Enhancing Pure Data Interactivity With Computer Vision (Open CV)

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ABSTRACT

Nowadays Computer Vision is acquiring a growing relevance in the field of interactive arts. The purpose of this paper is to introduce some computer vision techniques which are the base of the actual pd_opencv library, a set of objects (delivered as independent objects and not a library), utilities and examples to use those techniques inside the Pure Data programming language. At the same time we introduce some practical examples of the possible use cases on this topic, and a brief introduction to the internals of the pdp and Gem libraries and the openCV API in order to understand the way to refine and extend the actual pd_opencv approach, as like as a desired routemap for further pd_opencv development.

Keywords

computer vision, gesture recognition, motion tracking, motion detection.

1. Introduction

Nowadays Computer Vision is acquiring a growing relevance in the field of interactive arts. From the Myron Krueger's pioneering artwork in the 70's to the present days, lots of artists had been using Computer Vision techniques on their works, extending its field of traditional applications : medical, military, industrial, ... Massively popularized around 2002 with the introduction of the Eye Toy in the game scene, contemporary to the firsts works of Golan Levin, the actual screenario includes lots of interesting pieces in all the interactive and multimedia arts including video dance performances, installations, see for example the popular IR multi-touch screen designs and the acclaimed Reactable musical instrument. In all that time, Computer Vision discipline never stopped to improve.

Pure Data [10] as a programming environment for interactive art has a set of functions and libraries to deal with different interaction paradigms, including HID, networking and communication protocols (osc, midi, dmx, etc), physical computing (i.e. arduino boards) and obviously also computer vision. However, the tools actually included in the graphical libraries for Pure Data (pdp/pidip [7,8] and Gem [9]), are far of the high depth sensing level present in other programming languages. If you take a look at other interactive authoring tools as Open Frameworks, Max/MSP or Proce55ing, you will notice that all of them uses Computer Vision implementations based on the same programming library, namely Open CV [1].

Open CV [1] (Open Source Computer Vision) is a free open-source library of programming functions with more than 500 algorithms mainly aimed at real time computer vision. Open CV is written in performance optimized C/C++ code, it can run on Windows, Linux, and Mac OS X, and is free for commercial and research use under a BSD license. Optionally, when running on an Intel-compatible processor, it makes use of some highly optimized assembly routines : the Intel Integrated Performance Primitives library, IPP [3], designed for an efficient use of the processor features for multi-media processing.

Example applications of the Open CV library are Human-Computer Interaction (HCI), Object Identification, Segmentation and Recognition, Face Recognition, Gesture Recognition, Motion Tracking, Ego Motion, Motion Understanding, Structure From Motion (SFM), Stereo and Multi-Camera Calibration and Depth Computation, Mobile Robotics.

At this point of development, it seems now obvious that a high performance Computer Vision library for Pure Data must be based on Open CV, for its convenient API dedicated to image analysis and for its included mathematical utilities (matrix algebra, ...).

Rather than to rewrite code our proposal will be to provide Open CV bindings for Pure Data, that will give qualitative information that can come out of image and video analysis, in order to include it in a Pure Data processing chain, the data detected by some visual processing will be then able to command vocal synthesis, light control, activation of electronics devices through arduino, ... and, more generally, being a way of controlling all what Pure Data can do.

2. Motivations and Goals

As usual in the PD community, the starting point in the development of new modules reflects an uncovered necessity of the user, who doesn't find a concrete functionality among the existing libraries. If one make a search for existing CV objects in both the most common graphical libraries for pure data (PDP/PiDiP [7,8] and Gem [9]) you will find some useful objects as the pdp_mgrid, pdp_ctrack, pdp_shape and some image morphology objects which are part of pidip, and pix_movement, pix_blob, pix_fiducials in Gem, but these objects are based on very simple image algorithms : the detection of blobs for example common to pix_blob and pdp_shape is a simple analysis of adjacent pixels that forms some shapes or blobs, but this technique is a single-stage analysis technique and can be easily fooled when the contrast in an image is getting blurred and confusion often occurs with such simple techniques.

To access a more sophisticated level of analysis, we must introduce some image representation techniques : Histograms, Fourier Transform, ... and some interpretation techniques inspired by artificial intelligence : Haar's cascade decision tree, image segmentation, contours completion, polygonization, ... which are hopefully all easily available in Open CV (ref : 'Learning OpenCV' [4]).

The goal of the pd_opencv [2] project is to provide a collection of tools, externals and abstractions to perform tasks such as image segmentation, shape and gesture recognition, motion tracking, etc. as well as to provide simple examples to help understanding the basics of computer vision techniques.

pd_opencv [2] wants to be a starting point for a more complex image analysis library, open to research and development inside the pd community.

3. First Considerations Working With Computer Vision

Imagine a "dummy" scenario where a "dummy" artist wants to use the movement of people in front of a camera to, let's say, modify the ambient sound of the room. Motion detection is usually done by frame differencing, this technique attempts to locate moving "objects" in a video sequence by observing the difference on each pixel of the current frame with the corresponding pixel on the previous one. If the pixel color has changed more than a certain threshold value we assume there was some movement in that pixel (coordinates of the image). In the practice, this technique may fail on several situations, for example what happens if we don't have enough light in our room and the camera is producing an image with that typical granular noise? our algorithm will identify that noise as movement.

Imagine now the artist also wants to isolate the silhouettes of the visitors to show them projected on the wall. Background subtraction is another basic technique that identifies the pixels of the persons (or objects) in our captured frame according to their difference from a previously recorded background scene taken in the same place without any person (or object) in front of the camera, this is same math that in the movement detection algorithm but comparing each frames with a reference image (and not with the previous frame). This simple pixel by pixel difference operation will work under certain circumstances, but what happens if a person wears a t-shirt with exactly the same color as the background? and what about if the lighting conditions in the room has changed since we recorded our reference background image? these situations will introduce errors in our algorithm results.

As you can see in both the two previous examples, even as them are probably the more elemental CV techniques, those techniques require a well planned capture environment to produce correct results. And that consideration is a common issue for mostly all the CV techniques. In the words of Golan Levin :

<< ... the reliability of computer vision algorithms is limited according to the quality of the incoming video scene, and the definition of a scene's "quality" is determined by the specific algorithms which are used to analyze it, students approaching computer vision for the first time are encouraged to apply as much effort to optimizing their physical scenario as they do to their software code. In many cases, a cleverly designed physical environment can permit the tracking of phenomena that might otherwise require much more sophisticated software.>>

Interactive artists should be "hands on work" with CV to acquire the necessary experience to deal with that issues. Take again our "dummy" scenario for a last example related on that, imagine now our "dummy" artist wants to isolate the visitors silhouettes again but with an extra handicap that is the background image is a wall with a moving image projected on it. Anything we take as a reference background to be compared with captured frames will led our algorithm to a messy result, as the image of the background is not static. Making use of infrared light we'll find a solution for that problem: if we have the scene well illuminated with IR light, using an IR camera we'll be able to capture the scene without the video projection of the wall, as the light of the video projector projecting IR frequencies.

In that sense, a good setup and a fitted video capturing device can be as important as a good and very sophisticated algorithm. For this reason, we modelize an Open CV algorithm in 3 phases : filtering, pre-processing and analysis :
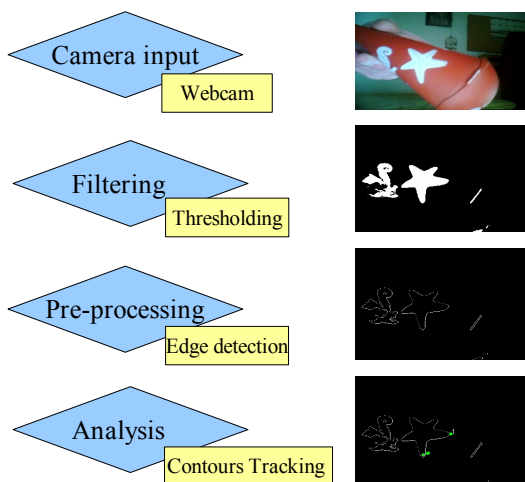
In this example, we want to track the extremities of a sea star form, so we pass through a stage of filtering that extracts only the significant forms of the image, then an edge detection stage that reduces the image to its boundaries and finally we pass the image to a contour tracking object that lets us mark the contours we are interested in, e.g. the extremities of the star.

Here the input device is a simple webcam, but for some setup, especially for live performance environment, you might also sometimes consider using special video devices, like IR cameras or heat-sensitive cameras.

We will now detail the actual state of development of pd_opencv, that implements a few Open CV algorithms, mostly taken from Open CV code samples directory and available as an object for PDP (pdp_opencv_*) or for Gem (pix_opencv_*).

4. Existing modules

4.1 Filtering modules

As explained in the general introduction, these modules are useful to transform the image in a simpler image to be processed by further analysis modules.

4.1.1 pdp/pix_opencv_threshold

Many of Open CV analysis object (blob detection, contours detection) operate better on binary images, this means on an image that is reduced to the pixels above or below a certain level of intensity.

The object threshold is the most used in an Open CV chain and can binarize images in a variety of modes :

It applies a fixed-level threshold to frames. It produces a binary like image but still in RGB (RGBA or whatever it was before).

Input Parameters :

mode :

CV_THRESH_BINARY : maxvalue if src>threshold

CV_THRESH_BINARY_INV : maxvalue if src<threshold

CV_THRESH_TRUNC : threshold if src>threshold

CV_THRESH_TOZERO : 0 if src<threshold

CV_THRESH_TOZERO_INV : 0 if src>threshold

threshold : value of the threshold for testing pixels.

maxvalue : maxvalue used for BINARY mode, default 255.

Output :

4.1.2 pdp/pix_opencv_athreshold

For some kind of images, where some zones are really dark and some zones are really bright, a fixed-level threshold might be too desctructive, and for such cases, we need to use an adaptative threshold filter, where the level of the threshold depends on the average luminosity in the block of surrounding pixels.

Input Parameters :

method :

CV_ADAPTIVE_THRESH_MEAN_C : use as a threshold the average value of pixels in the size x size surrounding pixels block.

CV_ADAPTIVE_THRESH_GAUSSIAN_C : applies a gaussian weight to the pixels around the current pixel. Pixels in the center have a heavier weight than the ones on the outskirts of the block.

mode :

CV_THRESH_BINARY : maxvalue if src>threshold

CV_THRESH_BINARY_INV : maxvalue if src<threshold

blocksize : size of the surrounding blosk to calculate the threshold.

dim : attenuation of the threshold, the real threshold used is the calculated threshold minus dim.

maxvalue : maxvalue used for BINARY mode, default 255.

Output :

4.1.3 pdp/pix_opencv_bgsubstract

This filter is used in motion detection when you want to distinguish moving objects from a static background.

It takes an image as a background reference when receiving a 'SET' message and then compare each incoming frame with that, using a threshold value to compare the pixels.

It is useful if you want to detect objects that are in front of an static background and you want to isolate the foreground silhouettes of moving objects.
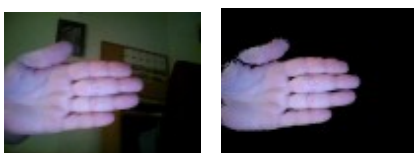
Input Parameters :

SET message :

This is used to capture the background.

threshold : value of the threshold for testing if pixels have changed.

Output :

This object works comparing color values of each pixel, so it can fail if the foreground object has the same color that the background, and also if the light conditions or the shadows changes since you 'SET' the background image.

4.1.4 pdp/pix_opencv_bgstats

This object is very similar to bgsubstract but it uses a time parameter and a statistical model that makes objects considered as the foreground disappear after a while and then be considered as background. So it behaves as an adaptive background extractor.

It also performs a suplemental stage os noise filtering through internal morphology (erosion / dilation) and eliminates small blobs that can be considered as noise.

The output of the foreground is in binary mode.
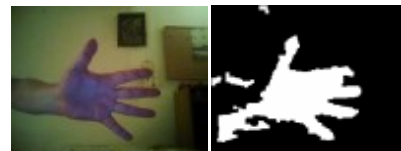
Input Parameters :

RESET message :

Reset the backgroumd to current frame.

alpha : period of time after which a foreground object is considered as background (default : 0.1 seconds).

erode : number of iterations of the erode/dilate filter to eliminate noise.

minarea : minimum sie of the objects shown in the foreground.

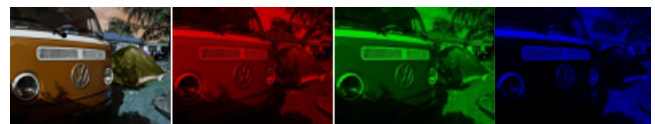Output :

4.1.5 pdp_opencv_channels

This object is a simple RGB channels separator that can be useful when it's necessary to detect some specific hues in a video input.

It only exists in the version for PDP, in GEM you can use pix_bitmask instead.

Input Parameters :

None.

Output :

4.2 Pre-processing modules

This category of objects operates a modification of the input sequence in order to retrieve analysis data in a subsequent stage. They apply some one-stage transformation on the input frames like for example to find adjacent pixels of the same color or something not too complex.

4.2.1 pdp/pix_opencv_morphology

This technique is aimed at distinguishing more precisely the forms in an image using the algorithms of opening/closing and erosion/dilation that increase or reduce the size of zones of bright or dark pixels. It works better on binary image and is helpful to join some zones in a picture that define a wider zone to be processed or tracked.

Input Parameters :

mode : switch between open/close and dilate/erode algorithms.

shape : form of the kernel that is used in the algorithm.

It can be one of : rectangle (0), elliptic (1) or cross-shaped (2).

second inlet : the second inlet indicates the number of iterations that has the effect of accentuating the transformation.

Output :

You see in this example how the zone of texts is 'melted' with the dilation to a single identified zone that can be better processed later.

4.2.2 pdp/pix_opencv_distrans

Another filter that is really close to morphology is the 'distance' algorithm filter that skeletizes the different forms in an image and let's you track a simplified form. It works better on binary images and is particularly appropriate to simplified silhouettes.
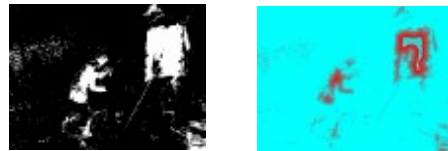
Input Parameters :

voronoi (0/1) : activates/desactivates the voronoi triangles partitioning.

type (0/3/5) : optionally uses a mask in the transformation. 0 is none.

second inlet : threshold to detect edges.

Output :

You see here the silhouettes can be isolated using a distrans filter.
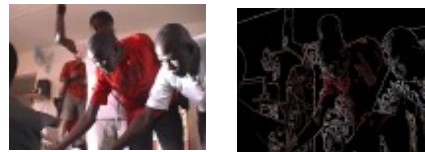
4.2.3 pdp/pix_opencv_edge

This filter is a classical edge detector that detects changes of pixels in the image (using first degree gradient), it can be useful to pre-process an image before passing it to a contour processing analysis object.

Input Parameters :

**second inlet** : threshold to detect edges.

Output :

4.2.4 pdp/pix_opencv_laplace

This filter is also an edge detector but it uses a calculation of the second derivative known as Laplace in both directions and detects more accurately the important edges in a picture.

Input Parameters :

second inlet : aperture size (number of points considered to calculate the derivative).

Output :
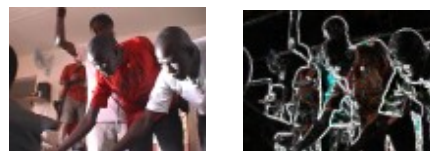
4.2.5 pdp/pix_opencv_dft

This filter is very useful in image analysis as it transform an image from its spacial representation to a frequency domain representation, modelizing an image as an infinite combination of sinusoidal waves. This is know as the Discrete Fourier Transform, very well known of people working in sound processing and it can be useful also in image analysis. It first binarize the incoming images and then calculates the Fourier magnitude and phase diagrams. As it is quite greedy of ressources, it only process a frame when it receives a 'bang' message.

Input Parameters :

bang message : triggers the calculation of a DFT.

Output :
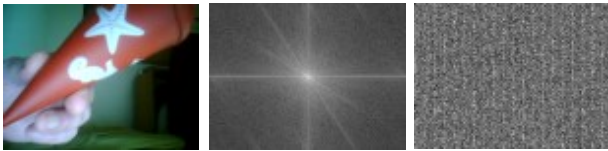
You see here the diagram of the magnitude and the phase of the DFT. The only useful diagram is the magnitude one, that can be compared with the DFT of another frame using binary operators like XOR to detect some patterns in an incoming frame, as shown in the help patch.

4.3 Analysis modules

4.3.1 pdp/pix_opencv_floodfill

This module marks some pixel zones that identifies some blobs, e.g zones of adjacent pixels of almost the same intensity and color, taking into account a tolerance in the variation of pixels. It also repaints these zones in a specific color.

Input Parameters :

second inlet : lower tolerance for pixels.

third inlet : upper tolerance for pixels.

connectivity : use 4-points or 8-points connectivity mode.

color : activates/desactivates color mode.

mark x y : mark a blob containing this pixel.

delete n : delete a marker.

clear : delete all markers.

fillcolor n r g b : set the fill color for blob n.

Output :

second outlet : position of each marked blobs in the form 'number x y width height'.

This object also outputs the coordinates of each detected blobs in the form : 'number x y width height' through its second outlet, so it could be considered as an analysis object, but the blob detection remains a very unstable technique and the tracking is very imprecise with this object.

4.3.2 pdp/pix_opencv_contours_boundingrect

This object calculates the up-right bounding rectangle of all contours of an image. This object works better on binary images distinguishing white pixels zones on a black background.

Input Parameters :

mode : contour detection mode (see cvFindContours [1]).

method : contour detection method (see cvFindContours [1]).

second inlet : minimal size of a contour.

third inlet : maximal size of a contour.

maxmove : maximum movement of a contour between 2 frames

(used for identification/numbering of contours).

ftolerance : number of frames where a contour can disappear without being considered as lost (used for identification/numbering of contours).

nightmode 0/1 : only shows the detected contours.

draw 0/1 : draw the contours.

show 0/1 : show the bounding rectangle or not.

Output :

second outlet : position of each contour in the form 'number x y width height'

third outlet : number of detected contours.

This object outputs on its second outlet the position of each contour in the form : "number x y width height" and the total number of contours on its third outlet.

It works detecting any white areas in the input image, it's important to set max/min values of the areas you want to detect to filter non interesting noise or areas, also sometimes you will need to use morphology to transform the contours of the shapes you want to be analyzed.

4.3.3 pdp/pix_opencv_contours_convexity

This object looks for the convexity curves of the biggest contour of an image. Each convexity curve is defined by three points : the starting point, the ending point and the depth point. This object works better on binary images.
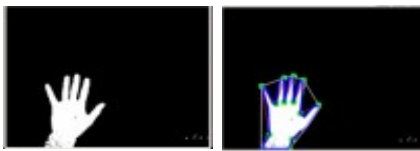
Input Parameters :

none.

Output :

second outlet : the number of convexity curves of the biggest contour.

Third outlet : the three points defining a convexity curve in the form : 'number xstart ystart xdepth ydepth xend yend'

This object outputs on its second outlet the number of convexity curves of the biggest contour and, for each convexity curve, it outputs on its third outlet the position of defining points : 'number xstart ystart xdepth ydepth xend yend'. This information is kind of dense and can realistically only be used for simple geometrical forms.

This object works detecting the biggest area in the input image, sometimes you will need to use morphology to transform the contours of the shape to be analyzed.

4.3.4 pdp/pix_opencv_lk

This object detects remarkable points in a contour, using Shi and Tomasi point detection algorithm, enabling to mark peculiar points like angles and asperities. You can then choose the points you want to track by clicking on them or select all of them for tracking, using Lukas-Kanade (hence lk) tracking technique.

Input Parameters :

init : re-calculates contours and most significative points.

mindistance : minimal distance between points.

quality : quality factor used in approximation. This behaves like a threshold on the gradient of remarkable points.

mark x y : mark a point to be tracked.

mark all : mark all points.

mark none : unmark all points.

delete n : delete a marker.

clear : delete all markers.

maxmove n : maximum displacement of a point between ywo frames (used for identification / numbering).

ftolerance n : number of frames where a point can disappear (used for identification / numbering).

delaunay on : draw a delaunay triangulation between all points.

delaunay off : disactivate the delaunay.

pdelaunay <n> <threshold> : draw a delaunay containing the point n and all points which difference with point n is below threshold.

nightmode (0/1) : show/hide original video frame.

second inlet : window size for calculating the gradient.

Output :

second outlet : for each marked point, point position in the form : 'number x y'.

This object outputs on its second outlet the coordinates of the points that you have marked clicking on them, just to be able to output the points that are of interest. It outputs coordinates in the form "number x y".

4.3.5 pdp/pix_opencv_surf

This object is very similar to Lukas-Kanade point tracking technique, but it uses the SURF (Speed Up Robust Features) to detect remarkable points. It generally detects more points than the lk detection algorithms.

This object seems to be available only with Open CV 1.1.0, it will not work with Open CV 1.0.0.

Input Parameters :

hessian : hessian threshold for the detection of points. This influences the number of detected points.

mark x y : mark a point to be tracked.

mark all : mark all points.

mark none : unmark all points.

delete n : delete a marker.

clear : delete all markers.

maxmove n : maximum displacement of a point between ywo frames (used for identification / numbering).

ftolerance n : number of frames where a point can disappear (used for identification / numbering).

delaunay on : draw a delaunay triangulation between all points.
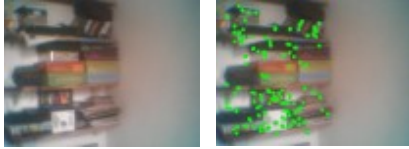
delaunay off : disactivate the delaunay.

pdelaunay <n> <threshold> : draw a delaunay containing the point n and all points which difference with point n is below threshold.

nightmode (0/1) : show/hide original video frame.

Output :

second outlet : for each marked point, point position in the form : 'number x y'.

4.3.6 pdp/pix_opencv_motempl

This object tracks movement of detected objects using the history of motion on a variable number of frames. It operates internally with binary images, thresholding the incoming frames and build an history of image changes with timestamps.

Input Parameters :

second inlet : value of threshold to distinguish blobs.

third inlet : minimal size of a detected blob.

fourth inlet : maximal size of a detected blob.

frame_buffer_size : number of frames in the motion history (default 4).

**max_time_delta** : maximum time of a pixel change in the motion history for detecting a movement.

min_time_delta : minimum time of a pixel change in the motion history for detecting a movement.

Aperture (1 | 3 | 5 | 7) : aperture size for the calculated derivative.

mhi_duration : duration of displaying the detected motions.

Output :

second outlet : for each blob detected, the position, the size of the blob and the direction of its movement in the form "number x y width height angle".
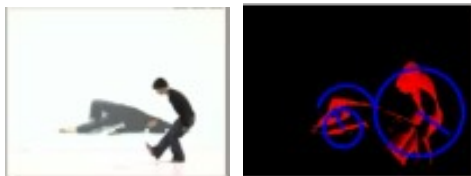
This object outputs on its second outlet for each motion component detected, the position, the size of the component and the direction of its movement in the form "number x y width height angle".

4.3.7 pdp/pix_opencv_hist_compare

This object memorize and draw the statistical composition of an image in the form of an histogram of the hue and saturation of the pixels. Therefore, it works only on color frames.

You can record up to 80 histograms that defines the composition of the image and by comparing them to the actual frame entering, you can recognize specific configuration of the input image if it has been memorized before. This can work quite well to recognize special gestures like from a human hand and can be used in a kind of gesture command to a pd patch.
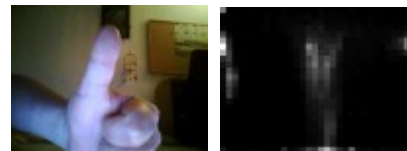
Input Parameters :

second inlet : send there a number to memorize a specific histogram.

Output :

second outlet : the closest stored histogram to the actual entering frame.

third outlet : all measured distances with presently stored histograms in the form 'd1 d2 d3...dn'.

This object outputs on its second outlet the number of the closest recorded histogram to the actual incoming frame and on its third outlets the measured distances of the actual frame with the stored histograms.

4.3.8 pdp/pix_opencv_haarscascade

This object loads a Haar's cascade decision tree in the form of an XML file, that is based on Haar's technique of dividing an image in squares and calculate some pixels sums on these squares, and the differences between them. Using this technique, we can detect some peculiar form in an image, but this needs to be trained to have the right coefficients stored in the XML with a great number of sample images (> 10.000). Open CV provides a tool to create such a decision tree, but the task is fastidious and not easy. There are various haar's cascade available on the web like this collection : http://alereimondo.no-ip.org/OpenCV/34.

Input Parameters :

load <xml file> : load an XML Haar's cascade decision tree.

mode (0/1) : use edge detection or not.

min_size : minimal size of a detected object.

min_neighbours : minimum number (minus 1) of neighbour rectangles that makes up an object (default 2).

scale_factor : scale applied for block size.

ftolerance : number of frames where an object can temporarily disappear (used for identification / numbering).

clear : clear all objects markers.

Output :

second outlet : number of detected objects.

third outlet : coordinates of each object identified by a circle under the form 'number x y radius'.

You have to load an .xml decision tree for object recognition. This object outputs on its second outlet the number of detected objects and on its third outlet, for each detected object, the coordinates and the size of the detected objects in the form 'number x y radius'.

4.3.9 pdp/pix_opencv_camshift

This object implements the Continuously Adaptive Mean-shift tracking algorithm (CAM). You can select an object with the mouse and it starts tracking the object from a rectangular zone around this point, but adapting the zone at each iteration. It gives also the orientation of the object. It's working in the HSV colorspace, distinguishing the hue from other fields S, V.

Input Parameters :

vmin : V pre-filtering minimal value.

vmax : V pre-filtering maximal value.

smin : S pre-filtering minimal value.

backproject (0/1) : show the backproject (binary image of selected pixels).

rwidth : initial width of the tracking zone.

rheight : initial height of the tracking zone.

track x y : track an object containing this point.

Output :

second outlet : coordinates, size and orientation of the track object (only one) in the form : 'x y width height angle'.

4.3.10 pdp/pix_opencv_hough_lines

This object detects segments of lines in the incoming frames using the Hough detection algorithm.

Input Parameters :

mode : detection mode used for the algorithm, one of :

CV_HOUGH_STANDARD : full lines.

CV_HOUGH_PROBABILISTIC : line segments.

CV_HOUGH_MULTI_SCALE : line segments.

maxlines : maximum number of detected lines.

threshold : difference threshold for detection of edges.

minlength : minimal length of a detected segment.

gap : gap between lines

(for mode CV_HOUGH_PROBABILISTIC)

aresolution : angle resolution

(for mode CV_HOUGH_MULTI_SCALE)

dresolution : distance resolution

(for mode CV_HOUGH_MULTI_SCALE)

nightmode (0/1) : show/hide the incoming video frame.

Output :

second outlet : for each detected line, coordinates of starting and ending points in the form : 'number xstart ystart xend yend'.

4.3.11 pdp/pix_opencv_hough_circles

This object detects segments of circles in the incoming frames using the Hough detection algorithm. Most of the time, the circles do not really exist but are 'almost there'.

Input Parameters :

maxcircles : maximum number of detected circles.

threshold : threshold used in the edges detection (cvCanny).

threshold2 : threshold used for the detection of the centers.
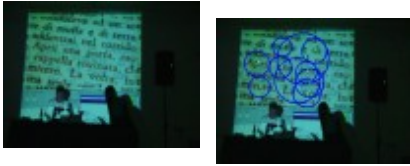
mindist : minimum distance between circles centers.

resolution : resolution of the accumulator.

nightmode (0/1) : show/hide the incoming video frame.

Output :

second outlet : for each detected circles, coordinates of the center and radius in the form : 'number xcenter ycenter radius'.

4.3.12 pdp/pix_opencv_hu_compare

This object takes two inputs, generally an incoming video stream and a pattern image, also in form of a video stream and tries to detect the pattern in the incoming video frames. It operates as follows : it extracts from the pattern image the biggest contour and compare the contours of the incoming video using cvMatchShapes, which compares contours calculating their Hu moments, characteristics of the topology of the contours.

Input Parameters :

minsize : minimal size of threated contours, to remove small shapes and noise.

method : method used in cvMatchShapes which can be one of :

CV_CONTOURS_MATCH_I1, CV_CONTOURS_MATCH_I2 or CV_CONTOURS_MATCH_I3 : the difference between the Hu moments are computed with different formulas (see cvMatchShapes documentation).

clear : recalculate the contour of the pattern image if ever it changes.

criteria : minimal distance under which the contours are considered as detected and highlighted.

Output :

first outlet : the contours of the incoming video stream with detected contours highlighted.

second outlet : the pattern image contour.

third outlet : the minimum distance between the contours of the incoming stream with the pattern image.

As the contours are all normalized before the comparisons, the size and orientation of the contours should not impair the detection, but from the tests we've been running, this is more relevant with the next module that compares contours using a PGH histogram.

4.3.13 pdp/pix_opencv_pgh_compare

This object is very similar to the previous one, except that for comparing contours, it uses a PGH histogram instead of the Hu moments. The PGH histogram is an histogram of the convexities of the contours storing the size and angle of each curve. This method is statistical and is better for detecting contours regardless of their size and orientation.

Input Parameters :

minsize : minimal size of threated contours, to remove small shapes and noise.

clear : recalculate the contour of the pattern image if ever it changes.

criteria : minimal distance under which the contours are considered as detected and highlighted.

Output :

first outlet : the contours of the incoming video stream with detected contours highlighted.

second outlet : the pattern image contour.

third outlet : the minimum distance between the contours of the incoming stream with the pattern image.

This object is less sensitive to the change of size and orientation, but as it is statistical, it can also confuse a contour for another that would include the same number of curves with the same angle.

4.3.14 pdp/pix_opencv_knear

This object compares the incoming video frames with a collection of samples loaded from a directory. The idea is to implement a kind of form recognition close to some OCR techniques that recognizes incoming characters calculating the distance from the current input with all the samples of a database. The calculated distance just calculates the number of pixels that are different after binarizing them.

Input Parameters :

load <directory> <count> : load all the samples from a database. The directory must contain files named : 000.png, 001.png....count.png.

bang : calculates the distance of the incoming video frame with the database.

Output :

second outlet : the distance of the incoming image with the database.

Here the database is a database of '+' signs and a distance smaller than 2000 detects a more-or-less well-formed sign but this threshold (2000) depends on the size of the samples and on the tolerance you want to give to the algorithm, so it must be adapted to each particular case.

5. Programing hints

We give here a few hints to enter into the programming of Open CV objects for PD in order to open the projects to other developers that are interested in collaborating to this effort.

5.1 Programing for PDP

Open CV works in RGB mode, so every pdp object for Open CV should start converting any incoming frame to an RGB packet with :

```
pdp_packet_convert_ro_or_drop(&x->x_packet0, (int)f, pdp_gensym("bitmap/rgb/*") );
```

Then, some processing in Open CV requires sometimes a Gray image, so you can convert the PDP packet to an Open CV bitmap in two steps : first, copying the PDP packet to an Open CV RGB image :

```
x->image = cvCreateImage(cvSize(x->x_width,x->x_height), IPL_DEPTH_8U, 3);
short int *data   = (short int *)pdp_packet_data(x->x_packet0);
memcpy( x->image->imageData, data, x->x_size*3 );
```

If you need an Open CV Gray image, you can convert it using :

```
x->gray=cvCreateImage(cvSize(x->x_width,x->x_height), IPL_DEPTH_8U, 1);
cvCvtColor(x->image, x->gray, CV_BGR2GRAY):
```

Now you can make all Open CV operations on the RGB or the Gray CV image, when you are done, you can copy the result in a new pdp packet to be propagated, if you don't PDP would modify the incoming image and it's surely not what you want :

```
short int *newdata = (short int *)pdp_packet_data(x->x_packet1);
memcpy( newdata, x->image->imageData, x->x_size*3 );
```

5.1 Programing for GEM

Here it's a bit different as Gem works in RGBA mode, but only if you specify it with a message to a pix_film or pix_video object for example, e.g. to the object that sends the video frame to your Open CV object.

Then, as in PDP you should copy the incoming GEM image in an RGBA Open CV image and eventually convert it to a Gray Open CV image with :

```
orig = cvCreateImage(cvSize(image.xsize,image.ysize), IPL_DEPTH_8U, 4);
gray = cvCreateImage(cvSize(orig->width,orig->height), IPL_DEPTH_8U, 1);
cvCvtColor(orig, gray, CV_RGBA2GRAY);
```

You can then proceed with your Open CV processing and when you're done, you should copy the result to the GEM image again :

```
memcpy( image.data, orig->imageData, image.xsize*image.ysize*4 );
```

6. Conclusion and Perpectives

The Open CV library seems at this date the most complete open source library for computer vision, and it's an assembly of many different techniques and algorithms. We just started a frame for Open CV support in PD, but still haven't explored all its possibilities and litterature, that is huge and we have only read some part of it.

Surprisingly, it's not always the most complex algorithms that work and sometimes a simple technique like the one of the histograms is capable of bringing a sense of intelligence to a pd patch, although it's only a statistical accounting but that, used in a specific context, can be more accurate than some other techniques involving artificial intalligence for example.

Every technique is valid in a certain context, for a specific goal, and it's good to have a variety of techniques to threat the same problem : providing an intelligent way to interact with a patch.

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