

Computer Numerical Control Machine Visual Tracking For Intelligent Controllers

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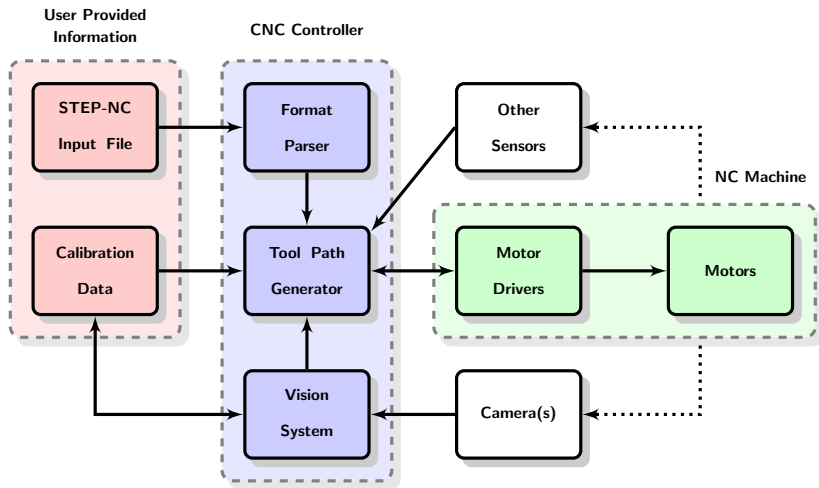
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CNC Machines

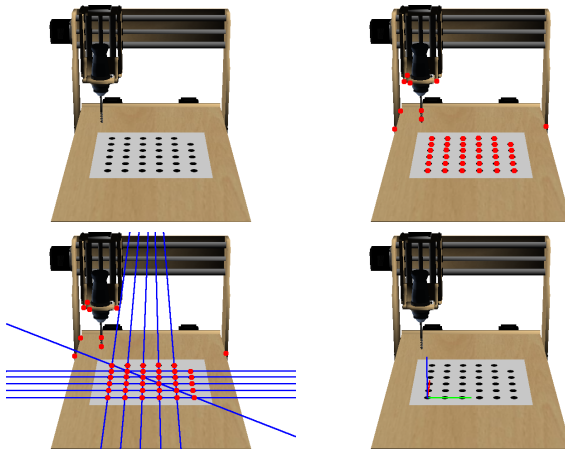


- Computer Numerical Control (CNC) machine
- Typically programmed using G-Code (ISO 6983)
- STEP-NC format to replace G-Code

Intelligent Controller



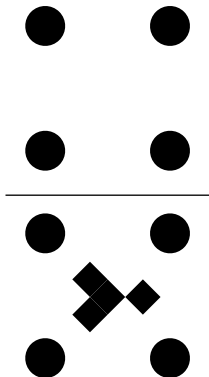
Tsai Camera Calibration Model [4]



Evaluated Methods

- Fiducial Markers
- Template Tracking
- Model Edges

Fiducial Marker Detector [1]



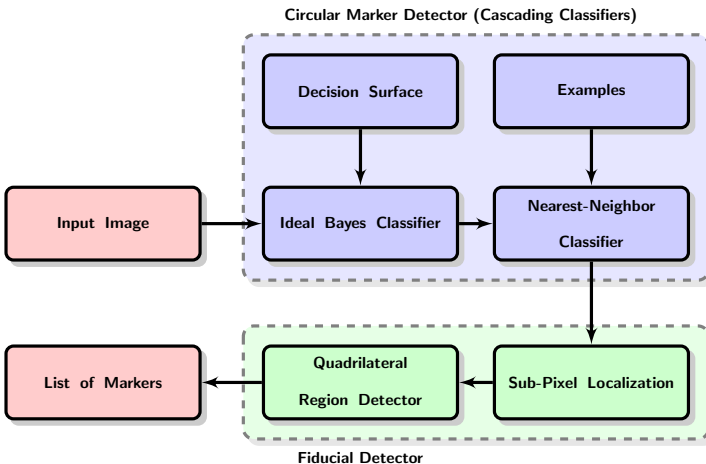
Pros

- Simple marker design
- Learnt detectors
- Can store information

Cons

- Intrusive
- Slow

Fiducial Marker Detector



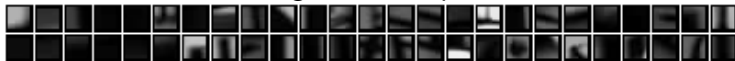
Examples

Classifiers are trained from examples

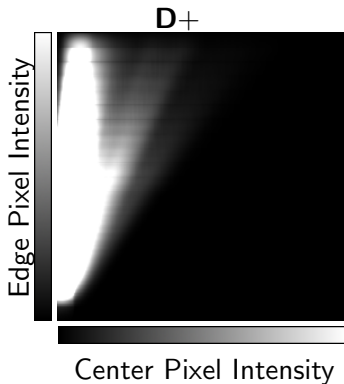
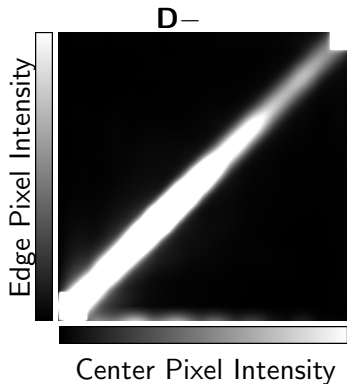
Positive Examples



Negative Examples



Decision Surface



Sample Tracking Sequence



Template Tracking [3]

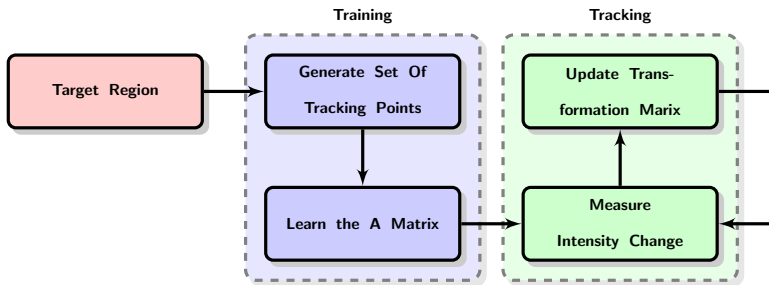
Pros

- Non-intrusive
- Extremely fast
- Fully online

Cons

- Prone to drift
- Require flat tracking surface

Template Tracking



Template Tracking Mathematics

Simplest motion model:

$$\mathbf{F} = \begin{bmatrix} s & 0 & T_x \\ 0 & s & T_y \\ 0 & 0 & 1 \end{bmatrix} \iff \boldsymbol{\mu} = [s, T_x, T_y]$$

Relation between intensity change ($\delta\mathbf{I}$) and motion ($\delta\boldsymbol{\mu}$):

$$\delta\boldsymbol{\mu} = \mathbf{A}_j\delta\mathbf{I}$$

Template Tracking Mathematics

Simplest motion model:

$$\mathbf{F} = \begin{bmatrix} s & 0 & T_x \\ 0 & s & T_y \\ 0 & 0 & 1 \end{bmatrix} \iff \boldsymbol{\mu} = [s, T_x, T_y]$$

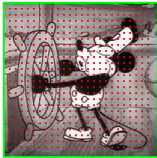
Relation between intensity change ($\delta\mathbf{I}$) and motion ($\delta\boldsymbol{\mu}$):

$$\delta\boldsymbol{\mu} = \mathbf{A}_j \delta\mathbf{I}$$

Warning

These equations are only valid for small motions $\delta\boldsymbol{\mu}$.

Sample Tracking Sequences



Model-Based Tracker [2]

Pros

- Non-intrusive
- Tracking in 3D space

Cons

- Requires model of tracked object
- Not robust to noise
- Prone to drift
- Slow

Model-Based Tracker

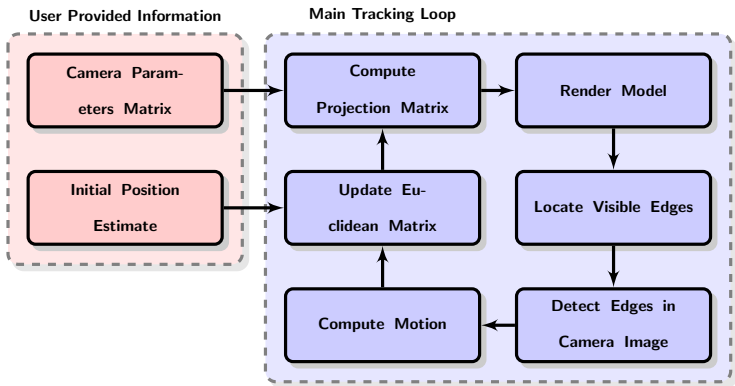
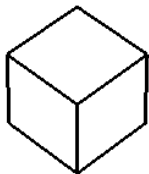
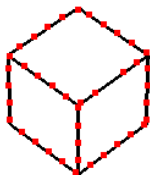


Image Measurements

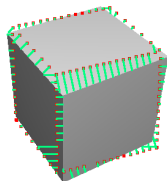
- 1 Render model
- 2 Locate visible edges
- 3 Locate edges in camera image



1

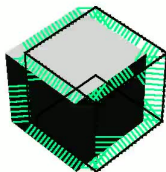


2



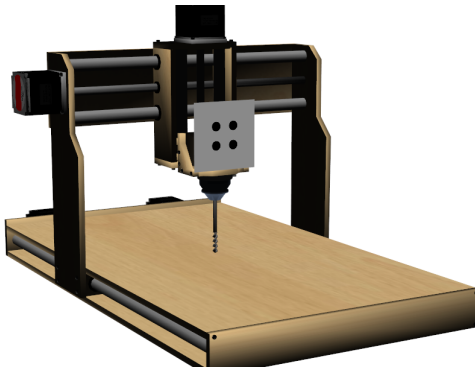
3

Sample Tracking Sequence



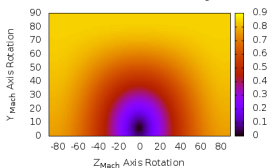
OpenGL Simulator

- Visual Simulator, not physical simulator
- Full control over scene parameters

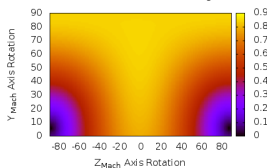


Sensor Planning

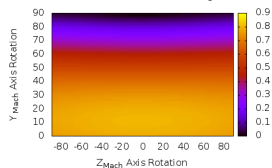
2D Distance Per 3D Unit Movement Along The X Axis



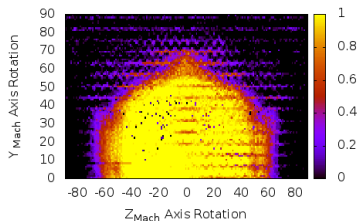
2D Distance Per 3D Unit Movement Along The Y Axis



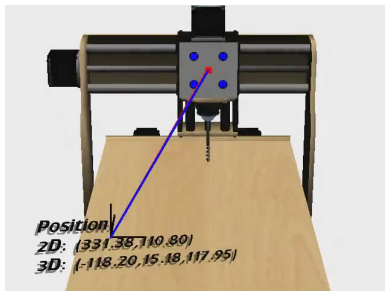
2D Distance Per 3D Unit Movement Along The Z Axis



Marker Visibility Ratio



Sample Tracking Sequence



References



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