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Keys to Successful Integration of Vision Guided Robotics

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#TheVisionShow

Keys to Successful Integration of Vision Guided Robotics

Introduction and Overview

Vision Guided Robotics Concepts

VGR Markets and Industries

Vision Guided Robotics

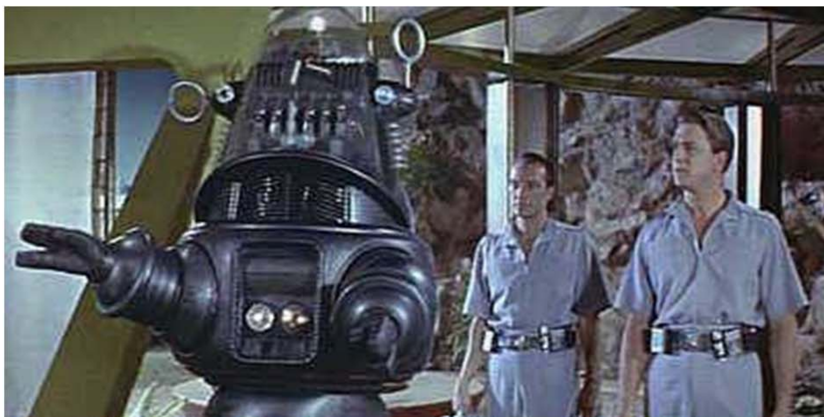
A definition:

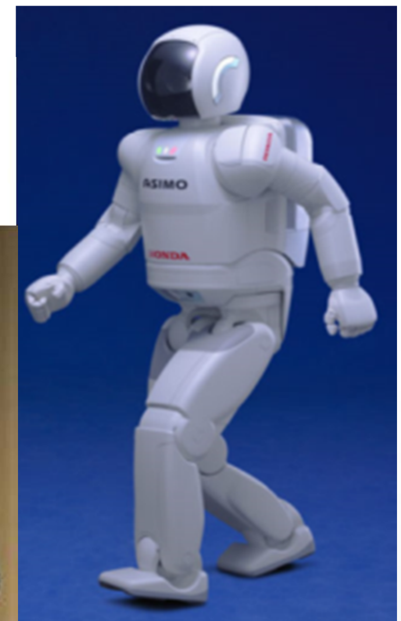
- An autonomous process in which imaging and machine vision technology are used to locate an object or feature in space, and communicate that position to a robot in an appropriate coordinate frame.
- “Holy grail” of flexible automation

Vision Guided Robotics

Vision and visual perception remain key challenges

- Robbie, QURO, ASIMO





Vision Guided Robotics

Not a trivial task as a global concept

- Industrial applications must be segmented and constrained for success
- VGR contains all of the challenges of machine vision, further complicated by inherent position variation



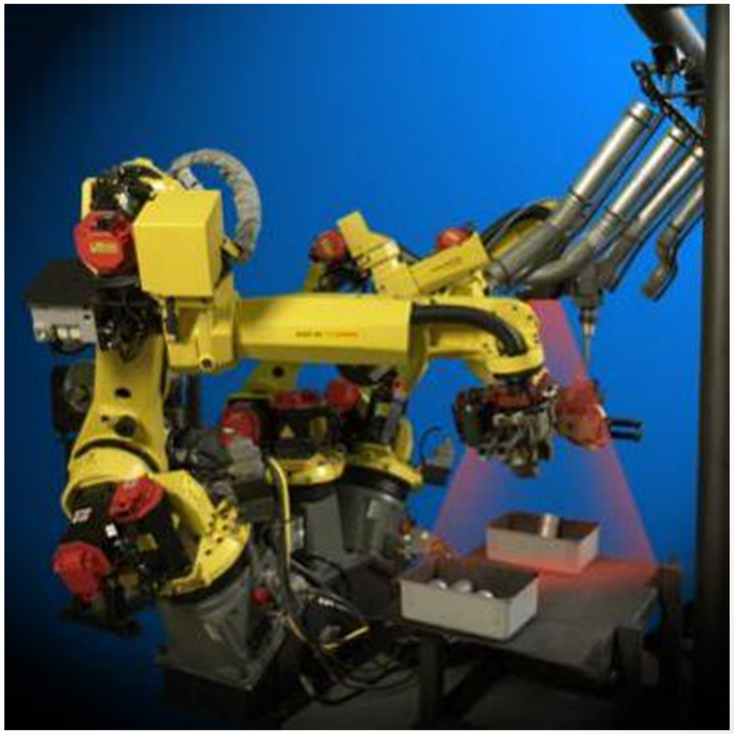

Applications for Vision Guided Robotics

Discrete part pickup/placement

- Unload parts from conveyor (moving or indexed)
- Unload nested parts (trays, boxes...)
- Part placement/assembly (blind pick)
- Racking/de-racking

Applications for Vision Guided Robotics

- The purpose of VGR is to reduce or possibly eliminate the need for hard fixturing of parts when using a robot for a process with that part
- Flexible Automation



Applications for Vision Guided Robotics

Process guidance

- Adhesive, sealant application
- Welding
- Cutting/trimming/de-flashing/de-gating
- Screw/bolt insertion, driving
- Painting, finishing, repair

Applications for Vision Guided Robotics

Bin-picking

- Capture of randomly or semi-randomly oriented parts from bins or boxes

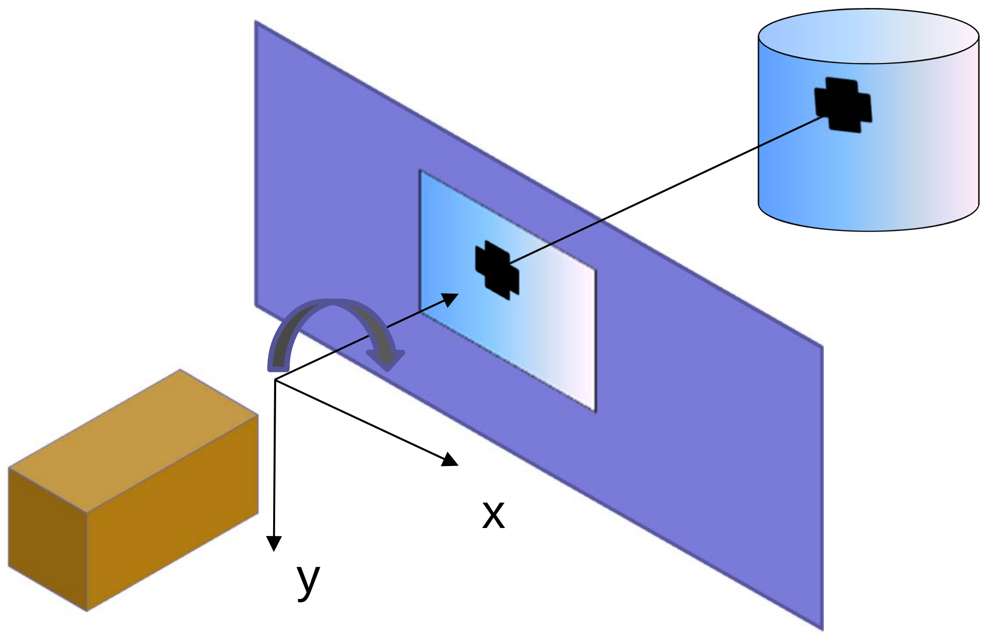
Keys to Successful Integration of Vision Guided Robotics

VGR Components and Implementation

2D and 3D imaging concepts
Components and capabilities
Specifying and implementing VGR

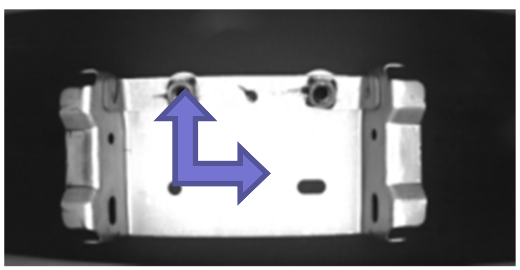
2D Imaging for VGR

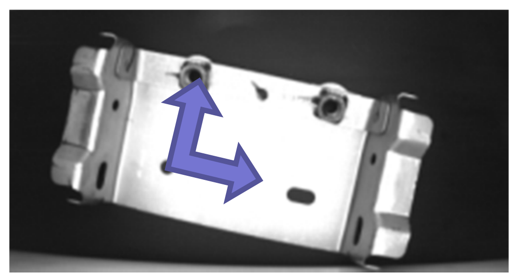
2D imaging delivers a planar (x,y) coordinate with z-axis rotation



2D Imaging for VGR

Part location and orientation (x, y and z rotation)

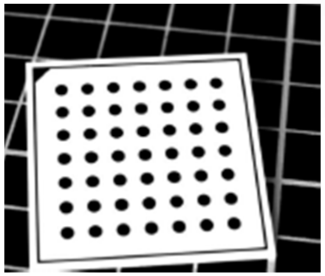


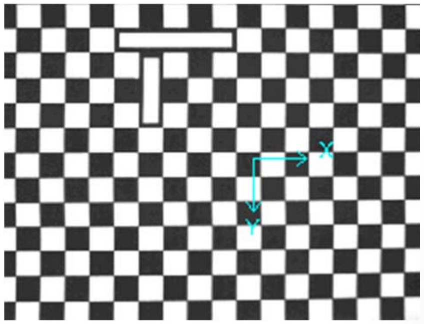


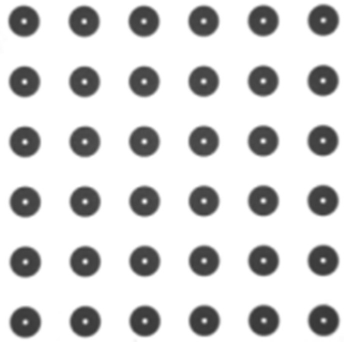
Single Camera Calibration

Calibration

- Maps image positions to real world coordinates
- Also can correct for optical distortion
- Typically involves a physical grid of points with known world coordinates

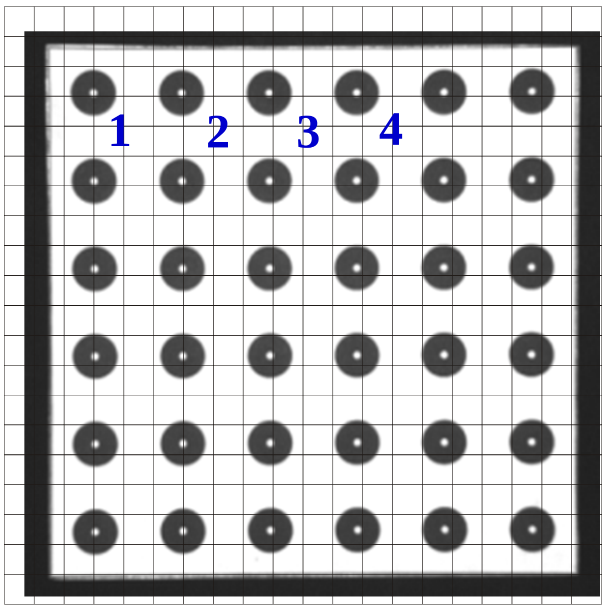






Single Camera Calibration

Camera calibration



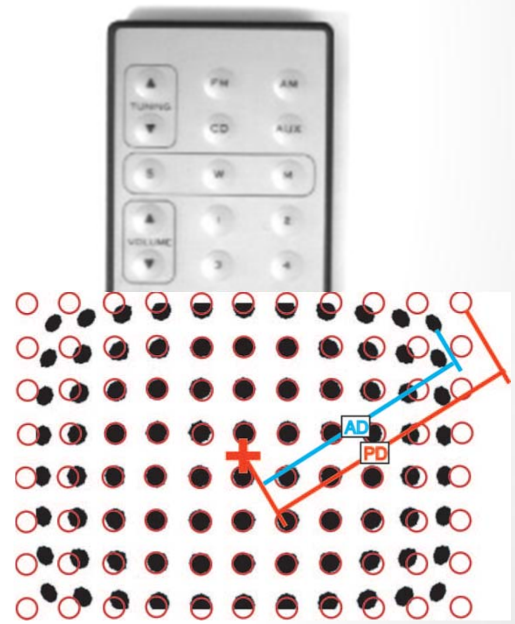
Object	Actual position on grid (mm)	Observed Pixel position (pixels)
1	(0,0)	(22,24)
2	(10,0)	(145,26)
3	(20,0)	(264,29)
4	(30,0)	(387, 31)
…		

Single Camera Calibration

Camera calibration

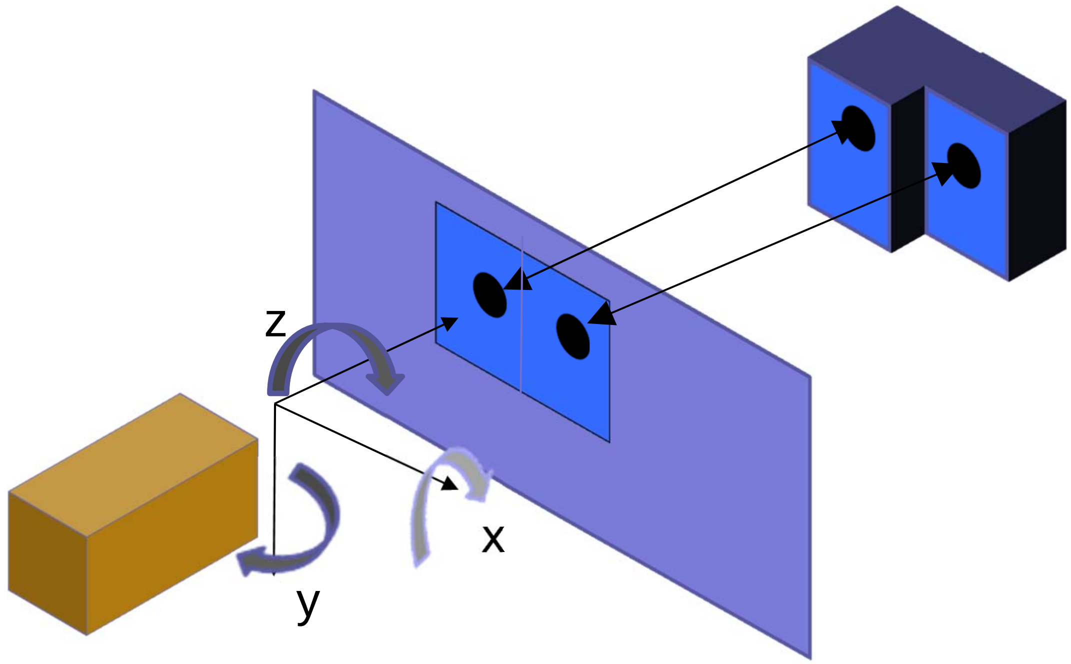
- May be simple linear relationship, straight 2D transformation, or non-linear transformation
  - o Non-linear calibration also corrects for significant perspective distortion and planar distortion. It creates a "warped", corrected image

Acquired Image of Part



3D Imaging for VGR

3D imaging delivers an (x,y,z) coordinate with z-axis rotation and height, and optionally x-axis and y-axis rotation (yaw, pitch, roll)



3D Imaging for VGR

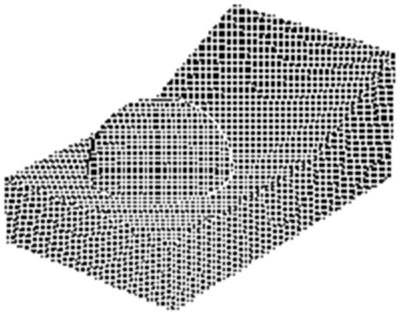
Within the context of machine vision for VGR a one-to-one relationship exists between an object and the robot regardless of imaging technique

- Different imaging techniques exist which are beneficial in extracting point data for different applications

3D Imaging for VGR

3D image representation

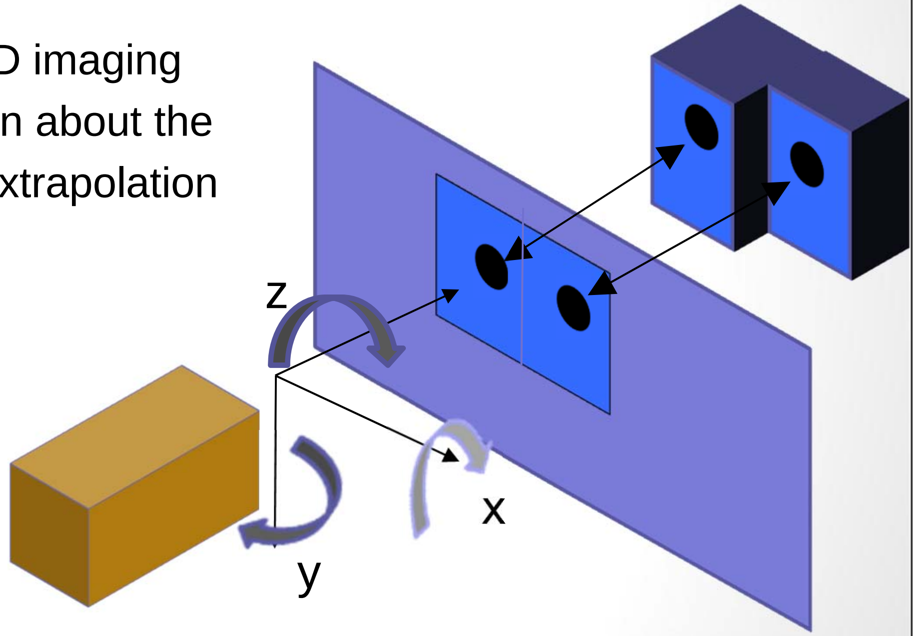
- 3D point
- Image reconstruction
- 3D point cloud



3D Imaging for VGR

Techniques

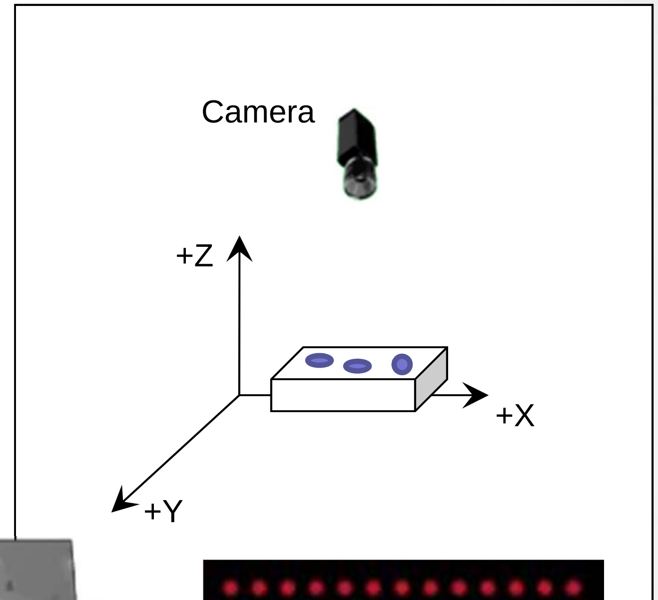
- Single camera
  - o 3D point representation
  - o Same planar data as available for 2D imaging
  - o Z-axis (height) and (possibly) rotation about the x- and y- axes is obtained through extrapolation
    - Feature geometry
    - Structured lighting (static)
    - External distance sensing
    - Range from focus
    - Range from photometrics

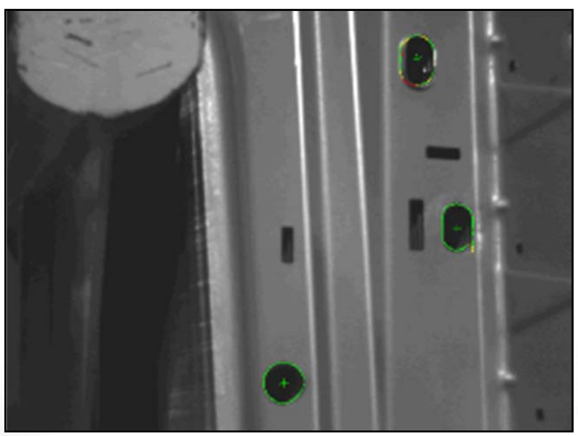


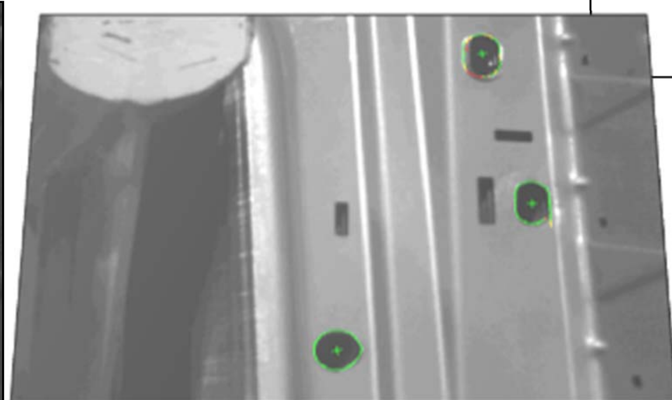
3D Imaging for VGR

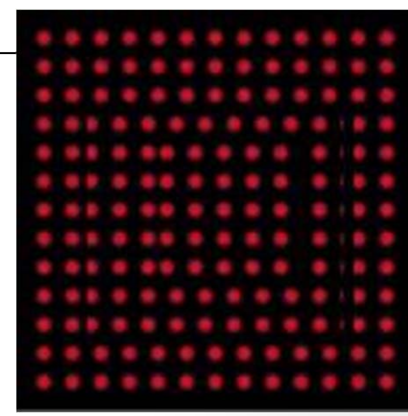
Single Camera

- Extrapolate from feature geometry
  - o Features must be known and consistent
  - o Structured line or point lighting can be used to create geometric features that can be imaged





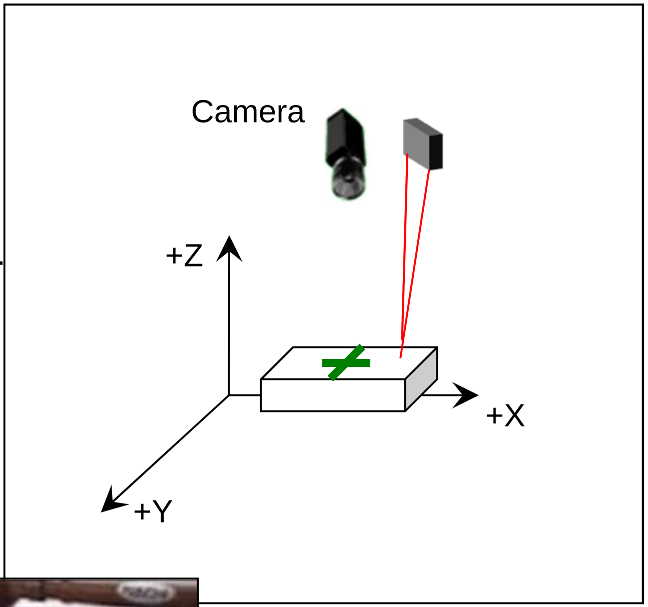




3D Imaging for VGR

Single camera

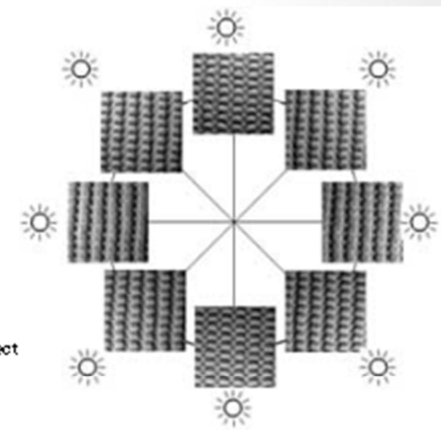
- External distance sensing
  - o One (or more) sensors to provide
  - o z-axis height information at one or
  - o more points
  - o More complex integration with less flexibility

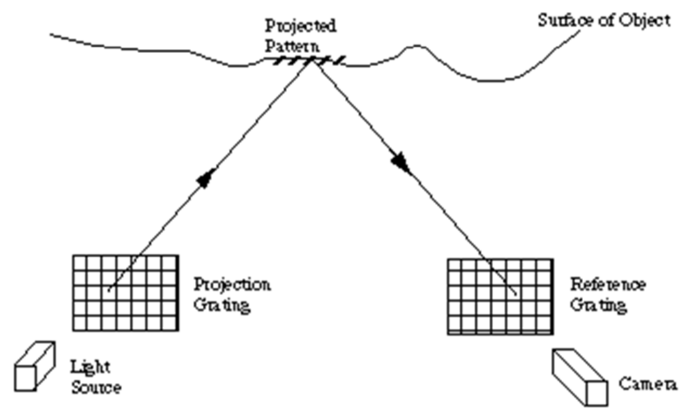


3D Imaging for VGR

Single camera

- Depth from focus
  - o Requires multiple images
- Photometric 3D
  - o Multi-image 3D imaging
  - o Depth is extrapolated from image variation created by lighting at varying angles
- Others
  - o Moire fringe
  - o Laser triangulation
  - o Colored light
  - o Time of flight sensor

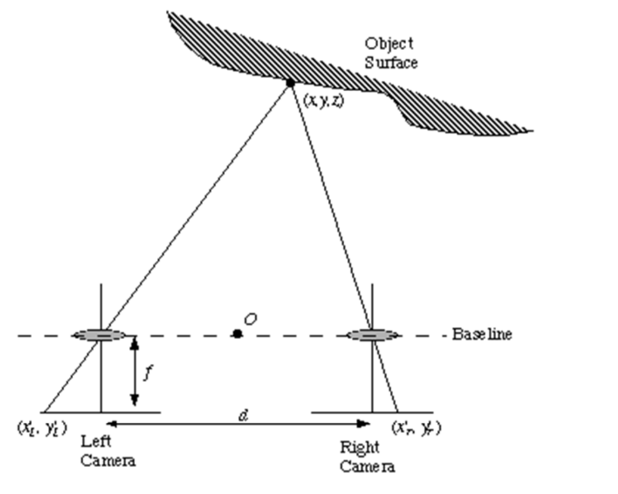


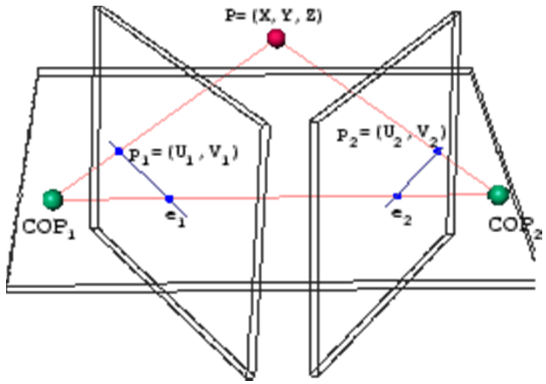


3D Imaging for VGR

Techniques

- Stereo/multiple cameras
- The correspondence problem

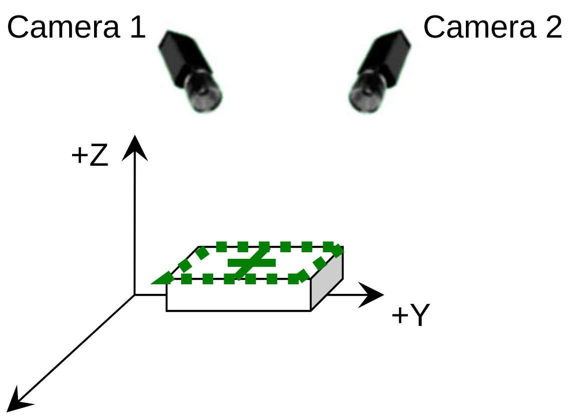


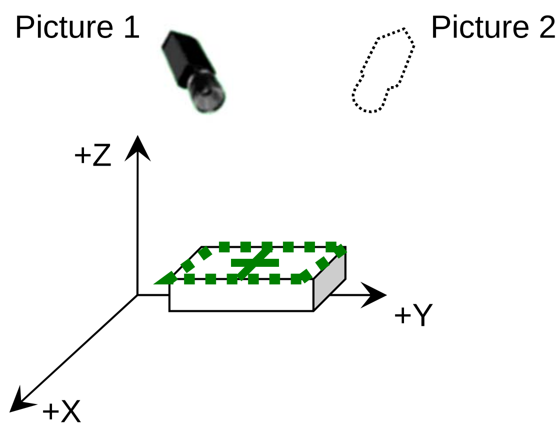


3D Imaging for VGR

Stereo camera architectures

- Single point features

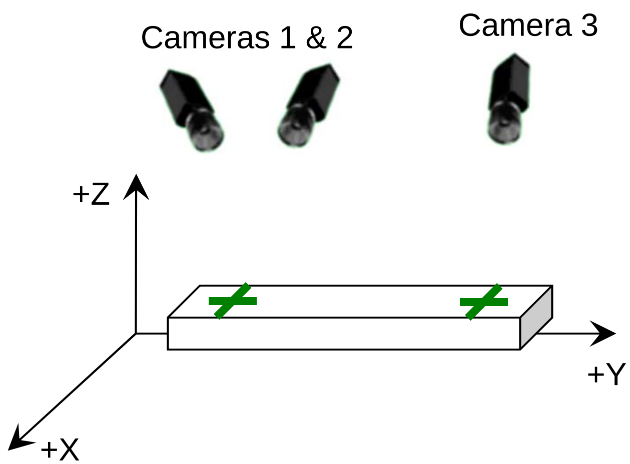


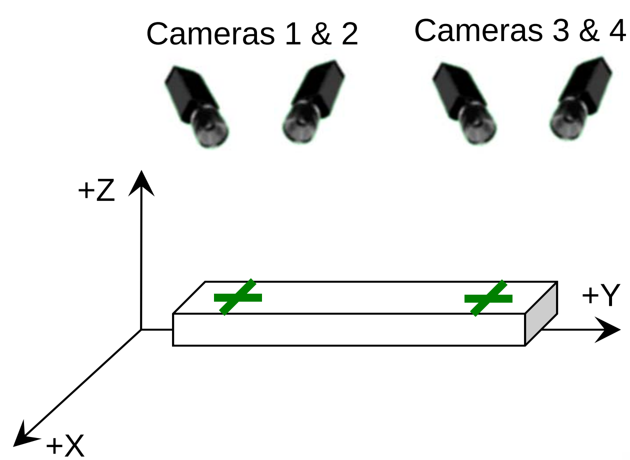


3D Imaging for VGR

Stereo camera architectures

- Single point features

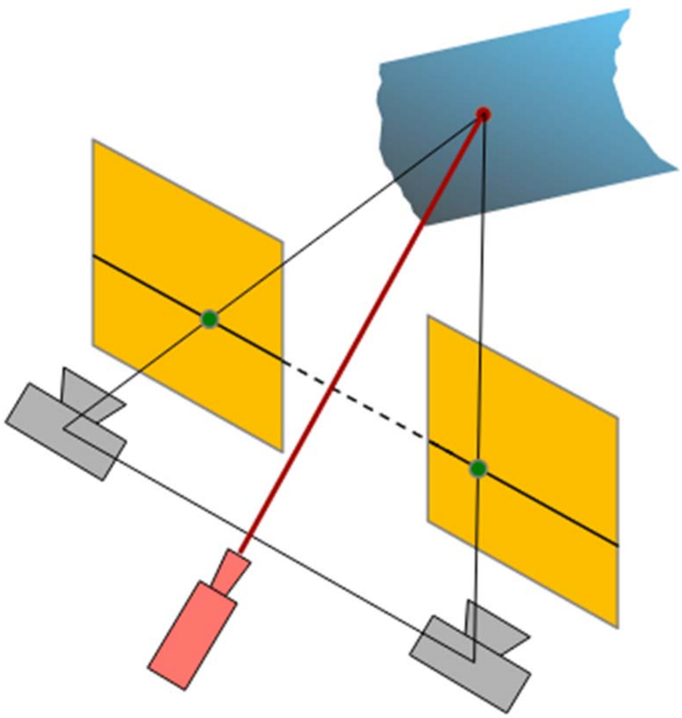


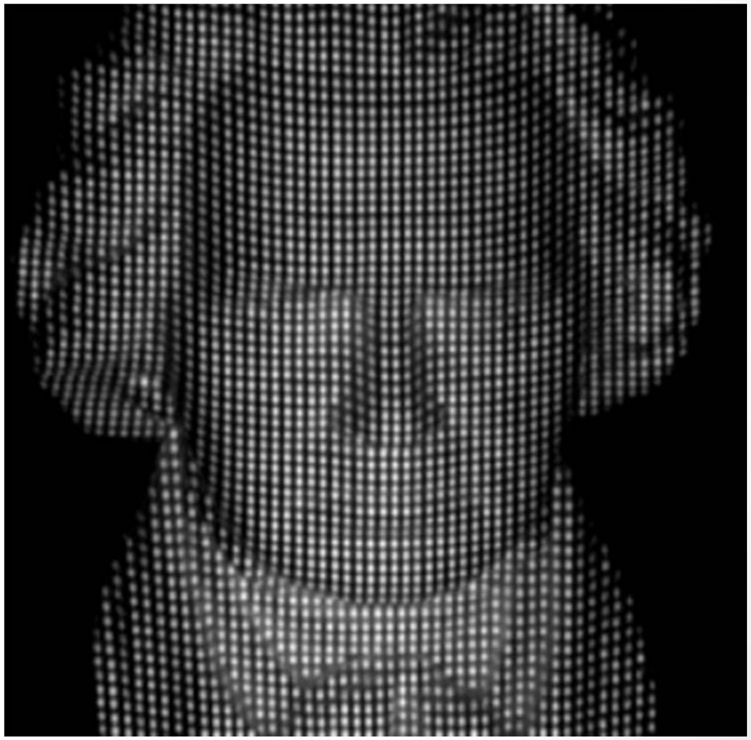


3D Imaging for VGR

Solving the correspondence problem

- Projected light

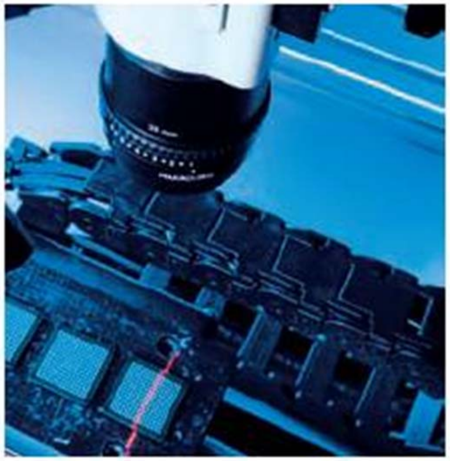


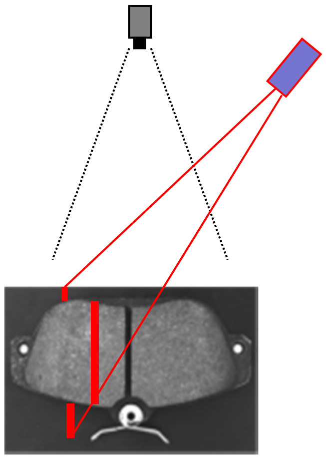


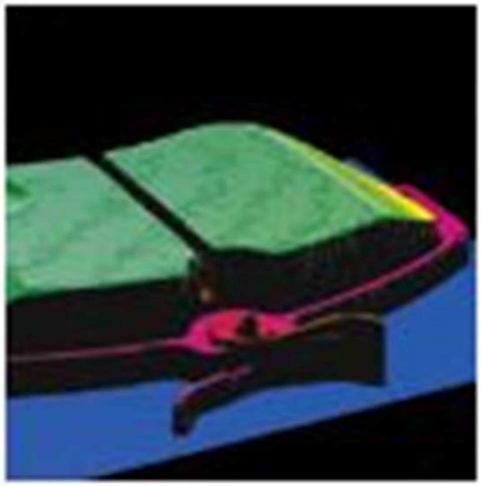
3D Imaging for VGR

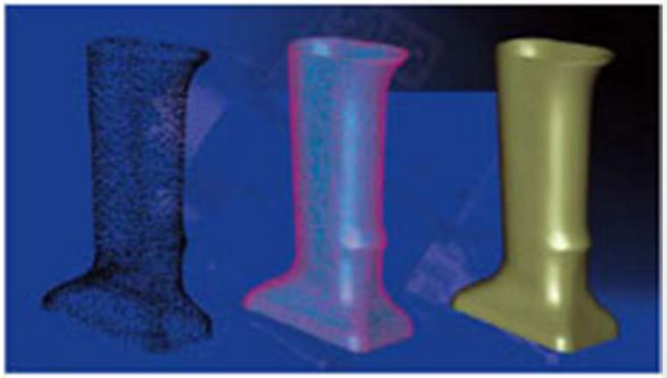
Structured lighting

- Point cloud imaging
- Object scanning to create a full 3D profile representation of a part





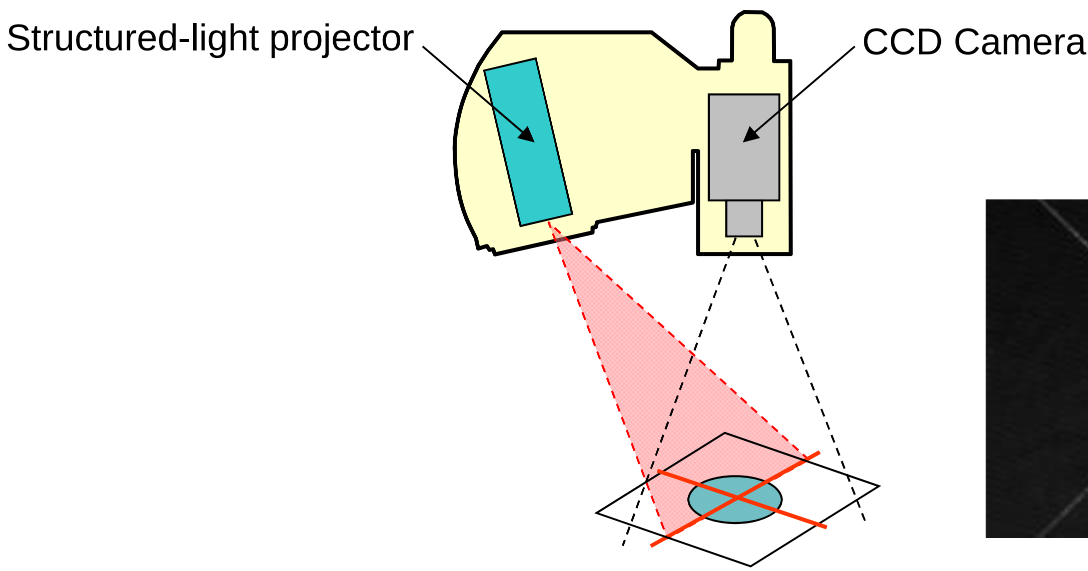




3D Imaging for VGR

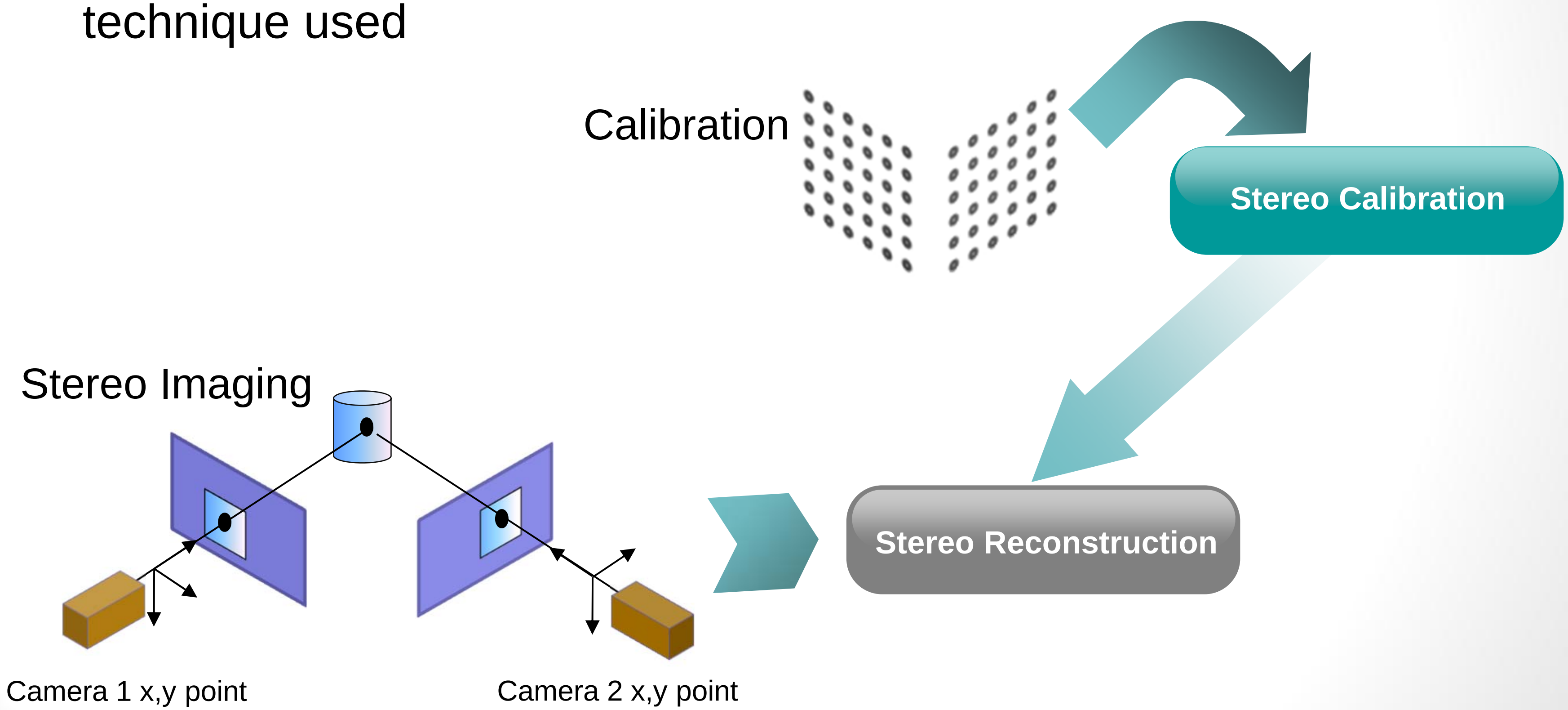
Structured lighting

- Feature pose



3D Calibration

- Calibration is the key component to 3D imaging
- Calibration approaches vary widely depending upon imaging technique used



3D Calibration

- As with single camera calibration, a known calibration grid is used
- 3D calibration usually requires several steps depending upon the specific implementation

Plan, Specify, Implement

- Define the target application and inspection criteria
  - o Describe the desired inspection
    - Avoid discussion of machine vision technique and components
  - o Clearly define good part criteria and bad part criteria
  - o What is the reason for the inspection?
  - o What will happen to a bad part – can it be recovered?
- Define the part(s) to be inspected
  - o Include physical detail about geometric structure, features
  - o Identify all possible part variations; color, size, structure
  - o Describe the materials and surface finish of the part
  - o Will the part change over time?
  - o Get photos, samples

PLAN

Plan, Specify, Implement

PLAN

- Analyze the production process
  - o Background information about how the part is manufactured and moved
  - o Production rates, number of shifts
  - o What factors in the process cause the bad parts?
  - o Benefits of implementing inspection
    - What happens if a bad part gets through?
    - Will costs, yield, quality be improved?
  - o What is the cost of a falsely reject part?
    - Can rejects be recovered/repaired?
- Consider business issues
  - o Scope of supply/deliverables; who is responsible for what?
    - Engineering: design, integration, shipping, installation
    - Hardware components
    - Warranties
    - Documentation and training
  - o Contractual items
    - Performance guarantees
    - Terms
    - IP ownership

Plan, Specify, Implement

- Consider the application requirements
- Define the resolution that will produce the required results
- Define software, processing, and interfacing requirements
- Design systems that are flexible, but focus on critical application requirements

Specify

- Define performance criteria
  - The performance criteria of the system should include:
    - Actual inspection capability (measurement tolerance, feature detection, etc.) with respect to the target application
    - Throughput and speed of inspection
    - Anticipated lighting and imaging methodology
    - General overview of the operation of the inspection system
    - Description of the automation and appropriate performance related a specific process if applicable

Plan, Specify, Implement

- Identify possible system limitations in advance
- Determine acceptance criteria

Specify

Plan, Specify, Implement

Putting it all together

- Implementation and integration – where you have to make it work
- Key pre-requisites in the industrial environment:
    - Application-based lighting and optics
    - Understanding of imaging and input devices
    - Electrical and mechanical engineering
    - Industrial automation systems and components
    - Machine vision algorithms
    - Programming and/or system configuration
    - Project management and customer support

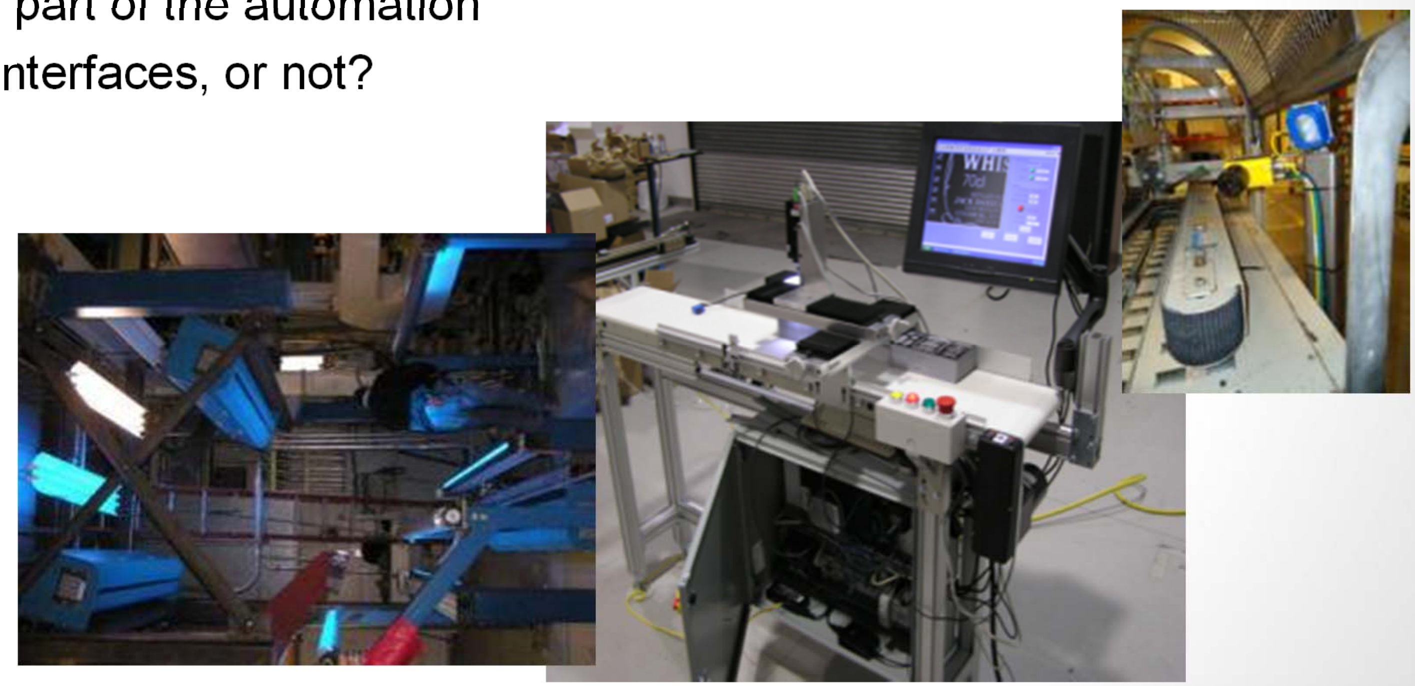
Implement

Plan, Specify, Implement

Implement

Plant floor integration

- Typical system layout
- How to mount and fixture components
- Wiring notes
- Becoming part of the automation
- Operator interfaces, or not?



Integration

Selecting and working with systems integrators

- As an end user, can the integration be done in-house?
- Key questions when deciding to use in-house resources or outsourced integration services:
  - Do we have or are we prepared to fully develop all of the technical skills this project requires?
  - Can we maintain the skills developed in-house and benefit from the experience of integrating a machine vision system?
  - Do we have sufficient time and resources available to see the project through to success?
  - If the project turns out to have unexpected challenges, how will we meet them?
  - Are we able and willing to retain ownership of the system for the long term with respect to maintenance, support, service, and upgrades or re-configuration?

Integration

Selecting and working with systems integrators

- Selecting the right outside integrator
  - o Purposes of outsourcing integration tasks: cost reduction and mitigation or transferal of project risk
  - o Sources: publications, referrals
  - o Types of capabilities:
    - Consultation
    - Software, system configuration
    - Application specific integration
    - Fixturing, robots and vision integration
    - Complete machine integration

Integration

Selecting and working with systems integrators

- Choosing an integrator
  - Develop subjective criteria
  - Evaluate technical capability relative to the project
  - Determine competence based upon response to specification
  - Look for a system guarantee with turnkey installations
  - Cost is not the defining factor

Keys to Successful Integration of Vision Guided Robotics

Current Status and Future of VGR

General trends
Emerging technologies

General Trends

Machine vision remains the fundamental challenge for all guidance applications

- Mathematics and standard techniques for calibration of 2D and 3D scenes for all camera configurations are well known and well implemented
  - o A 2D or 3D grip point will be reliably calculated if camera feature data is correct
- The primary imaging issue for VGR comes from random part presentation
  - o All parts have one or more “stable resting states”; positions at which the part will come to rest when moved
  - o These states may be constrained somewhat by automation and part fixturing
- Part occlusion is a further issue with certain applications

General Trends

Part presentation

- Lighting, imaging, and inspection methods as impacted by part resting states


Future Trends

- Integrated components
- 3D sensors with embedded processing
- Dedicated lighting components
- 3D shape modeling and matching
- Bin-picking advances

Future Trends

Vision is used to:

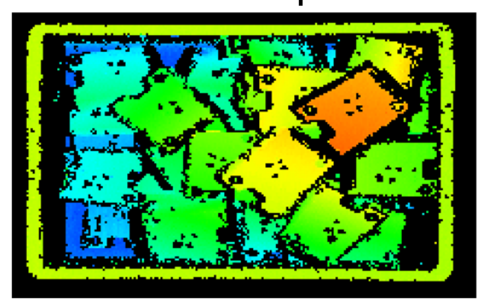
- Find the bin
- Find the part
- Make sure not to collide with the bin walls
- Pick the part with the robot tool at the right angle

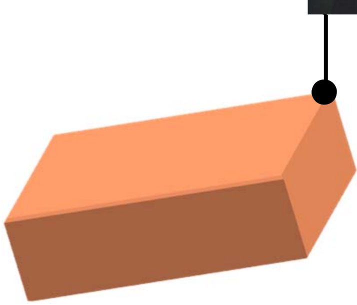
Future Trends

More flexible bin picking solutions

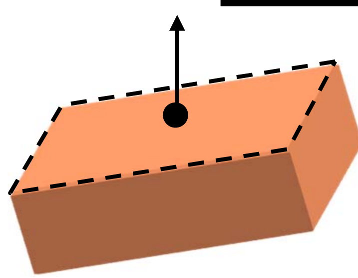
- A point cloud sensor finds parts or surfaces in 3D space
- The 3D part information guides the robot to pick parts from the bin
- 3D software can locate parts with a wide range of sizes and shapes. Locate parts with flat surfaces or parts with compact surfaces
- Verify the bin is empty after all parts have been picked

3D map

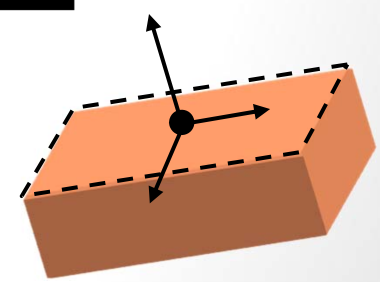




Find locally highest positions



Find positions of gravity centers of surfaces



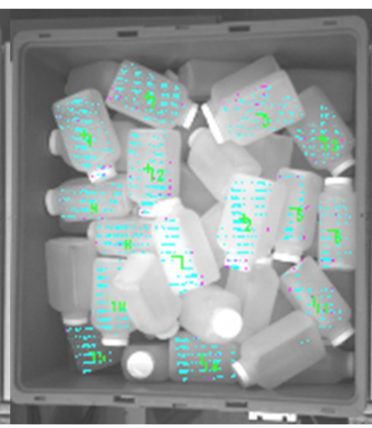
Finds position and orientation of model or object

Future Trends

Bin picking strategies

- Locate 3D position of next pickable part while robot is processing current part
- Measure whole area of bin at once
- Always pick up the highest pickable part
- Verify the bin is empty after the last part is picked
- Use 2D to quickly determine part orientation and grip location while robot passes part in front of secondary camera in motion

Image of parts in a bin



The planes of the flat surfaces found

The location of the highest points (peaks) found

Empty bin
Nothing found

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