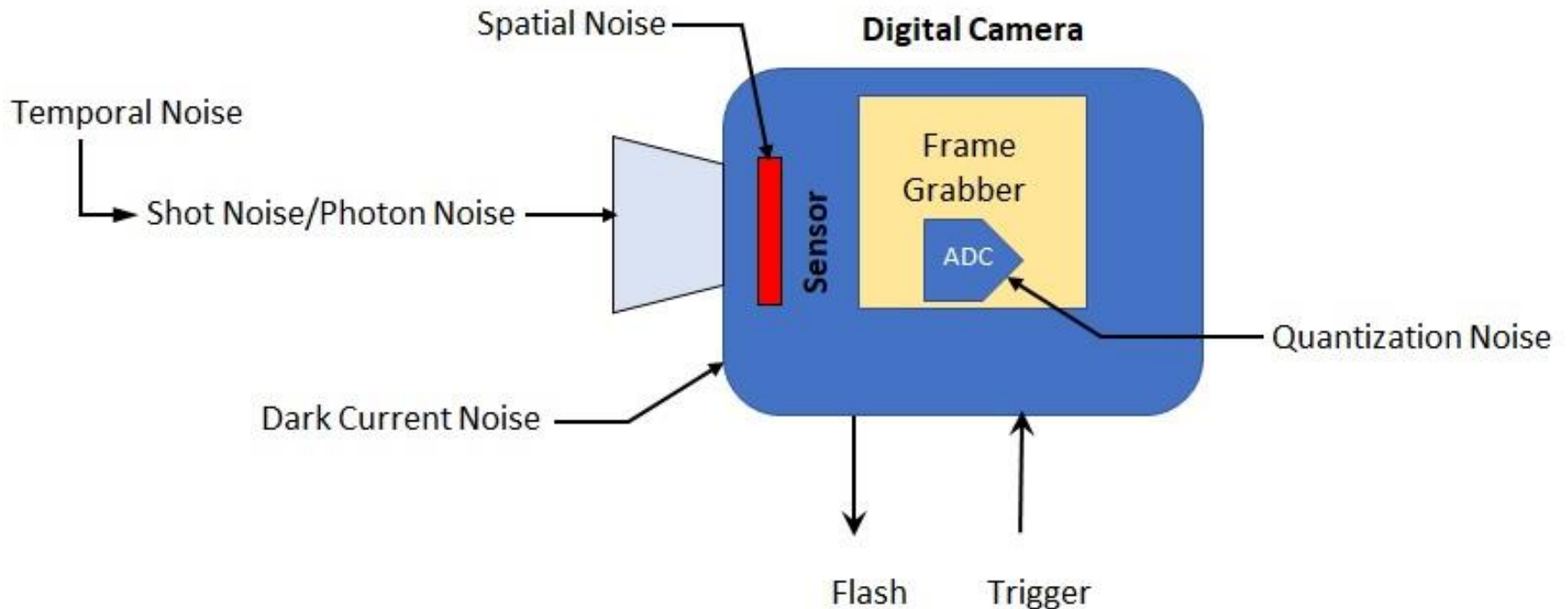
Signal to Noise Ratio (SNR):

- The ratio of a good signal caused by light to unwanted noise
- The most important measurement of image quality for digital cameras.

Image Sensor Simulator...



Camera/Image Sensor Noise Components



Question 3:



What noise component is concern with the rate at which the electrons are produced due to thermal effects ?

Image Sensor Simulator...



The screenshot shows the 'IMAGE SENSOR SIMULATOR' interface. It features a top bar with 'Help' on the right. The main area is divided into two identical panels, each containing a 'Scene' view (with a woman's face), a 'Photon Flux Histogram' [p/s/um^2] with a scale from 0.0 to 5.0, and a 'Sensor Parameters' table. The parameters table includes: Read Noise [e] (4.0), Quantum Efficiency [%] (80), Dark Current [e/s/um^2] (0.1), Exposure Time [s] (1), PSF std [um] (4), and Pixel size [um] (8). Below the table are checkboxes for 'Use multiple readout method?' (checked), 'Non-Destructive CDS Readout?' (unchecked), and 'Auto set black & white levels?' (checked). Further down are 'Black Level [e]' and 'White Level [e]' fields, both showing 'N/A'. A 'Global Controls' bar at the bottom contains buttons for 'Remove Sensor', 'Add Sensor', 'Abort', and 'Run'. A white line with a pointer indicates the 'Sensor Widgets' area (the two main panels) and another white line with a pointer indicates the 'Global Controls' area (the bottom bar).

<http://www.pixpolar.com/imager-simulator/index.html>

Image Sensor Simulator...



Sensor Parameters

Read Noise [e]	4.0
Quantum Efficiency [%]	80
Dark Current [e/s/um ²]	0.1
Exposure Time [s]	1
PSF std [um]	4
Pixel size [um]	8

Use multiple readout method?

Frame Rate [frames/s] 30

Non-Destructive CDS Readout?

Auto set black & white levels?

Black Level [e] N/A

White Level [e] N/A

Image Sensor Simulator...



Sensor Parameters Experimentation

The screenshot shows the Image Sensor Simulator interface. It is divided into three main sections: 'Scene', 'Sensor Parameters', and a large image output area. The 'Scene' section on the left shows a grayscale image of a galaxy with navigation arrows and a 'Photon Flux Histogram [p/s/um^2]' below it. The histogram shows a peak on the left and a long tail to the right, with 'Min' and 'Max' values of 1 and 5.0 respectively. The 'Sensor Parameters' section in the middle contains a table of parameters and their values, along with several checkboxes and dropdown menus. The large image output area on the right shows a noisy grayscale image. At the bottom, there are four buttons: 'Remove Sensor', 'Add Sensor', 'Abort', and 'Run'.

Sensor Parameters	
Read Noise [e]	7
Quantum Efficiency [%]	1
Dark Current [e/s/um^2]	0.8
Exposure Time [s]	1
PSF std [um]	4
Pixel size [um]	50
Use multiple readout method?	<input type="checkbox"/>
Frame Rate [frames/s]	N/A
Non-Destructive CDS Readout?	
Auto set black & white levels?	<input checked="" type="checkbox"/>
Black Level [e]	N/A
White Level [e]	N/A

Image Sensor Simulator...



Resource for Image Sensor Simulator

Fundamentals of Image Sensor Performance

<http://www1.cse.wustl.edu/~jain/cse567-11/ftp/imgsens/index.html>

Fundamentals of Image Sensor Performance

Timothy York, timothy.york@gmail.com (A paper written under the guidance of [Prof. Raj Jain](#))



Abstract:

Image sensors are everywhere. They are present in single shot digital cameras, digital video cameras, embedded in cellular phones, and many more places. When many people purchase a digital imager, the primary metric they use as a comparison is the pixel array size, expressed in megapixels. The higher the megapixel count, the better the imager is the prevailing wisdom to most consumers. There are many more metrics with which to compare imagers that may give a better indication of performance than raw pixel counts. Further, many of these metrics may be based on the type of imaging technology, CCD (charge coupled device) or CMOS (complementary metal oxide semiconductor). This paper will explain the fundamentals of how a digital image sensor works, focusing on how photons are converted into electrical signals, and thus images. It will detail the difference between the functionality of CCD and CMOS sensors, the two chief architectures for image sensor design. It will also discuss various metrics which are commonly used in analyzing the performance of image sensors. It will include a statistical comparison of recent CCD and CMOS imaging systems from the literature using these metrics, and compare them to some commercially available sensors. It will also develop a model for how two of these metrics, well capacity and conversion gain, are related.

Keywords: Image sensor, CMOS image sensor, CCD, performance analysis, well capacity, conversion gain, image sensor metrics

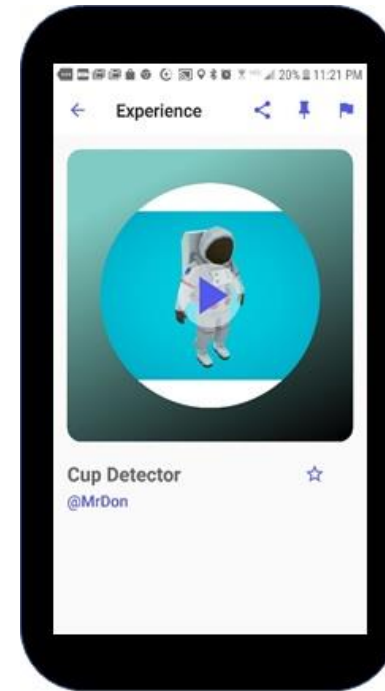
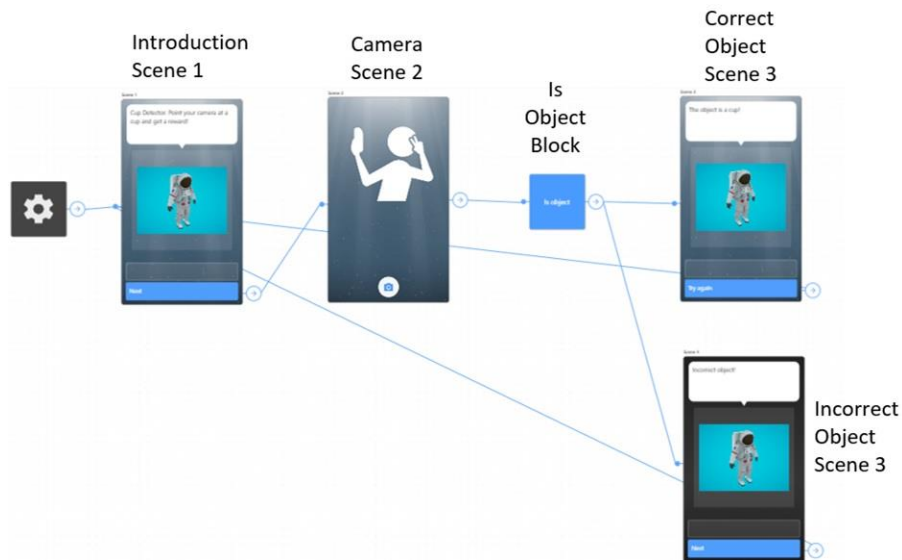
Table of Contents:

- [1. Introduction](#)
 - [1.1 The Physics of Silicon Image Sensors](#)
 - [1.2 Measuring Light Intensity](#)
 - [1.3 CCD Image Sensors](#)
 - [1.4 CMOS Image Sensors](#)
- [2. Performance Metrics for Image Sensors](#)
 - [2.1 Metrics Related to Pixel Layout](#)
 - [2.2 Metrics Related to Pixel Physics](#)
 - [2.3 Metrics Related to Pixel Readout](#)
- [3. A Performance Comparison of Selected Image Sensors](#)
 - [3.1 Comparing CCD vs CMOS Sensors](#)
 - [3.2 A Model of Conversion Gain and Well Capacity](#)
 - [3.3 Discussion of Results](#)
- [4. Summary](#)
- [References](#)
- [List of Acronyms](#)

1. Introduction

<https://www.cse.wustl.edu/~jain/cse567-11/ftp/imgsens.pdf>

Lab Project: Build an Augmented Reality (AR) based smartphone vision device...



Lab Project: Build an Augmented Reality (AR) based smartphone vision device



Learning Outcomes

- To use an online design studio software to create AR apps for smartphones.
- To use Google vision block to detect and recognized objects with a smartphone.
- To use the Google API to enable a Machine Learning (ML) feature for object recognition.

Lab Project: Build an Augmented Reality (AR) based smartphone vision device...



Create Augmented Reality experiences for iOS and Android, without writing code.

Hundreds of thousands of experiences have been created by regular people from over 180 countries.

[Start Creating](#)

Lab Project: Build an Augmented Reality (AR) based smartphone vision device...



Metaverse AR Studio



[Blog](#) [Forum](#) [Tutorials](#) [Learn](#) [My account](#) [Create experience](#)

Search

[My experiences](#)

[Collections](#)

[My favorites](#)

[My walls](#)

[My polls](#)

[Discover](#)

New
From Metaverse
Koji
The Place to Make Apps
[Check it out](#)

Getting Started

Download the Metaverse app

You'll need to download the Metaverse app on your phone, tablet, or chromebook in order to use the experiences you create in the Studio.



Additional Resources

- [Watch Metaverse Tutorials](#)
- [Read the Metaverse Guide](#)
- [Metaverse Community](#)
- [Join the conversation on Twitter](#)

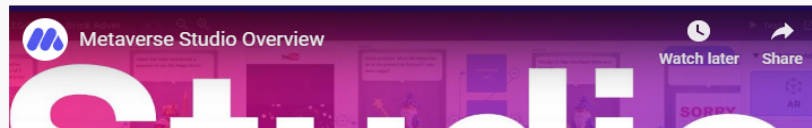
Metaverse For Teachers

Create a collection to group, view, and edit Experiences created by your students.

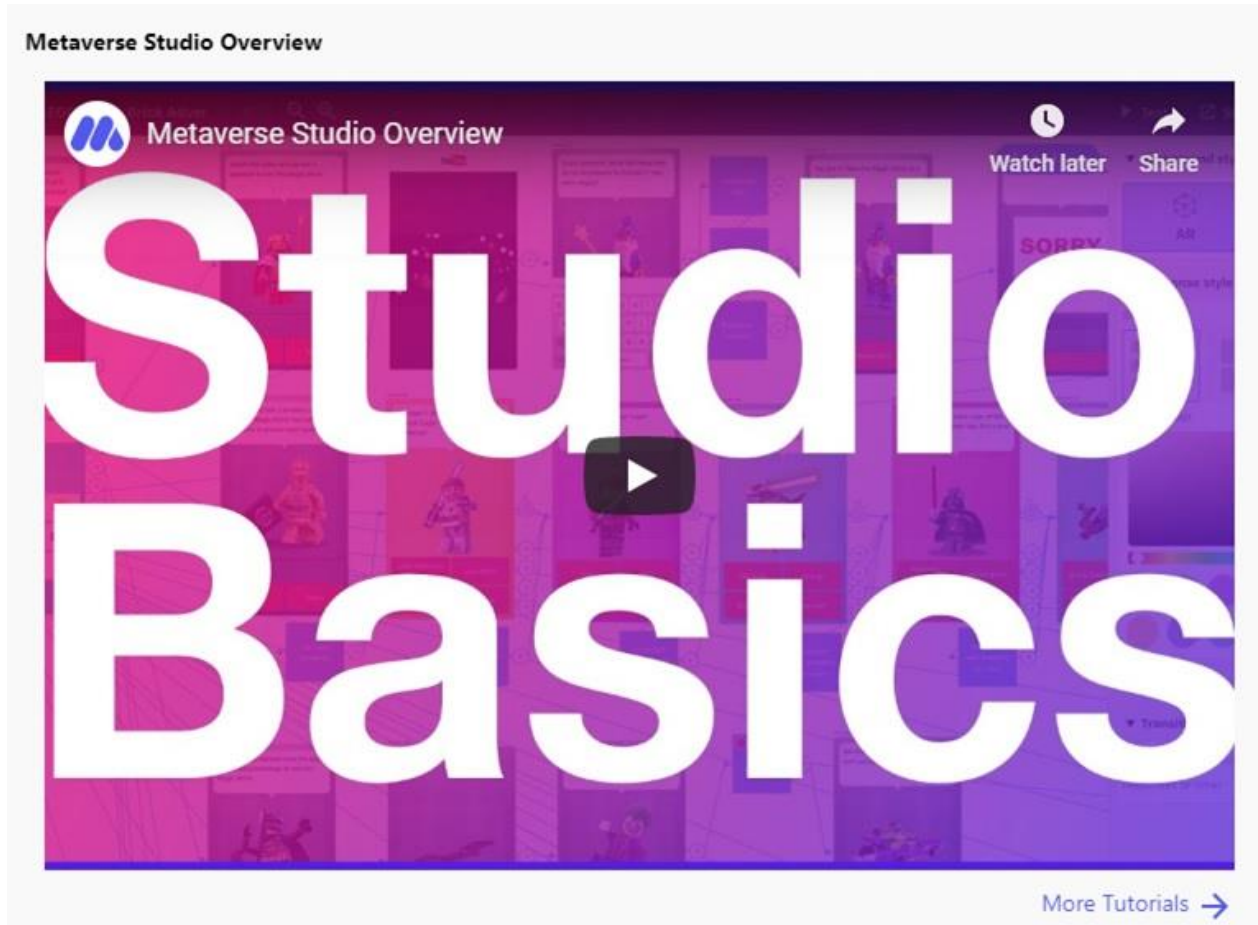
[Learn More](#)



Metaverse Studio Overview



Lab Project: Build an Augmented Reality (AR) based smartphone vision device...



Lab Project: Build an Augmented Reality (AR) based smartphone vision device...



Metaverse Mobile App

Getting Started

Download the Metaverse app

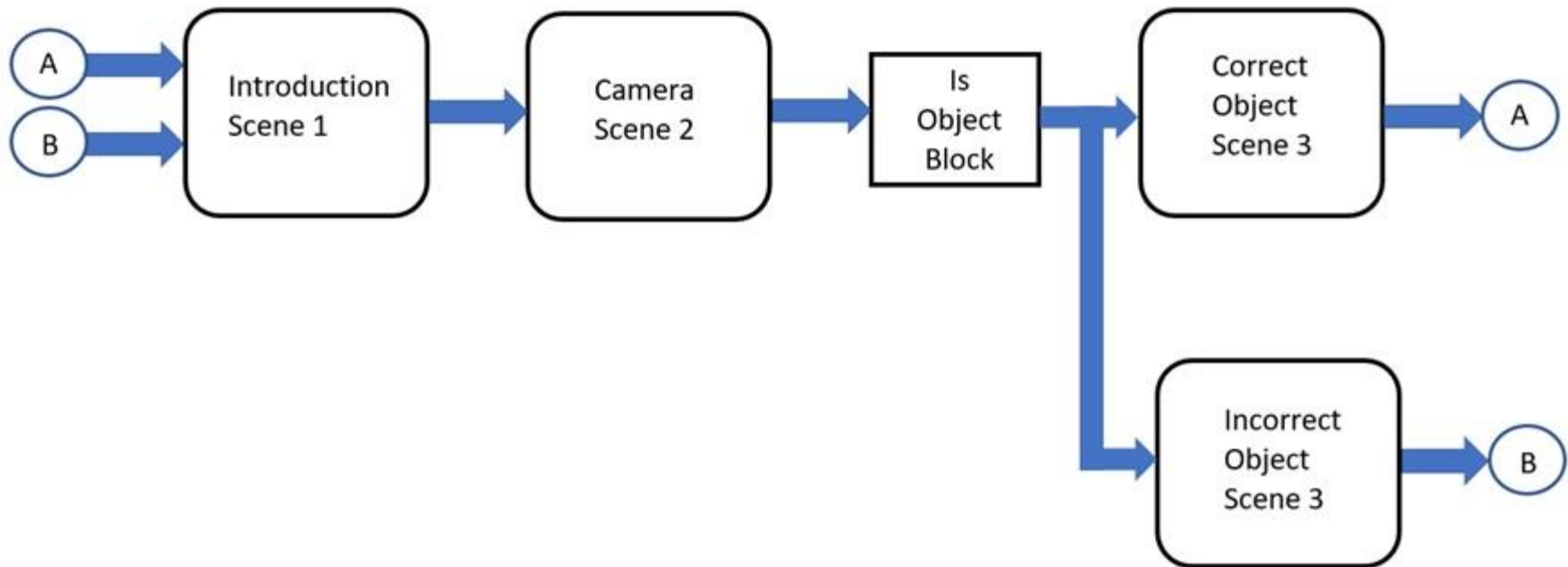
You'll need to download the Metaverse app on your phone, tablet, or chromebook in order to use the experiences you create in the Studio.



Lab Project: Build an Augmented Reality (AR) based smartphone vision device...



System Design for AR based smartphone vision device

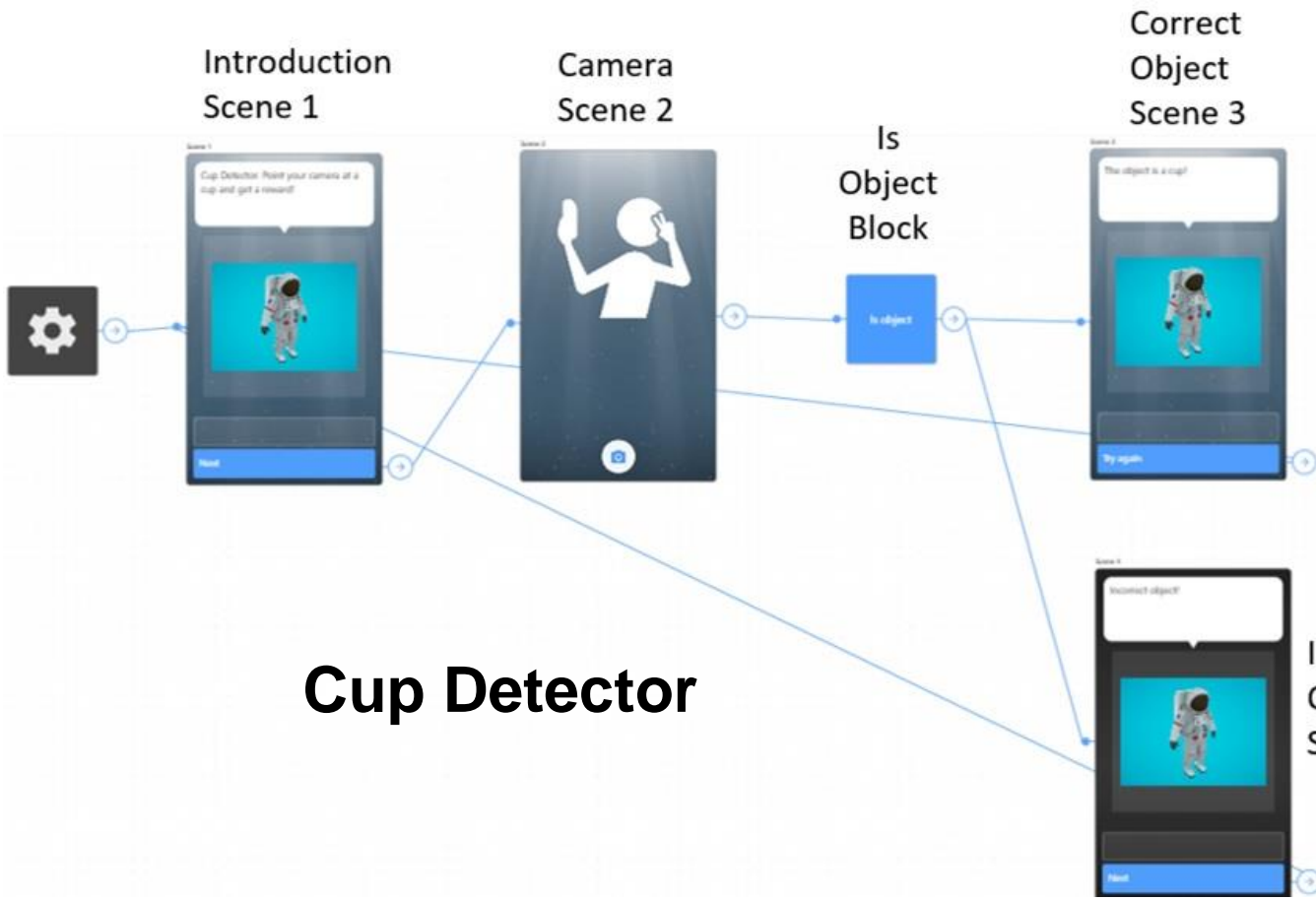


Question 4:



Which image sensor parameter effects the resolution of the image?

Lab Project: Build an Augmented Reality (AR) based smartphone vision device...



AR smartphone vision device Storyboard

Cup Detector

Lab Project: Build an Augmented Reality (AR) based smartphone vision device...



Google Vision

A screenshot of the Unity Visual Scripting interface. The 'Add new...' window is open, displaying a list of blocks under the 'Google vision' category. The left sidebar shows the 'All scenes' and 'BLOCKS' sections, with 'Google vision' selected. The main area shows several blocks: 'Increment user property by input', 'Check user property', 'Is text', 'Is object', 'Count faces', and 'Is happy'. Each block has a description and a 'USE' button.

Add new...

SCENES

All scenes

BLOCKS

Walls

Text

Polls

Probability

Leaderboard

Environment properties

Experience properties

User properties

Google vision

Inventory

Time controls

Unity

Increment user property by input
Increment a property on a user's account by the amount returned from the preceding block.
USE

Check user property
Test the value of a user property.
USE

Google vision

Is text
Connect this block to a Camera Scene to check if a photo taken by the user contains a text.
USE

Is object
Connect this block to a Camera Scene to check if a photo taken by the user contains a specified object.
USE

Count faces
Connect this block to a Camera Scene to count how many faces are in a photo.
USE

Is happy
Connect this block to a Camera Scene to check if the most prominent face in a photo is of a person who is happy.
USE

Inventory

Question 5:



What instructional design approach is used to develop an AR app using Metaverse?

Lab Project: Build an Augmented Reality (AR) based smartphone vision device...



To create object recognition capabilities

A screenshot of the Google Cloud Vision AI product page. The page features a navigation bar with links for Google Cloud, Why Google, Solutions, Products, Pricing, and Getting started. Below the navigation bar, there are buttons for 'Contact sales' and 'Try free'. The main content area is titled 'Vision AI' and includes a description: 'Derive insights from your images in the cloud or at the edge with AutoML Vision or use pre-trained Vision API models to detect emotion, understand text, and more.' A 'Get started' button is prominently displayed. To the right of the text is a video player showing a wind turbine in a desert landscape. A sidebar on the left lists various sections under 'VISION AI', including Overview, Vision API demo, Benefits, Features, Customers, Use cases, Pricing, Resources, Training, and Get started.

<https://cloud.google.com/vision/>

Lab Project: Build an Augmented Reality (AR) based smartphone vision device...



To create object recognition capabilities...

A screenshot of the Google Cloud Vision API product page. The page features a navigation bar with 'Google Cloud' and various menu items like 'Why Google', 'Solutions', 'Products', 'Pricing', and 'Getting started'. Below the navigation, there are buttons for 'Contact sales' and 'Try free'. The main content area is divided into two columns: 'AutoML Vision' and 'Vision API'. The 'AutoML Vision' section describes automating the training of custom machine learning models. The 'Vision API' section describes using pre-trained machine learning models through REST and RPC APIs. At the bottom, there is a 'Try the API' section with a dashed box containing the text 'Drag image file here or Browse from your computer' and a placeholder image icon.

<https://cloud.google.com/vision/>

Lab Project: Build an Augmented Reality (AR) based smartphone vision device...

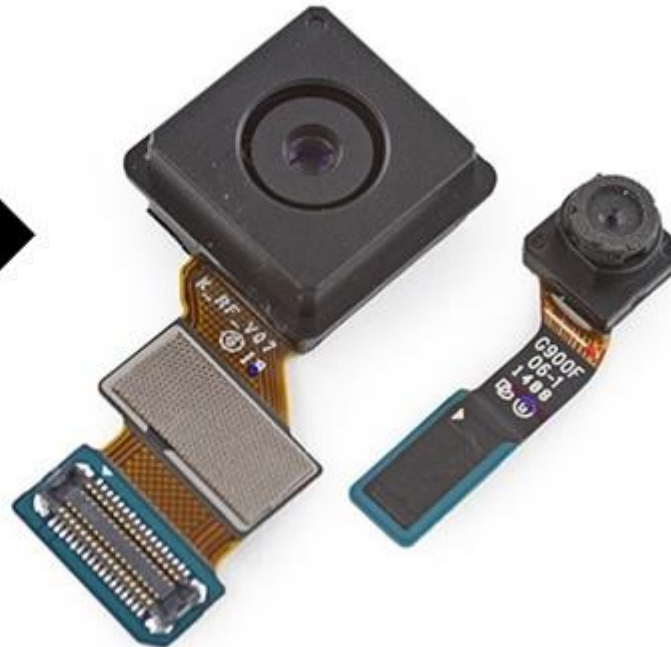


To create object recognition capabilities...

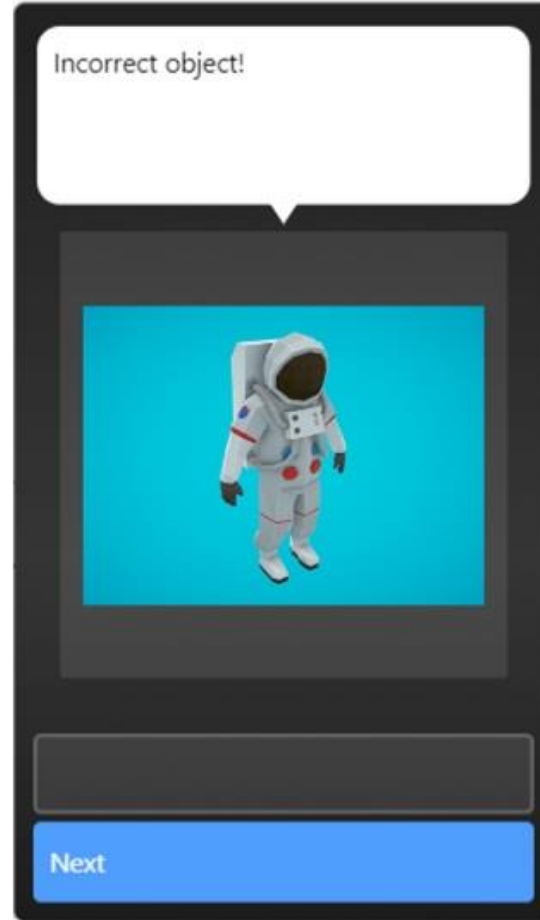
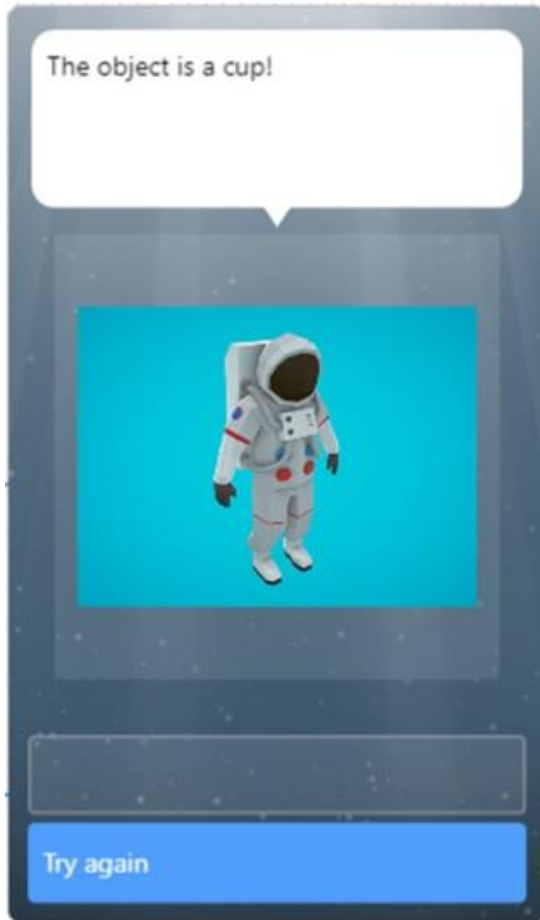
Vision API and
AutoML Vision



Smartphone
Camera Module



Lab Project: Build an Augmented Reality (AR) based smartphone vision device...



**Cup Detector
Visual Outputs**

Question 6:



What software components are used to create object recognition with a smartphone camera module?

Lab Project: Build an Augmented Reality (AR) based smartphone vision device...



Try It Out with the Metaverse Mobile App!!!

