Influence of Image Bit Depth for Subpixel Detection Sensitivity

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Abstract. *Determination of corner point in subpixel accuracy is widely used in image processing area these days and it has high significance in many practical applications. This contribution deals with sensitivity of subpixel detection if we consider the influence of image bit depth. For this experiment there was a very accurate pointing device chosen and sets of images for every position taken. The main goal is comparison of found corner point subpixel coordinates and standard deviations for every bit depth we consider. The results are illustrated in a plot and listed in a table. This contribution answers the question if the really high bit depth can improve the subpixel detection sensitivity in case of standard brightness condition and, if the usage of these high bit depth cameras is reasonable for this purpose.*

Keywords: Subpixel Detection, Harris Detector, Bit Depth

1. Introduction

The area of corner point detection is well known and very often used in many practical tasks, for example motion tracking, object detection and recognition, 3D modelling and many others. As it is known, the smallest part of an image is a pixel. We cannot access information "between" pixel in usual. But there is a possibility to use some mathematical techniques to interpolate or approximate the brightness intensity among pixels and increase the accuracy of detected corner points. The possibility of a more accurate location can decrease costs for cameras and other hardware equipment. Be able to find the chosen image features with a better accuracy could be very useful in many practical fields. For example, the camera calibration or experimental measurement verifications for specific sensors [1] are just some of them. This paper slightly follows our previous papers [2], [3] dedicated to accuracy and sensitivity of subpixel detection. The main aim was to investigate the effect of image bit depth on detection sensitivity results we can obtain. Reference [4] deals with precision of subpixel detection for example.

2. Harris corner detector

We can imagine corner point as a point, where at least two edges are intersected, the point around which is high change of brightness intensity in all directions or the point having the smallest radius of curvature for example. Many corner detectors were invented over the years and the Harris corner detector is one of the most famous. This detector was developed by Chris Harris and Mike Stephens in 1988 [5]. The basic idea is to find the minimum of intensity difference between the chosen part of an image (marked as *W*) and the shifted part of image *W* in all directions. There is the first-order Taylor series approximation for that purpose used:

$$M(x,y) = \sum_{W} \left(\begin{bmatrix} I_x \\ I_y \end{bmatrix} \cdot \begin{bmatrix} I_x & I_y \end{bmatrix} \right) \qquad (1)$$

The first step is determination of the matrix *M* as it is shown in Eq. 1. The variables I_x, I_y are approximations of derivations (also referred as differences) in horizontal and vertical directions. These differences are usually computed by using suitable convolution masks. The window W has usually size 3x3, 5x5 or 7x7 pixels. The matrix M is calculated for every pixel in the image. The next step is determination of the matrix C by using Eq. 2. But there are many possible modifications of this formula. The matrix C has the same size as the original image and it contains the specific value for every pixel in the image.

$$C(x, y) = \min(\lambda_1(x, y), \lambda_2(x, y)) \qquad (2)$$

The variables x and y are coordinates of a particular pixel in the corresponding directions. The symbols λ_1, λ_2 are eigenvalues of 2x2 sized matrices M and they are computed by using appropriate mathematic formulas.

The last step is looking for elements in the matrix C having the highest values. These points are marked as corner points. It is necessary to use global and local thresholding, of course. As it is obvious, this algorithm can be used to find corner points with pixel accuracy. If we want to obtain the subpixel coordinates using Harris detector, we need to interpolate the brightness intensity values among the pixels. For that reason, bilinear or bicubic interpolation is usually used. The procedure is following: Firstly, we find corner points with pixel accuracy according to the method we mentioned before. Then we choose the small window surrounding corner pixel and define the brightness intensity values among the pixels. We may use step 0.01 pixel between original pixels for example. It means that 1 pixel contains 100 subpixels in this case. So we can reach 100 times higher accuracy as initially. The rest of the procedure is exactly the same as we described before.

3. Experimental tests

The tests we have taken are very similar to the tests described in [2], [3]. We have chosen very accurate (up to 0.01 mm) pointing device. We fixed a small picture of chessboard segment (because it contains easy detectable X-corner points) to pointing device and we set small shifts on device (the orders of hundredths of millimeters) in horizontal direction. Then we took series of images with high-resolution camera and we found subpixel coordinates by the Harris corner detector from every single image from series. There were 30 images for 10 different positions taken in our measurement.

Our research is based on comparison of the found corner point subpixel coordinates and standard deviations for every bit depth. We consider 8, 7, 6, 5 and 4 bit length values. It also slightly follows our previous papers [3] and especially [2], dedicated to sensitivity of the subpixel detection. All shifts on the pointing device are recalculated in pixels, not hundredths of millimeters. It is important to notice, that we got the images under standard lighting conditions (brightness intensity changes).

4. Experimental results

There are 5 different types of values in Fig. 1 and they are marked as A, B, C, D and E in legend. It represents the average values of horizontal coordinates (based on the used pointing device shifts) for 8, 7, 6, 5 and 4 bit length in the corresponding order. This plot is illustrative example of subpixel coordinates we can obtain, if we set the different bit length. As can be seen, there is very small difference between data A and the other type of data in case of data B and C. In case of the values D and mainly E, there is a little bit more significant difference (up to 0.03 pixels).

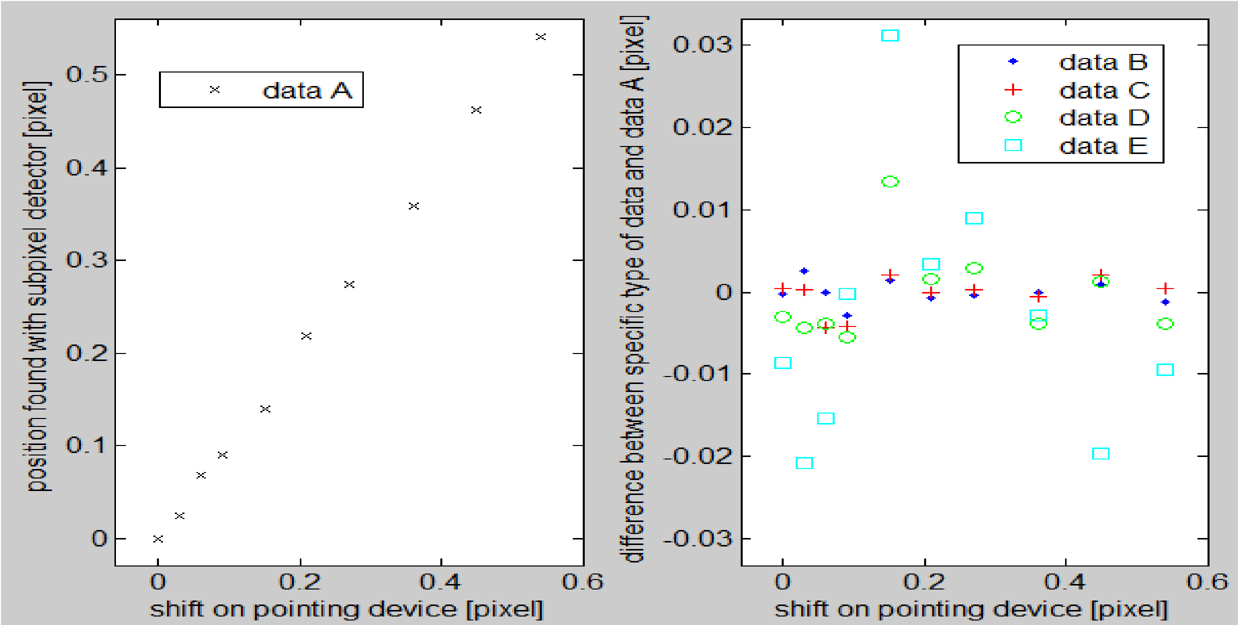

Fig. 1. Horizontal subpixel coordinates for every considered bit length

It is caused by smaller number of bits used for coding the brightness intensity value.
We determined the standard deviation for every single shift in every considered bit length. It is obvious, that average values of the corresponding data are very similar in case of 8, 7 and 6 bit length (*A*, *B* and *C*). If we compare our findings to the results published in [2], we can see that the smallest distance necessary to differentiate shift of image (shift of pointing device) for 8 bit length is around 15 hundredths of pixel. This quantity was determined by comparing 3σ limits between various positions. Because of very similar standard deviation stated for *A*, *B* and *C*, we can also assume sensitivity of subpixel detection around 15 hundredths of pixel for all of them. The standard deviations of *D* and *E* prove that, if we use only 5 or 4 bit depth, then the sensitivity and accuracy of subpixel detection decrease rapidly.

Table 1. The standard deviations for every considered bit length

data	**A (8 bits)**	**B (7 bits)**	**C (6 bits)**	**D (5 bits)**	**E (4 bits)**
shift [pixel]	*σ [pixel]*	*σ [pixel]*	*σ [pixel]*	*σ [pixel]*	*σ [pixel]*
0	0.0200	0.0198	0.0183	0.0185	0.0175
0.03	0.0174	0.0168	0.0161	0.0226	0.0306
0.06	0.0187	0.0207	0.0211	0.0239	0.0356
0.09	0.0180	0.0189	0.0216	0.0249	0.0406
0.15	0.0221	0.0218	0.0230	0.0295	0.0321
0.21	0.0180	0.0177	0.0185	0.0189	0.0279
0.27	0.0208	0.0201	0.0218	0.0236	0.0314
0.36	0.0144	0.0139	0.0135	0.0188	0.0190
0.45	0.0105	0.0121	0.0141	0.0176	0.0260
0.54	0.0159	0.0167	0.0174	0.0224	0.0394
$\overline{\sigma}$	**0.0176**	**0.0178**	**0.0185**	**0.0221**	**0.0300**

It is obvious that increasing of the bit depth (more than 8 bits) is not necessary, especially in standard brightness conditions. One of possible explanations might be that reducing of image bit length works also as a smoothing filter (Gaussian for example) and smoothing is usually the first step in subpixel detection to avoid noise in image.

5. Conclusions

This contribution deals with the sensitivity of subpixel detection considering the influence of various image bit depth values. The Harris corner detector was chosen for its very good detection qualities and a possibility to be successfully applied in real conditions. We implemented the experiments with a very accurate pointing device. Then we have been changing positions of a chessboard image fragment and we observed how obtained coordinates change. We performed statistic analysis resulting in a plot and table.

As it is shown in Fig. 1, the found absolute horizontal coordinates of our data types (8, 7 and 6 bit depth) are very similar and there is no significant difference between them. Only in case of *D* and especially *E* (5 and 4 bits), the difference is a little bit more significant. This is caused by smaller number of bits used for coding the brightness intensity value and this kind of image cannot approximate original image well enough.

We determined the standard deviation for every single shift in every considered bit length. We found that sensitivity of subpixel detection for 8, 7 and 6 bit depth is around 15 hundredths of pixel. The standard deviations for *D* and *E* prove that, if we use only 5 of 4 bit depth, then the sensitivity and accuracy decrease rapidly. Increasing of the bit depth (more than 8 bits) in case of standard lighting conditions is not reasonable for that reason. It could be caused by smoothing character of decreasing bit depth. The possibility to use, e. g. 6 bit length instead of usual 8 bit length (75% of all bytes amount) is very convenient in many applications, where data compression is a goal and we can still reach very similar precision and sensitivity of detection.

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