[Thesis Title]

Thesis by

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In Partial Fulfillment of the Requirements for the degree of

[Name of Degree]

INNOPOLIS UNIVERSITY

Innopolis, Russian Federation

[Year Degree Conferred]

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ACKNOWLEDGEMENTS

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ABSTRACT

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PUBLISHED CONTENT AND CONTRIBUTIONS

[Include a bibliography of published articles or other material that are included as part of the thesis. Describe your role with the each article and its contents. Citations must include DOIs or publisher URLs if available electronically.

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Cahn, J. K. B., A. Baumschlager, et al. (2016). "Mutations in adenine-binding pockets enhance catalytic properties of NAD (P) H-dependent enzymes". In: *Protein Engineering Design and Selection* 19.1, pp. 31–38. DOI: `10.1093/protein/gzv057`.
J.K.B.C participated in the conception of the project, solved and analyzed the crystal structures, prepared the data, and participated in the writing of the manuscript.

Cahn, J. K. B., S. Brinkmann-Chen, et al. (2015). "Cofactor specificity motifs and the induced fit mechanism in class I ketol-acid reductoisomerases". In: *Biochemical Journal* 468.3, pp. 475–484. DOI: `10.1042/BJ20150183`.
J.K.B.C participated in the conception of the project, solved and analyzed the crystal structures, prepared the data, and participated in the writing of the manuscript.

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INTRODUCTION

Start off all chapters with `chapter`. `\extrachapter` will give you an unnumbered chapter that's added to the Table of Contents.

Here's an example of a citation (Goresky and MacPherson, 1981). Here's another (Parusiński and Pragacz, 1998). These will appear in the big bibliography at the end of the thesis.

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You can define nomenclatures as you talk about key terms in your thesis. So what's a galaxy?

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Chapter 2

SYSTEMATIC LITERATURE REVIEW

2.1 Rationale

As a part of this thesis work, the systematic literature review was performed. The objectives of the work done include the following: to know what technologies, methods, and concepts we are going to work with, to get familiar with existing research on related topics and achievements in related fields, as well as to assess results of previous works and extent of their applicability to development of the system that is a subject of this dissertation. Other few goals were analysis of used tools and strategies and their effectiveness and efficiency and retrieval of information regarding reliable ways to evaluate the work of the system.

Furthermore, there is quite an amount of justification of decision to perform the systematic literature review instead of a classical one, namely that it is convenient enough to have all the scholarly sources sorted, classified and analyzed rigorously enough to exploit the accumulated information efficiently to proceed further.

2.2 SLR protocol development

Research questions

In this literature review, it is attempted to answer such research questions that they include maximum relevant information needed to know in order to implement the proposed system. They are formulated as follows:

- **RQ1:** "What technologies, tools and methods are suitable for implementing a computer vision and machine learning based environment modelling system?"
- **RQ2:** "What is needed for it to be used as a part of a smart parking system?"
- **RQ3:** "What measures of efficiency are best to evaluate the system and what results should be achieved to compete state-of-the-art approaches?"

Searching process

This section provides the specification of searching process, including used search resources, keywords and search queries, study inclusion and exclusion criteria, evaluation scheme and the related methodology.

Resources

The search included electronic sources only. The following sources and tools were used for the search:

- IEEExplore Digital Library
- ResearchGate
- Google Scholar
- ACM Digital Library
- Arxiv.org

This is the exhaustive list, as no more sources were used in the process.

Search queries

For the search, five key topics were identified:

- Computer vision
- Machine learning
- Software design
- Smart parking
- Data collection on vehicles

For each topic, key concepts were written down, then synonyms found. As the result, all searches were performed using OR-combinations of the following queries:

- (automatic OR smart OR IoT OR internet of things) AND (parking OR parking lot OR parking slot OR parking space) AND (utilization OR occupancy OR tracking OR detection OR monitor OR management) AND (sensor OR camera OR video)
- (trigger OR event OR conditional execution OR decision making) AND (patterns OR design principles OR implementation OR usability OR user-friendly OR gui OR user interface)

- (vehicle OR car OR moving object) AND (data OR dataset OR metrics OR information)
- (machine OR supervised OR unsupervised OR deep) AND (learning OR classification OR regression) AND (algorithm OR dataset OR evaluation OR application)
- (computer OR machine OR automated) AND (vision OR recognition OR image processing OR scene reconstruction) AND (moving object OR shape OR vehicle)
- parking AND lot AND occupancy AND detection AND computer AND vision

The queries were edited to fit in the search opportunities of each system, but overall the semantics was left the same.

Inclusion and exclusion criteria

To decide which papers will be included in the review the following inclusion criteria were employed:

- Found using search queries specified above
- Related to computer science or data collection
- Written in English
- Published not earlier than in 2000
- Journal and repository articles, conference proceedings, master's and doctoral degree dissertations
- Peer-reviewed
- Primary studies or systematic literature reviews

Papers that didn't fit at least one of inclusion criteria were excluded from the review, as well as duplicates.

Quality assessment

To assess the quality of included papers, a set of questions was developed. The 'yes' answer yields 1 point, 'partially' yields 0.5 points, 'no' yields 0 points. The points obtained on every question are then added up. The questions are:

1. Are objectives clear and specific?
2. Does the research satisfy the objectives appropriately?
3. Is research process clear and reproducible?
4. Were the results assessed properly in a paper?
5. Were the results summarized to provide a clear conclusion?
6. Are there any comparisons with alternatives?

So basically the score range is 0 (the worst) to 6 (the best).

Search and synthesis strategies

For papers found using resources and queries specified above, papers were evaluated according to inclusion and exclusion criteria by one of researchers each. After that, from included papers, 20 were chosen at random to be assessed against quality assessment criteria by both researchers. For differences in judgement, the mean result was taken and patterns in disagreement identified to perform systematic corrections of scores of remaining papers after they are reviewed by one of researchers.

The synthesis was performed both qualitatively and quantitatively. Statistics about the papers was gathered, such as key topics, years of publication and quality assessment. Also, we classified the found information by methods and results.

2.3 Results

Search Sources Overview

First of all, we are going to represent some information regarding the resources used to search papers, in order to aid assessment of the work done. In the Table 2.1, we discuss advantages and disadvantages of the sources.

Excluded Papers

Basically, there were thousands of paper found with our queries. Nevertheless, the time constraints didn't allow us to look up them all, so we opted to only look through

Source	Advantages	Disadvantages
IEEExplore Digital Library	Published papers can mostly be assumed to be peer-reviewed	Paywall
ResearchGate	Open access; well-formatted, full-color articles	Requires registration; problems with account confirmation
Google Scholar	Diverse sources, helpful in finding open access articles	Some sources can be unreliable, and some behind the paywall
ACM Digital Library	A good source of interesting and high-quality papers in IT, convenient means of search	Paywall
Arxiv.org	Open access, diverse papers	Very likely to be not peer-reviewed, sometimes outright poor quality, non-intuitive search

Table 2.1: Sources advantages and disadvantages

first 100 papers in every search, throwing out everything that did not fit inclusion criteria, that was fortunately possible to do due to the nature of criteria, that are generally possible to determine by metadata. As the result, we have gathered 93 papers, that were reviewed one more time during quality assessment. After review, 22 more papers were discarded, leaving us with 71 acceptable papers. In the table below, we present information on reasons the papers were excluded.

Reason to exclude	Quantity	Percentage (of 93 papers)
Not a primary study	4	4.3
It wasn't peer-reviewed/Draft	5	5.3
Duplicate	4	4.3
Not in English	1	1
Not conference proceedings or journal articles	3	3.2
Other reasons	5	5.3

Table 2.2: Reasons for exclusion

So, hereinafter we are only going to work with 71 remaining papers in this review.

Studies Classification

In this section, we will first present some statistics on quality and content of studied papers, and then the overview of said content.

Right below, we have a table that organizes information by major topics we have. Note that these topics are not exclusive, as one paper may belong to several major topics, so percentage will not add up.

Topic	Years	Number of papers	Percentage
Computer vision	2003-2017	35	49.3
Neural networks	2003-2017	11	15.5
Machine learning	2006-2017	16	22.5
Scene reconstruction	2009-2017	10	14
3D	2001-2016	8	11.3

Table 2.3: Key topics distribution

The next table describes statistics by years of publication. For the sake of simplicity, we split all papers to five-year periods, with the last one being 2016 to present time, or a shorter one.

Years	Quantity	Percentage
2000-2005	7	9.9
2006-2010	16	22.5
2011-2015	28	39.4
2016-now	20	28.2

Table 2.4: Distribution by year

As we can see, number of relevant papers grows approximately twice every five years, and since we got almost as many papers for 2016 and 2017 as for previous five years, it is safe to conclude that interest in the topic is rising rapidly. Furthermore, according to our observations, the overall quality of research is steadily improving over the years. Speaking of quality, in the next table we present statistics on quality assessment.

QA score	Quantity	Percentage
0-2.5	34	47.9
3-3.5	13	18.3
4-6	24	33.8

Table 2.5: Quality assessment statistics

The good news are latest research papers have significantly improved in quality, so QA scores are generally 4 or above. Nevertheless, even papers with poor QA score can be useful in providing valuable information, even though we would not fully trust the results regarding efficiency of applied technologies.

2.4 Discussion

We have analyzed plenty of articles to determine which aspects and methods of computer vision and machine learning are used. In early 2000s, the following approaches were used:

- With use of Active Data Repository framework: vertex caching, approximate cube projection, density-based model fitting (results not well-reported) - human silhouette recognition (Borovikov and Sussman, 2003)
- Principal component analysis + Bayes-based classifier (False alarm rate 3.21%, mistake rate 1.01%) - parking cell detection (Deng, Jiang, and Wei, 2006)
- With use of MATLAB: Object placement relation + K-NN (Accuracy 67.55%) - scene construction (Subpa-asa, Futragoon, and Kanongchaiyos, 2009)
- With use of MATLAB: Fuzzy C-means classifier (Sensitivity up to 99.92%) - vehicle detection (Ichihashi et al., 2009)

These approaches are based on a variety of mathematical techniques and concepts. Thus, K-NN is a method that uses vectors of features by computing distances between them, and then choosing K nearest objects according to this distance and computing a sort of central value to predict classification label, while fuzzy C-means classifier implies non-strict clustering, where each object is assigned to several clusters with certain probability, in a way that minimizes sum of squares of distances to each cluster center. Later on, with development of new techniques, these approaches gave the way to newer and better ones, such as the following:

- Sift + Gist + SVM (accuracy up to 80%) - threat detection (Madikenova, Galimuratova, and Lukac, 2016)
- Sift + Extreme learning machine (Accuracy 86.05%) - general scene recognition (L. Wu, Yu, and Gu, 2016)
- Global features extraction + spatial transformer + CNN (accuracy 82.10%) - general scene recognition (Guo et al., 2016)
- Regions of interest + SVM - Boosting hybrid (accuracy 87%) - obstacle recognition in traffic scenes (Mocan and Dios, 2016)

- Principal component analysis + K-means clustering + Spatial Pyramid VLAD encoding + SVM (accuracy up to 96.15%) - traffic scene recognition (F.-Y. Wu et al., 2017)
- Deep convolutional neural networks (AUC up to 0.9997) - Parking lot vacancy indication (Valipour et al., 2017)

Overall, it is easy to notice that accuracy has undergone improvement with time, thanks to new methods usage, as well as sensible combination of existing methods. Among all these approaches, the most popular were CNN, SVM, Naive Bayes and Random Forest, that have shown decent quality measures in solving the problems related to our field.

CNN (Convolutional Neural Network) is, by definition, a class of deep, feed-forward artificial neural networks. Having been applied successfully to visual imagery analysis, this kind of neural networks is notable in the sense that it is well-suited for work with diverse variations of image recognition. CNNs have the following advantages: they are easily parallelizable, as well as relatively robust with regard to rotation and translation. The disadvantages, however, include, for instance, the excessive amounts of network parameters, that are not understandable easily in practical sense, i.e. in fine-tuning to the each task and computational resources available. These various parameters can be any of the following: number of layers, convolutional kernel dimensionality, number of kernels for each layer, kernel shift step for layer processing, necessity of subdiscretization layers, extent of dimensionality reduction, dimensionality reduction function, neuron transmission function, existence and parameters of fully connected layer before the output, etc. All these parameters influence the results significantly but are chosen by researchers empirically. There are plenty of existing and well-tested CNN configurations, but we in fact lack recommendations to build a network for our task. CNNs were used for parking lot occupancy detection (Valipour et al., 2017; Amato et al., 2016) with AUC varying from 0.8826 to 0.9999 and accuracy varying from 0.398 to 0.981; and also for general scene recognition (Guo et al., 2016) with accuracy between 0.5395 and 0.8210.

SVMs (Support Vector Machines) are again, by definition, supervised learning models for regression and classification, with associated learning algorithms. Their advantages are:

- it is guaranteed, that a globally optimal solution will always be found;

- there are plenty of implementations of this learning algorithm for different programming languages and packages;
- both hard-margin and soft-margin data are susceptible to the method;
- SVMs support semi-supervised learning.

The only real serious disadvantage of the method is relatively low suitability to natural language processing tasks, which do not relate to our case in any way. Also, SVMs cannot return probabilistic values, that makes the method in some sense non-intuitive for interpretation. SVMs were used for parking space detection (Almeida et al., 2013) with accuracy between 0.9151 and 0.9984; for traffic scene detection (Chen, Choi, and Chandraker, 2016) with F1-score between 0.2445 and 0.5415; for traffic obstacle recognition (Mocan and Dios, 2016) with accuracy up to 0.87; for online vehicle detection (Neumann et al., 2017) with recall around 0.86 and precision around 0.94.

Naive bayes is one of simple classification method, based on Bayes' theorem. The key assumption of the method is that all incoming data are strongly independent. Good examples of advantages of the method would be training set size insensitivity, fast learning, and overfitting robustness. These are reasons why Naive Bayes is used where there are not much training data available, or else when there is too much data and the learning speed is critical. Disadvantages are rather poor quality of prediction as compared to alternative methods, especially when data are in fact dependent. Naive Bayes algorithm was used for parking space detection (Deng, Jiang, and Wei, 2006) with accuracy between 0.9781 and 0.9899.

Random forest is another classification and regression method. The main idea is randomly making a set of decision trees at a training time and using them all together for prediction. The method was introduced to overcome a strong tendency of decision trees to overfit, and it has, in fact, enough advantages to consider using it. For example, it is able to process data that has a lot of features and perform extensive multiclass classification. Then, it is not sensitive to any monotonous normalization of features. Furthermore, both discrete and continuous features are processed rather efficiently, along with ability of random forests to work with data with some missing features. There are also methods to estimate importance of different features within the model. Finally, random forests are easily scalable and parallelizable. However, there is also a considerable disadvantage, namely a large size of resulting models, linearly dependent on the number of trees. Random forest was used for parking lot detection (Dube et al., 2014) with average accuracy of 0.979; for image understanding (Hoo et al., 2014) with accuracy between 0.392 and 0.8529.

Along with machine learning methods described above, some auxiliary methods were used. Semi-hard clustering and fuzzy C-means were used for parking space detection (Ichihashi et al., 2009), to yield accuracy between 0.6206 and 0.9952. Extreme learning machine, proposed in (L. Wu, Yu, and Gu, 2016), gave accuracy between 0.767 and 0.878. Haar-like features gave recall of 0.7 and precision of 0.65 for online vehicle detection, while HOG features allowed to achieve recall and precision both being 0.76 for the same task (Neumann et al., 2017). These methods were not used often, so we were not able to gather enough statistics to be sure in objectivity of information we have, especially considering the fact that in many cases we didn't have enough information on datasets to evaluate objectivity of the quality measures presented.

Methods change over the years, yet there is one certain rule that still holds: the more data we use to train learning models and the more representative it is, the better the results are in the end, which leads to an obvious conclusion that we will need really large amounts of data in order to train our system well.

So overall, a lot of work has been already done in related fields. For instance, in (Neumann et al., 2017; Valipour et al., 2017) the car detection was implemented reasonably, but existence of, say, bicycles or pedestrians, was not taken into account. In (Barnouti, Naser, and Al-Dabbagh, 2017; Masmoudi et al., 2016), on the other hand, researchers were implementing parking space detection, but did not take into account the fact that lighting can be lacking, as well as that vehicles can be fairly large. As a whole, a task of parking lot detection has been already solved efficiently, as well ad person recognition in some implementations, but still nobody has yet implemented what we are proposing - namely, everything that they have, including parking space detection, vehicle detection, people detection, both at daytime and nighttime, along with event-based triggers that would allow to integrate similar sensor systems into IoT infrastructures. So we are going to combine all the work done in order to get a much more complex product than ever, with better accuracy and easy scalability and ease of amending the system with new functionality. Therefore, the research gap is that everything we need already exists as separate parts, but has not been combined yet.

2.5 Conclusion

In this SLR, we tried to find out what methods and techniques are the most suitable for the system we are going to implement. A thorough analysis has shown that apparently, CNN and SVM and other methods are quite popular for this group of tasks, that must be for a reason, since they seem to be the most suitable for the field, so we must conclude that it is justified their further use, along with certain preprocessing techniques such as principal component analysis or K-means clustering.

Considering datasets to use for training and testing, it would come in handy to collect our own custom dataset in addition to dozens of relevant open source datasets available online. As for measures of efficiency, accuracy seems to be the most appropriate since it is easily extendible to multiclass classification case and shows relevant statistics when datasets are not strongly skewed. The aim for efficiency should be set as high as 95% accuracy or higher, to beat state-of-the-art results.

Finally, these considerations are subject to further refinement, since a certain amount of small changes in methodology can basically lead to radical change in results. Nevertheless, the chosen methods form a good starting point we are going to use.

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Chapter 4

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If you'd like to have separate bibliographies at the end of each chapter, put a `refsection` around the material of each chapter, then cite as usual – e.g. (Goresky and MacPherson, 1981; Fulton, 1983; Yadav, Shukla, and Sethi, 2016). Then do a `\printbibliography` just before the `refsection` ends.

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Chapter 5

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Chapter 6

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Chapter 7

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Chapter 8

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Appendix A

QUESTIONNAIRE

Appendix B

CONSENT FORM

[1]Endnotes are notes that you can use to explain text in a document.

POCKET MATERIAL: MAP OF CASE STUDY SOLAR SYSTEMS