ViSP 2.6.0: Visual servoing platform

ViSP tracking methods overview

October 12th, 2010

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Tracking methods with ViSP

1. Dot tracker
2. KLT point tracker
3. Moving edges tracker
4. 3D model-based tracker
1. Dot tracker

A dot:
- A dot is a part of image where the connected pixels have the same level
- Not necessary an ellipsoid (even it is by default)
- Two classes vpDot and vpDot2

The dot in ViSP is defined by:
- The gray level
- The center of gravity (cog)
- The size
- The moments:
  - The surface $m_{00}$
  - Inertia first order moments along $i$ and $j$ $m_{01}$ and $m_{10}$
  - Inertia first second moments along $i$ and $j$ $m_{02}$ and $m_{20}$
  - $m_{11}$
1. Dot tracker with vpDot class

Tracking method : vpDot

• Initialization : Define the dot cog (generally by clicking in the dot)

• Tracking :
  - Binarisation of the image
  - Recursive method to detect all the neighbour components belonging to the object. Start from the previous coordinates of the center of gravity
  - If the dot is found : Compute the parameters (size, moment, …)
  - If no dot is found : The tracking fails
1. Dot tracker with vpDot2 class

Tracking method: vpDot2

- Initialization: Define the dot cog (generally by clicking in the dot)

- Tracking:
  - Binarisation of the image
  - From the previous position of the cog, goes right to detect the boundary, then follow the boundary in order to compute the Freeman chain
  - Use the Freeman Chain to find the dot characteristics (cog, size, moments)
  - If a dot is found, check if it looks like the previous dot (size, moment)
  - If no dot or not similar, check if the dot is in an image part around
1. Dot Tracker

Advantages:

• Robust: Almost no tracking error if noise and specularity not too strong
• Give information about the tracked objects (cog, moments)
• In vpDot2: automatic dot detection for initialization and if a dot is lost search a similar dot in a larger ROI

Limits:

• Speed depends on the size: may be slow if the object is big, especially with vpDot.
• vpDot can not track an object if the displacement is too large
• Due to the recursivity limitation on some OS like windows, vpDot is not able to track huge dots.
2. KLT point tracker

KLT : Kanade – Lucas - Tomasi
- The goal is to align a template $T(x)$ to an input image $I(x)$
- Could be also a small window in the image
- Based on a gradient method

KLT in ViSP :
- `vpKltOpenCv` class that interfaces the KLT implemented in OpenCV
- A patch is defined by :
  - the tracked points in the current image
  - the tracked points in the previous image
- The points lost during the tracking are given if necessary
2. KLT point tracker

Tracking method:

• The goal is to move the patch until minimizing the image dissimilarity

\[
\sum_x [ p - T(x) ]
\]

• Where \( W(x,p) \) corresponds to a warp which can be more or less complex

• Assuming that \( p \) is known and best increment \( \Delta p \) is sought, the problem becomes:
2. KLT point tracker

Tracking method:
- The problem is
2. KLT point tracker

Good features :

• A good point to track :
  - Textured
  - High intensity variations in both x and y axis
• Harris points are used

Advantages :

• Very fast method
• In ViSP, Harris points detection is automatic

Limits :

• Displacement between two images must be small
• In ViSP : use IplImage instead of vpImage : need conversion
• Few parameters are available.
3. Moving edges tracker

Moving edges:
- Based on edge detector with gradient filter
- 3 types: line, ellipse and nurbs

In ViSP:
- `vpMeLine`, `vpMeEllipse`, `vpMeNurbs` classes that inherit from `vpMeTracker`
- `vpMeTracker` contains a list of `vpMeSite`
- Each `vpMeSite` corresponds to one edge point in the image.
- `vpMeSite` is defined by:
  - A position (i,j)
  - An angle which corresponds to the normal to the edge
  - An history of the previous convolution result
3. Moving edges tracker for a line

Method:
- Capture a new image
- For each vpMeSite: build a list of points along the normal to the edge centered on the edge point previous location
3. Moving edges tracker

Method:
• For each point computes the convolution with a filter optimized to detect edges with an angle near the previous angle
3. Moving edges tracker

Method:

• If one point respects the two conditions:
  - The convolution result is close to the previous one
  - The convolution result is high enough
• Then it is considered as the new edge point
3. Moving edges tracker

Method:

- After all vpMeSite are detected, characteristics of the line, ellipse and nurbs are used to detect outliers
- To suppress outliers: a robust method based on M-Estimators is used

vpMeLine class:

- A line is defined by its equation

\[ ai + bj + c = 0 \]

\[ i \cos(\theta) + j \sin(\theta) - \rho = 0 \]
3. Moving edges tracker

vpMeLine class:
- The parameters:
  - a, b and c
  - rho and theta

vpMeEllipse class:
- An ellipse is defined by its ellipse equation

\[ i^2 + K_0 j^2 + K_1 ij + 2K_2 i + 2K_3 j + K_4 = 0 \]

- The K parameters are available in vpMeEllipse class
3. Moving edges tracker

vpMeEllipse class:

- These two equations describe the ellipse points too:

\[
i = i_c + b \cos(e) \cos(\alpha) - a \sin(e) \sin(\alpha)
\]

\[
 j = j_c + b \sin(e) \cos(\alpha) - a \cos(e) \sin(\alpha)
\]

- Parameters \( i_c, j_c, a, b \) and \( e \) are available in vpMeEllipse. \( \alpha \) is in \([0,2\pi]\)
3. Moving edges tracker

vpMeNurbs class:

- The edge is defined by a parametric curve

\[
N_{i,0}(u) = \begin{cases} 
1 & \text{si } u_i \leq u < u_{i+1} \\
0 & \text{sinon} 
\end{cases}
\]

\[
N_{i,p}(u) = \frac{u-u_i}{u_{i+p}-u_i}N_{i,p-1}(u) + \frac{u_{i+p+1}-u}{u_{i+p+1}-u_{i+1}}N_{i+1,p-1}(u)
\]

where \( 0 \leq u \leq 1 \)

Edge points coordinates →

\[
C(u) = \frac{\sum_{i=0}^{a} N_{i,p}(u) \omega_i P_i}{\sum_{i=0}^{n} N_{i,p}(u) \omega_i}
\]

where \( P_i \) are control points and \( \omega_i \) are weights.

- All the points coordinates are given
- All the derivatives at any points are given too
- All the parameters \( N_{i,p}, P_i \) and \( \omega_i \) are available
3. Moving edges tracker

Advantages:
• Gives the equation of the tracked edges
• Fast tracking method
• Useful to initialize visual servoing features implemented in ViSP

Limits:
• The speed depends on the number of points and the size of the search range. If the parameters are not optimal, the algorithm can be “slow”
• vpMeNurbs parameters are difficult to set correctly
• vpMeNurbs is not so robust if the shape of the edge is too complex
4. 3D model-based tracker

Model-based tracking:
- Track a 3D model thanks to the moving edges method
- Use a virtual visual servoing
- In ViSP implemented in vpMbEdgeTracker class

Method: Initialization
- Require a 3D model (CAO, WRL, …)
- Need to compute the initial pose
- The pose is used to project the model on the image
- The moving edges points can be initialized
4. 3D model-based tracker

Method: Tracking

- Assuming that the pose corresponding to the previous image is known.
- The new lines are tracked.
- The goal is to "move" the pose to match the object in the new image with the projection of the model.
- The pose to compute is defined by:

\[
\text{rg}_{cR_o, cR_o} \min \sum_i \left( p_{d_i} - pr\left(\widehat{cM_o}^oP_i\right)\right) \widehat{cM_o} = a_i^2
\]

- The entire model is taken into account during the minimization.