REVIEWER'S OPINION OF FINAL THESIS

I. IDENTIFICATION DATA

Thesis name:	**All-speed Long-term Tracker Exploiting Blur**
Author's name:	**Denys Rozumnyi**
Type of thesis :	master
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Cybernetics
Thesis reviewer:	Matej Kristan
Reviewer's department:	Faculty of computer and information science, University of Ljubljana

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment **challenging**

Evaluation of thesis difficulty of assignment.

The subject of the assignment is tracking fast moving objects recorded by a moderate frame rate camera. During a single exposure, the object potentially travels a distance equal to several object sizes, which results in an extremely high degree of blurring. Thus, instead of extracting a single position or an object bounding box, as is the case in standard tracking problems, the given assignment requires extracting an entire trajectory of positions along which the object moved during the exposure, and connecting these over consecutive frames into the final track. The major challenge comes from the fact that a series of inverse problems and estimation of partially observed noisy processes need to be solved to accomplish this. The assignment adds an additional level of difficulty in requiring that the tracker should work for all object speeds. Currently there is no published work that would address all these requirements.

Satisfaction of assignment **fulfilled**

Assess that handed thesis meets assignment. Present points of assignment that fell short or were extended. Try to assess importance, impact or cause of each shortcoming.

All points of the assignment have been fulfilled. The implemented approach is thoroughly validated and sets a clear new state-of-the-art.

Method of conception **correct**

Assess that student has chosen correct approach or solution methods.

All steps of the proposed approach apply modern state-of-the-art solutions. The overall method follows a long-term tracking paradigm of tracking by detection. The inverse problem solution for local trajectory extraction is very interesting and advanced. Robustness is maintained by application of robust fitting approaches.

Technical level **A - excellent.**

Assess level of thesis specialty, use of knowledge gained by study and by expert literature, use of sources and data gained by experience.

The work presented in the thesis is a clear state-of-the-art, drawing on the expert knowledge from a range of computer vision subfields and most recent methods in tracking.

Formal and language level, scope of thesis **B - very good.**

Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.

The thesis agrees with the standard form of scientific reporting. The language is very good and the ideas are clearly put forward. I would have liked to see a more detailed explanation of the optimization for the inverse problem solution of the blur kernel, but the exposure provided suffices for the general understanding of the solution.

Selection of sources, citation correctness **A - excellent.**

Present your opinion to student's activity when obtaining and using study materials for thesis creation. Characterize selection of sources. Assess that student used all relevant sources. Verify that all used elements are correctly distinguished

from own results and thoughts. Assess that citation ethics has not been breached and that all bibliographic citations are complete and in accordance with citation convention and standards.

The thesis draws on works published in major computer vision conferences and journals. The sources are appropriate, the contributions are clearly separated from prior art. Citations are in accordance with citation convention and standards.

Additional commentary and evaluation

Present your opinion to achieved primary goals of thesis, e.g. level of theoretical results, level and functionality of technical or software conception, publication performance, experimental dexterity etc.

The primary goals of the thesis have been achieved and exceeded at some points. The thesis is a mix of proposing basic mathematically supported approaches to solve particular elements of the tracking pipeline and of a well-engineered system that ties all parts into a working tracker. All steps are sufficiently well explained and supported with convincing arguments. Experiments are well designed and analyze advantages and drawbacks of the method. Results show state-of-the-art performance, outperforming all previous works. A very interesting experimental analysis shows that, under certain constraints, the accuracy of the proposed system is no par with much more expensive active systems, which is likely to have important practical applications.

III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION SUGGESTION

Summarize thesis aspects that swayed your final evaluation. Please present apt questions which student should answer during defense.

The thesis addresses a challenging and relatively new problem in computer vision. The proposed solution is well engineered from a systems perspective, while its individual parts and design choices are mathematically supported. The resulting tracker goes beyond the current state-of-the-art and has potential for scientific publication.

I recommend the following questions:
1) How is the non-negativity constrained accounted for in the ADMM formulation of (3.4) and F<M in (3.5)?
2) How does the approach deal with situation of a motion direction change during occlusion, e.g., a ball is thrown, gets occluded by a wall, during occlusion it bounces back and becomes visible again?
3) What kind of performance degradation is expected for non-circular objects?
4) The approach is said to fail if several fast moving objects are present in the scene. But, could the approach be modified to work at least in situations in which the different objects differ in appearance?
5) The deblating weight \alpha_H is set to different values depending on the sequences. Could this parameter be estimated as part of the algorithm?
6) All parts of the approach are solved by a mathematical model. However, in many modern trackers, deep neural nets are used to replace often over-idealized models of the underlying processes. Which part of your approach might benefit from replacement with an appropriate deep model, if any?

I evaluate handed thesis with classification grade **A - excellent.**

Date: **29.5.2019** Signature: