Posudek závěrečné práce Lukáše Novotného: Detection of Fast Moving Objects

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Detection and tracking of fast moving objects is important, but so far not well studied problem in computer vision, which make the bachelor thesis's assignment very actual. The assignment guidelines consists of the following five points:

(1) **Collect sequences of objects with significant motion blur:** Student collected 9 sequences of ball motions from different sporting activities ranging from table tennis to hockey. He also provided annotations of blurred strokes. I very appreciate, that instead of building a dataset which would satisfy (sometimes) unrealistic assumptions of the proposed algorithm, the student collected a fair real-world dataset which demonstrates all possible challenges.

(2) **Propose a method to detect such objects in the scene:** Lukas Novotný proposed the algorithm, which consists of two steps: (i) detects connected components on the thresholded difference image, (ii) match closest connected component from two consecutive difference images. The matching uses K-Nearest-Neighbour (KNN) algorithm with the similarity measured by the relative position and the average color of connected components. The algorithm has two rather strong assumptions: static background (eq 4.3.) and constant velocity (eq. 4.4). It would also help to have an algorithm overview already in the introduction.

(3+4) **Estimate continuous trajectory of blurred objects:** Student proposed algorithm based on skeletonization (see Section 5.6). It is not clear to me, whether the skeletonization works in frames in which the ball does not follow the ballistic trajectory (i.e. it is bouncing), since in this case the entry and exit points might be at the same position.

(5) **Evaluate the method:** The evaluation reveals, that the algorithm perform well only for table tennis sequences in which (i) the static background assumption (eq 4.3) and (ii) constant speed assumption (eq 4.4) are satisfied. All results are reasonably commented and failures are well justified.

I believe that the bachelor thesis assignment was fully satisfied. Quality of the English language used in the thesis is above standard, however it was not easy for me to fully understand details of the proposed algorithm. For example

connection of the function knnMatch used in the algorithm with the section 5.4: K-nearest neighbours is rather vague. Also assumptions of static background and constant velocity are a bit strong. Nevertheless the overall work is above standard, therefore I suggest **grade A**.

Minor comments (mostly to the author):

- Equation 4.7 seems strange, c and alpha appears suddenly without index (and x-argument). It is better to use an index or mention that due to assumption (4.3), the following notation is used: $c = c_{t+1} = c_t$.
- Figure 4.1 colorbar at th difference image might help to understand the meaning of colors better than the Figure caption.
- Following work seems to be also related: Hailin Jin, Paolo Favaro, Roberto Cipolla, Visual Tracking in the Presence of Motion Blur, JC, 2005 `http://www.vision.ucla.edu/papers/favaroJC05.pdf`
- "One of the inputs to KNN algorithm is a training set." however, there are two inputs: knnMatch(cct-1, cct). It is not easy to understand the connection of these inputs with the training set Γ described in the corresponding section.

Question for the discussion:

1. Do you normalize features? It might be necessary for using Euclidean distance in KNN.
2. Is the proposed algorithm going to work in frames in which the assumption on constant velocity is strongly violated (e.g. when bouncing)? If not, what kind of improvement would help?