Posudek vedoucího diplomové práce "Detekce chodců v nepříznivém počasí pro autonomní mobilní roboty"

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Cílem předložené práce byl návrh a implementace robotického navigačního systému schopného bezpečného nasazení v podmínkách snížené viditelnosti. Systém se skládá ze dvou modulů, z nichž jeden realizuje navigaci podél vytyčené trasy a druhý musí být schopen detekovat a lokalizovat chodce v podmínkách kdy tradiční senzory selhávají. Zatímco modul vizuální navigace koncepčně vychází ze starší práce, kterou rozšiřuje a zdokonaluje, modul pro detekci chodců představuje nový koncept dlouhodobého učení pro senzorickou fúzi.

Práce je díky logické struktuře a dobré jazykové úrovni snadno čitelná. Autor podává ucelený přehled problematiky navigace a strojového vnímání v nepříznivých podmínkách, a představuje použitý navigační systém a vyvinutý modul detekce chodců. Samotný modul detekce kombinuje laserový a radarový senzor nejen tradiční fúzí, ale i tak, že data z jednoho senzoru jsou využita pro učení druhého. Jak ukazuje v provedených experimentech, výše uvedený princip vede k postupnému zpřesňování lokalizace chodců během provozu systému a celý systém je schopen detekce chodců i při silné mlze a intenzivním dešti.

Předložený text je shrnutím nejdůležitějších výsledků několikaleté spolupráce studenta na vědeckých projektech realizovaných na půdě FEL ČVUT, během kterých student přispěl k řadě konferenčních článků o vizuální navigaci [1, 2, 3, 4, 5]. Klíčový výsledek předložené práce, tedy systém detekce chodců využívající strojové učení byl vybrán mezi 10 nejlepších příspěvků na European Conference on Mobile Robots [6] a byl přijat k publikaci ve zvláštním vydání Robotics and Autonomous Systems [7]. Komponenty vyvinutých modulů byly použity v řadě jiných systémů, například v pozemním robotu který byl součástí vítězných týmů DARPA SubT a MBZIRC. Práce splnila všechny vytyčené cíle, považuji ji za velmi kvalitní a proto ji klasifikuji známkou

A - výborně.

Mělník, ČR,
dne 14.8.2020

doc. Ing. Tomáš Krajník, Ph.D.
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THESIS REVIEWER'S REPORT

I. IDENTIFICATION DATA

Thesis title:	**Pedestrian detection in adverse weather conditions for autonomous mobile robots**
Author's name:	**Filip Majer**
Type of thesis :	Master
Faculty/Institute:	Faculty of Electrical Engineering
Department:	Department of Control Engineering
Thesis reviewer:	Kevin Li Sun
Reviewer's department:	Computer Science

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment **Select: challenging**

How demanding was the assigned project?

Please insert your comments.

Fulfilment of assignment **Select: fulfilled**

How well does the thesis fulfil the assigned task? Have the primary goals been achieved? Which assigned tasks have been incompletely covered, and which parts of the thesis are overextended? Justify your answer.

Please insert your comments.

Methodology **Grade: A**

Comment on the correctness of the approach and/or the solution methods.

Please insert your comments

The proposed method is novel and the resolved problem is significant. The human detection is devised for extreme environments which leverages two complementary sensors with good intuition provided. Two sensor fusion strategies are proposed to fuse the lidar detections with radar detections. The multi-sensor based human detection system is integrated with the Visual Teach&Repeat navigation stack, hence a significant amount of work has been done.

1) A better link can be built to bridge the lidar/radar-based human-aware navigation with the visual-based navigation modules. Why not use lidar/radar for navigation or image for human detection? Will the visual-based navigation fail in extreme environments?
2) What can be concluded from the human-aware navigation experiment (Section 6.2)? Why errors of human-aware navigation slightly larger than vanilla visual navigation over time?
3) In Fig. 13, can the ground truth bounding box be provided? Moreover, the cyan spheres are the detected legs from the leg detector, where are the 3D points of the legs?
4) The features for pedestrian classification were originally used in 3D lidar based methods [65-66], will these all useful in radar applications? An ablation study can be provided to investigate the effectiveness of these features.

Technical level **Grade: A**

Is the thesis technically sound? How well did the student employ expertise in his/her field of study? Does the student explain clearly what he/she has done?

Please insert your comments.

The proposed method is technically sound. Comprehensive experimental results are provided to evaluate the proposed method. The methodology is well-written which is presented clearly with details. There are some minor issues that can be further clarified:

1) As presented in Section 6.1.1, the sensors are mounted on cardboard. Can the author provide more details about sensor calibration, can the cardboard setting maintain a satisfactory calibration?
2) In Table 2, the switch based fusion outperforms weighted fusion. However, the results shown in Fig.16 and 17 are the opposite. Can the author explain why the results are not consistent?

Formal level and language level, scope of thesis **Grade: B**

Are formalisms and notations used properly? Is the thesis organized in a logical way? Is the thesis sufficiently extensive? Is the thesis well-presented? Is the language clear and understandable? Is the English satisfactory?

Please insert your comments.

The thesis is well-written in general. The formalisms and notions are used properly. There are several grammatical issues and typos can be polished:

1) One of the approaches to **illumination** or seasonal changes is to exploit the fact that they are periodic and thus we can predict those changes and use them for navigation.
2) A separate calibration achieved the obtained transformation, which **using** the iterative closest point (ICP) and outputs of both modules for detections, the lidar detection and SVM.
3) Typo. in which results in the lidar-only system not beiing capable of detecting the pedestrian.
4) In particular, the crash by Uber cars [2], **which** happened during the night and Tesla car crashes [3], **which** happened in foggy weather conditions implies that for autonomous **car** these conditions are a challenging task.
5) Thus the older detections are penalized, making the system depend on more recent observations **or (than?)** older, which have lower uncertainty.

Selection of sources, citation correctness **Grade: A**

Does the thesis make adequate reference to earlier work on the topic? Was the selection of sources adequate? Is the student's original work clearly distinguished from earlier work in the field? Do the bibliographic citations meet the standards?

Please insert your comments.

The literature review is adequate for MSc thesis and the related research is reviewed and acknowledged properly. I suggest that more deep learning point cloud classification/segment literature can be reviewed. Especially for these light-weighted deep models that have the potential to be used in robotic applications.

This thesis proposed a novel radar-lidar based pedestrian detection approach for extreme environments and the perception pipeline has been integrated with a mobile robot navigation stack for human-aware navigation. The proposed research is original and publishable, I suggest highlighting the main contributions (scientific novelty) at the end of the Introduction Section.
Apart from this, there are some minors:

1) Fig 3 needs a more detailed caption.

2) Section 2.2.1(Kalman filter) needs to drive deep into mapping or multisensor odometry as Kalman filter is very generic method that can be applied to a board range of applications.

Additional commentary and evaluation (optional)

Comment on the overall quality of the thesis, its novelty and its impact on the field, its strengths and weaknesses, the utility of the solution that is presented, the theoretical/formal level, the student's skillfulness, etc.

Please insert your comments.

The proposed method is novel and publishable. As far as I understand, part of the thesis is presented on a good robotics conference - ECMR2019 [64].

III. OVERALL EVALUATION, QUESTIONS FOR THE PRESENTATION AND DEFENSE OF THE THESIS, SUGGESTED GRADE

Summarize

Overall, this thesis proposed a novel approach for multi-sensor based human detection. The method is innovative and the experimental result is solid. The codes are well implemented with real-time performance. The detection module has been integrated with navigation stack and demonstrated using a real robot, hence a significant amount of work has been completed. This thesis makes a significant contribution to robot vision and autonomous systems. This thesis is well-written in general though there are several minor issues that can be improved and the English can be further polished. I suggest marking these as grade A - as recognition of it being a piece of excellent work.

The grade that I award for the thesis is **A**

Date: 1st Sep 2020

Name and signature: Li Sun Li Sun