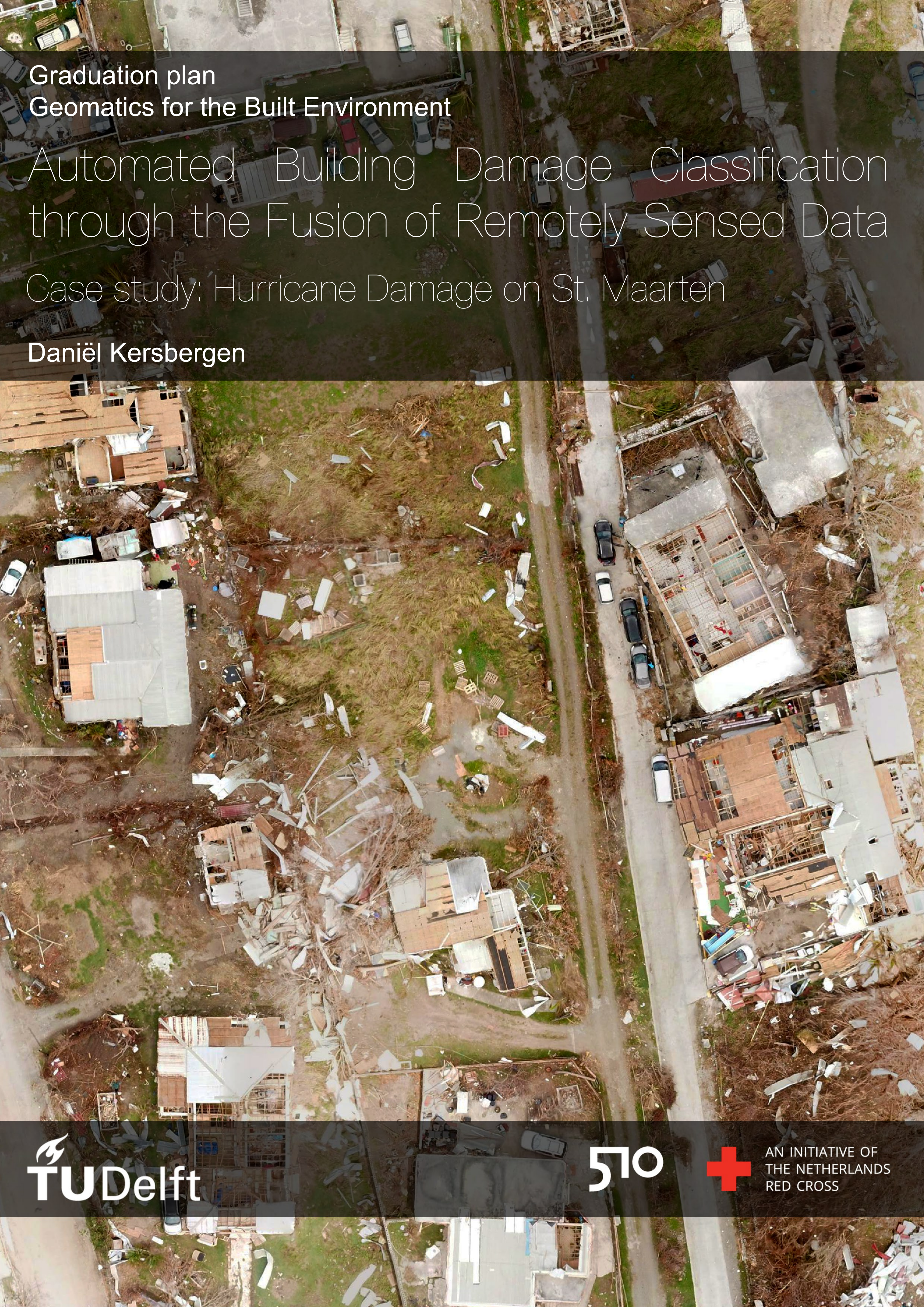

Graduation plan
Geomatics for the Built Environment

Automated Building Damage Classification through the Fusion of Remotely Sensed Data

Case study: Hurricane Damage on St. Maarten

Daniël Kersbergen

TUDelft

510

AN INITIATIVE OF
THE NETHERLANDS
RED CROSS

COVER IMAGE:
UAV imagery from Cay Bay on St. Maarten after Hurricane Irma. (Source: Netherlands Red Cross (12 Sept. 2017), Cole Bay - Sint Maarten [georeferenced image], used under CC-BY4.0 as part of Open Imagery Network, retrieved from www.openaerialmap.org)

AUTOMATED BUILDING DAMAGE CLASSIFICATION THROUGH THE FUSION OF REMOTELY SENSED DATA

Case study: Hurricane damage on St. Maarten

A graduation plan submitted to the Delft University of Technology in partial fulfilment of the requirements for the degree of

Master of Science in Geomatics for the Built Environment

by

Daniël Kersbergen

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CONTENTS

ACRONYMS

DEM digital elevation model

DRM disaster risk management

EM emergency mapping

GIS geographic informations systems

JAXA Japan Aerospace Exploration Agency

NLRC Netherlands Red Cross

SEM satellite-based emergency mapping

UAV unmanned aerial vehicle

1 INTRODUCTION

Weather related natural disaster cost the world economy around 100 billion dollars every year [Kousky, 2014]. The Centre for Research on the Epidemiology of Disaster [2015] calculated that an average of 69.800 deaths per year are inflicted due to these disasters, combined with earthquakes. The effects are felt around the world, however most deaths occur in low or middle income areas. The interval between disasters is shortening, resulting in more disaster per year [figure 1.1]. They are furthermore causing more damage than before, with the most economic damage in 2011 [Kerle, 2015]. 2017 was an exceptional year, less people were killed by natural disasters, however the economic damages where much larger than average [Munich RE, 2018].

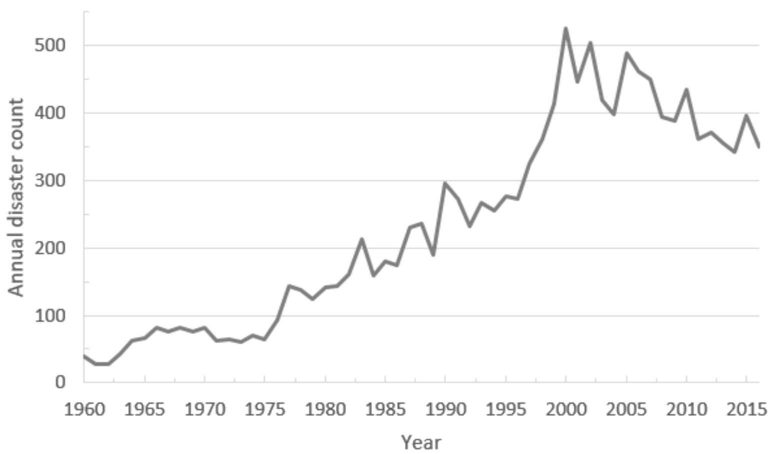

Figure 1.1: Natural disaster per year from 1960 to 2016 [From: EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium]

1.1 HURRICANE IRMA

One of the major disasters of 2017 was hurricane Irma, being labelled the worst storm in the Caribbean in recorded history [Daniell et al., 2017]. In the first week of September this hurricane raged over multiple islands causing billions worth of damage, affecting millions in its path [Phipps, 2017; Daniell et al., 2017]. One of the islands affected is St. Maarten, part of the Kingdom of the Netherlands. It was hit by the eye of the hurricane on the 6th of September with winds up to 185 miles per hour [Wilts, 2017]. Two other major hurricane passed over the area in the weeks following hurricane Irma, however, fortunately these did little to no extra damage on the island

[Gray, 2017; Bijnsdorp, 2017]. First damage estimates show that 70 - 90% of the island may be affected by the storm [Rode Kruis, 2017; UNOSAT, 2017]. The indication and location of the damage caused is a leading planning tool for organisations like the Netherlands Red Cross (NLRC), providing a first indication of the most vulnerable people in an affected area. Indications of damage have allowed the NLRC to help 18.881 individual people since the landfall of hurricane Irma and subsequent relief operation; and long term operations are being started right now to facilitate the rebuilding of the island [Rode Kruis, 2017].

1.2 REMOTE SENSING

In the context of disasters the decision making process and risk management process, as performed by the NLRC are bounded by three key characteristics [Zlatanova and Li, 2008]. [1.] Rapid action needs to be taken, [2.] aware of the situation and context [3.] with a connected overview of the data available. The goal of the disaster risk management (DRM) is to minimize the impact from a disaster [Piero and FabioGiulio, 2012]. Information on the extent of the damage is therefore paramount, as demonstrated by the relief operation from the NLRC. Building damage is an essential indicator for this [Schweier and Markus, 2006]; but can be hard to establish as it requires a lot of manual labour [Kerle, 2010]. Automated detection of building damages could be the solution [Vetrivel et al., 2016b].
Remote sensing has long been part of the DRM cycle. According to Kerle [2015] this started at the beginning of space-based remote sensing around the 1960s and 1970s and brought about the increase in information within the DRM. From here the development of remote sensing techniques accelerated over the past 50 years and increasingly allow for higher resolution information in a more timely manner. The performance increase in remote sensing solutions make it applicable for the automated classification of building damage [Dell'Acqua and Gamba, 2012; Dong and Shan, 2013]. Many solutions for automated damage detection or classification have been developed over the past years based on several remote sensing techniques. Dong and Shan [2013] provides a clear overview of the solutions up until 2013 and several more have been developed since [Dominici et al., 2017; Sharma et al., 2017; Kakooei and Baleghi, 2017; Vetrivel et al., 2016b; Menderes et al., 2015]. However in practice service from the International Charter, like Copernicus and UNOSAT, are mostly used for satellite-based emergency mapping (SEM) [Voigt et al., 2016] as they produce usable results [Kerle, 2010]. The method for damage classification used by these services is manual visual interpretation of remotely sensed data, as is indicated by the disclaimers or map information of products from these services and a program specialist at UNOSAT [Copernicus EMS, 2017; UNDAC, 2017].

1.3 RESEARCH

It is remarkable that the extensive academic research is not implemented in the disaster relief sector, As the building damage is a fundamental indicator used in DRM and relief operations [Schweier and Markus, 2006]. The lack of implementation of automated methods can be seen as an indicator of the absence of support from the humanitarian agencies. Several considerations could be the cause of this; [1.] there is too little communication between humanitarian agencies and academics, resulting in too complex methods or inadequate solutions. [2.] the methods proposed do not deliver the expected outcomes concerning effectiveness or accuracy. [3.] there are no resources to implement the new methods in existing procedures. An example of this can be found in Ajmar et al. [2011]. This research will establish a method for the accurate classification of building damage after a natural disaster. Existing academic methods will be taken into consideration and tested on the available "real world" data from St. Maarten. Furthermore the research will be conducted in cooperation with NLRC to cope with some of considerations that might be causing the lack of implementation. Advances in remote sensing techniques, machine learning and geographic informations systems (GIS) are recognised as upcoming and supportive technologies within the organisation, as it established a new data team [510] in 2016. The data team and NLRC, as well as other humanitarian organisations, could benefit from the research into the automated classification of building damage after a disaster, as it would allow for more efficient delivery of aid and humanitarian relief. The academic field working on remote sensing for disaster situations could also benefit from this research as it will provide a comparison between methods in a scenario different from the academic examples.

This graduation plan consists out of four parts besides this introduction. Firstly a short overview of the research objectives will be presented in chapter 2, followed by a literature overview of the academic work related to methods for automated damage classification or detection [chapter 3]. From the academic background a methodology is developed as proposal for the graduation project [chapter 4]. The document concludes with chapter 5 describing the overal planning and proposed tools to be used.

2 RESEARCH OBJECTIVES

The objective of this research is: *to find a method for the automatic classification of damage inflicted by hurricanes on the island of St. Maarten using remotely sensed data.* Based on the findings of Kakooei and Baleghi [2017] the research will be focused around an implementation from various sources for improvement in the accuracy of the classification To achieve this the following goals have been derived:

- Compare existing methods for building damage classification to each other and ground truth data.
- Find complementary methods and aspects of data that allow for fusion of data and methods to achieve an increase in accuracy.
- Develop a method which fuses the various data sources and methods to facilitate accurate classification of damage to buildings.
- Compare the results from the proposed method to existing methods and ground truth data.

With results from these goals the research question will be answered: *Is the fusion of remotely sensed data a viable option for the automatic classification of hurricane inflicted damage?*

An viable method would enable humanitarian organisations to accurately plan their interventions and relief operations on the basis of damage inflicted in disaster struck areas. This would allow for an increase in effectiveness of the activities, and therefore help more people affected by a natural disaster. To develop such method various other challenges will need to be handled. These will be dealt with in the literature research and analysis of existing academic methods.
A description of an effective method is necessary to develop one. To gain insight in the needs and possibilities of methods the following question will need to be answered: Which criteria are most useful for a damage classification framework? With which in turn two other questions are formed, what is damage classification and how does it differ from damage detection? And humanitarian organisations and disaster situations might impose various other criteria on methods. which should therefore be considered in the description as well.
The next scientific challenge lies in the determination of the effectiveness of existing methods. The main question to be answered in this regard is the accuracy comparison between ground truth data from St. Maarten and the results from these methods. The fusion of data is expected to improve the accuracy of the various methods, which subsequently will be one of the main indicators within the classification framework. From these results it will be possible to select the aspects of methods and data which will allow for fusion and also result in an accuracy boost in the new method.
From the answers to these challenge the new method can be developed but

will need to be validated to ensure the results are confirming to expectation and suffice for the use in humanitarian context. To do so the new results will need to be compared to the benchmark results from the existing methods.

With answers to all these challenges and the main research question, it would be necessary to see the proposed method on a broader scale and the fit within both the academic field and humanitarian field of operation. This will allow for reflection on the results and might allow for discussion on the possibility of implementation in the field.

2.1 RESEARCH SCOPE

This research will focus on the accurate and automated classification of building damage in a hurricane struck area. Limitations in a masters thesis are unavoidable as time and resources are limited. Spatially the research is restricted to the Dutch part of the island St. Maarten as well as temporally limited to the aftermath of hurricane Irma in 2017. This limitation is also supported by the fact that the author has been to the island in the aftermath of the hurricanes. This on-the-ground experience could be helpful in the understanding of the problem.
The method to be developed will be based on existing methods and will use, for where possible, existing software packages. This will shift the focus from a completely new method, to an adaptation with potential for implementation in various disaster procedures. This allows for more investigation into existing methods, and cherry-picking effective techniques. By choosing approach developing a method which would be added to a list of unused, existing methods, is avoided. To further reduce the scope, only two existing methods will be selected for rigorous assessment. These will be chosen through the theoretical framework and literature research.
For this research, the task of object detection, as used by various other academic methods [Vetrivel et al., 2016b; Kakooei and Baleghi, 2017], will not be used. The datasets available allow for the use of existing building outlines, gathered from recent data. The NLRC uses voluntary cartographers to map disaster areas shortly after a disaster and where possible, in case of the hurricane on St. Maarten, shortly before a disaster. Making sure that maps are up to date and can be used for planning. This eliminates the need for object detection from data sources, however requires the data input to be properly matched.
The research is limited to the various datasets available through the 510 team of the NLRC as cleaning, relief and reconstruction activities on the island make new data collection impossible. However these datasets can be considered a good representation of available data in the wake of large scale disaster. The cooperation with the data team of the NLRC allows for a good balance between the technical approach of the Delft University of Technology and a more societal aspect from a humanitarian organisation.
Section 3.1 will elaborate some of the scope reductions with literature research.

3 RELATED WORK

This chapter will give an overview of the literature related to the classification of damage to buildings inflicted by disasters. Firstly the definition of some of the terms will be discussed, further defining the research scope. This is followed by a description of categorisations within the field of remote sensing for disaster situations. From these categorisations a selection of methods is made to be used in this research as described in chapter 4. The research discussed is not limited to hurricane damage, as the classification of external damage to buildings is comparable between various natural disasters.

3.1 DEFINITION

The International Federation of Red Cross and Red Crescent Societies [2017] defines a disaster as follows:

> "A disaster is a sudden, calamitous event that seriously disrupts the functioning of a community or society and causes human, material, and economic or environmental losses that exceed the community's or society's ability to cope using its own resources."

These characteristics in this definition emphasize the need for timely intervention by others outside a community or area to help and support those affected. Ray Shirkhodai notes in Al Achkar et al. [2008, p. i] that a rapid overview of the situation and extent of damage is necessary to achieve this goal. This is corroborated by Schweier and Markus [2006]. To do so with minimum risk to aid workers, the international community established the so-called International Charter [Bessis et al., 2003]. With resources from various space agencies around the world it became possible to use SEM to provide rapid situation awareness after a disaster. However as described by Kerle et al. [2008] there are a diverse selection of other remote sensing techniques which can be used for the collection of data, which could make other forms of emergency mapping (EM) possible. This research will take into account this broader approach to remote sensing, looking at advances in unmanned aerial vehicle (UAV) and shrinking data collection technologies as new data sources in the immediate aftermath of a disaster.

The implementation of EM has various scales of resolution. For the purpose of this research these have been categorised as follows:

- Damage detection
- Damage classification
- Damage assessment

The lowest resolution considered is damage detection. In this form of EM the focus is to differentiate between buildings with and without damage. This comparable to the studies that can distinguish between two grades of damage as described by Dong and Shan [2013]. An example of this is Wang and Jin [2012], in which image classification is used to derive the difference between buildings damage and not damaged by a disaster.

One step up in resolution from detection is the damage classification as used within this research. For classification various grades of damage need to be considered. Dong and Shan [2013] describe this as three grades or more. They also provide a framework for five damage classes that can be used in achieving damage classification. These classes are derived from Grünthal [1998], however the ambiguity introduced with five classes, especially between the three middle grades, is not beneficial for humanitarian aid organisations. Therefore the classification method proposed by Al Achkar et al. [2008] will be used in this research. This framework is focused on damage inflicted to buildings, allows for sufficient variation between damage grades and has example of damage induced by wind. A variation of this is also used by the NLRC [available on 510.global].

The last resolution is damage assessment. This requires more insight in the damage caused, as well as interior damage which is usually not observable in EM or SEM. Therefore people on the ground are required to do thorough investigation into the damage caused. The exception to this is the use of high resolution oblique imagery, which in some cases might be able to distinguish damage in the vertical plane [Vetrivel et al., 2016a], however most damage assessment will need to be done by humans with guides from governments, like from The Federal Emergency Management Agency [2016].

3.2 FRAMEWORK

To assess the various remote sensing techniques and damage classification methods a theoretical framework has to be established. This framework will allow the organisation of methods and technologies and will allow the selection of appropriate approaches in various circumstances. The framework presented here is based on literature research from Dong and Shan [2013] and Kerle et al. [2008] in combination with requirements from the field.

Requirements from humanitarian organisations can be derived from the definition of a disaster as presented in section 3.1 and indications from Al Achkar et al. [2008] and Schweier and Markus [2006]. The unexpected nature of a natural disaster make it hard to prepare; the collection of datasets can therefore most of the time not be planned in advance. This is described by Christopher and Doeglas [2015] as window of opportunity. This describes the short amount of time certain data can be collected, this may vary per disaster. An example of this is that in case of a hurricane, clouds can obscure the struck area. Furthermore, is the magnitude of a disaster important for the planning of relief operations [Al Achkar et al., 2008; Schweier and Markus, 2006]. Which requires timely data, this is an conceptualisation of the time it takes to get data to the user while it is, still, or most valuable [Christopher and Doeglas, 2015]. In the case of disaster this can be defined as directly when available. The faster data is available for analysis, the quicker people affected by a disaster can be helped. Furthermore is the precision of the data a consideration as well. For the very first relief operations global data of damage will suffice as these kind of operations require a specific time to set up as well. However very quickly after that more detailed information is necessary for the planning of future operations and long term relief. Reflecting back on the requirements of time and resolution, it can be concluded that the chosen remote sensing techniques are very dependent on the resolution they can offer as well as the timely manner they can do that in. The methods chosen for implementation will need to reflect this as well.

An extensive analysis and description of remote sensing techniques can be found in Kerle et al. [2008]. The various specifications, capabilities, operation advantages and limitations, and examples are presented per system. This allows for a good overview of all the possibilities. However humanitarian organisations do rarely have the opportunity to choose out of all options as they require specialist operators or equipment. Those are most of the time neither available in disaster areas which limits the options. Exceptions on this rule is the availability of satellite data that becomes more open for humanitarian organisations around the world through projects like the International Charter [Voigt et al., 2016]. This program allows all involved in relief operations to gain access to satellite data and subsequent information. The advances of portable UAVs and smaller capture technologies also allows humanitarian organisations to quickly gather high resolution imagery of areas affected by disasters. They provide an economical substitute for regular aerial surveillance [Nex and Remondino, 2014] and are already more implemented in disaster situations [Lieshout, 2017; Johnson, 2017].

Dong and Shan [2013] give an overview of various building damage research up until 2013. A summery of the various techniques and data types is also presented. The classification of methods is done on the basis of data, collection platform and amount of damage levels that can be detected. This subdivision allows for the selection of appropriate methods in varying situations. However the clear absence of any indication of accuracy of methodologies only allows for an overview of the field of research and less for selection for implementation in operational procedures.

For an adequate selection of methods a combination of the above, with time indication, resolution, data, and accuracy is necessary. Some of these indicator will be connected and change dependently, however an overview in which all is displayed allows for a quicker overview of methods connected to remote sensing techniques. Section 3.3 gives such an overview.

3.3 EXISTING TECHNIQUES

Table 3.1 summarises the findings of various research of the past 15 years into the automated detection or classification of damage to buildings. This is a non-extensive summary but allows for a clear overview of the various approaches. Only automated solutions are taken into consideration, all information about technique, resolution and accuracy has been taken from the respective paper, while acquisition time has been related to sensing technique or taken from Kerle et al. [2008]. From this table it is clear that most research is already focused on the datasets mostly available in disaster situations. Furthermore is most of the research dedicated to the detection of damage and not classification. This proves a gap in the research which could benefit the humanitarian organisations. In this the fusion of methods with high accuracies and complementary remote sensing techniques could hence lead to improvements in the automated classification of damage.

Method	Technique	Resolution	acqn time	accuracy
[Antonietta et al., 2015]°	Satellite Optical	0.8x0.8m	6 days	70-80%
[Brunner et al., 2010]°	Satellite Optical and Satellite SAR	0.6x0.6m 1.1 x 1.0m	6 days	90%
[Li et al., 2017]°	Satellite Optical	0.6x0.6m	6 days	70%
[Martha et al., 2015]°	Satellite Optical	0.6x0.6m	6 days	NA
[Menderes et al., 2015]°	Aerial Optical	0.3x0.3m	Days	90%
[Ozisik, 2004]°	UAV Optical	NA	Hours	70-80%
[Samadzadegan and Rastiveisi, 2005]*	Satellite Optical	2.44x2.44m	3 days	74%
[Vetrivel et al., 2016b]°	UAV Optical	NA	Hours	80-90%
[Yun et al., 2015]°	Satellite SAR	2.7x22m	6 days	NA

Table 3.1: Overview of existing methods. * marks classification, and ° marks detection as described in section 3.1 [From: own work]

3.3.1 Selected methods

Methods considered for this research are limited to those that can be used with the data available and that have considerable accuracies in the prediction of damage classes. From table 3.1 it is clear that there are various valid options for the detection of damage and even possibilities for the classification of damage.

The selected methods for this research are Vetrivel et al. [2016b] and Yun et al. [2015]. These showed most promise in the research of the summary represented above. Vetrivel et al. [2016b] uses a machine learning approach and achieves a high accuracy. This methods is similar, using more modern techniques to Samadzadegan and Rastiveisi [2005] which was able to achieve classification of datasets available in this research. The implementation of the method will prove the transferability as claimed in the paper and will provide insights into the use of machine learning for classification of damage. Yun et al. [2015] is the only paper in the list that can cite users of the data and provides analysis using this method for other disasters. Proving the worth of the method and possible transferability. Both methods also use complementary techniques which could facilitate the development for an improved method using the fusion of data sources.

4 METHODOLOGY

Figure 4.1 represents the organisation and results for this research. The structure has been based on the findings of chapter 3. This chapter will discuss, and expand upon the various steps. First block A, the description of the theoretical framework; followed by block B the evaluation of existing methods; concluding with block C the description and assessment of a proposed method. Some datasets and tools will be mentioned in this chapter, however a full overview of all proposed tools and datasets can be found in chapter 5.2.

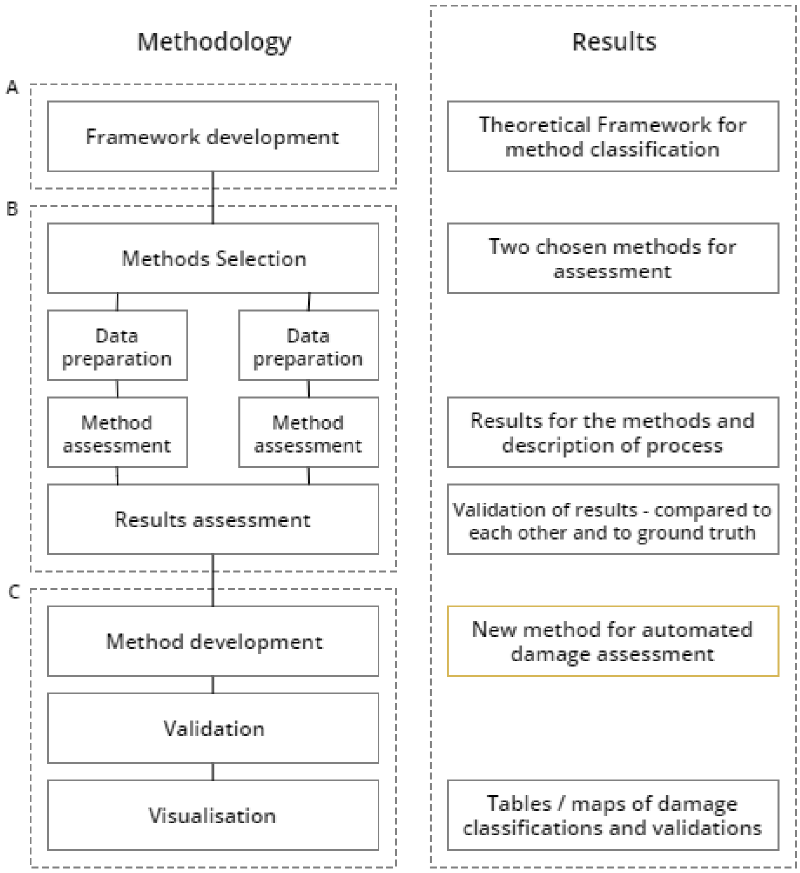

Figure 4.1: Methodology structure - the research objective is highlighted with a yellow boundary [From: own work]

4.1 THEORETICAL FRAMEWORK

For a solid basis, extensive literature research is required. The theoretical framework provides this comprehensive backing with the various criteria to which a method needs to suffice for efficient use in a disaster situation. The humanitarian field provides some of the criteria, besides those that are based on existing research for other methods. The combination of these allows for a new categorisation and overview of existing methods.
Besides the direct criteria for classification of methods, the theoretical framework also allows for background information on various topics needed in this methodology and to further define the scope for the research. Chapter 3 gives an overview of the developed framework, various criteria and background information.

4.2 EXISTING METHODS

The extent of existing methods can be found in section 3.3. To reduce the scope of this research a selection out of this group will be made for further analysis. This investigation into these methods will serve as the base upon which the proposed method can be developed.
To adequately select methods for further assessment, the extensive group needs to be tested and classified based on the theoretical framework. The first selection is done on the results mentioned in the literature combined with the applicability in disaster situations. Methods are not excluded if they do damage assessment for other types of disasters as the indicators of damage are likely to correlate. The results of this selection can be found in section 3.3.1.
Before the methods can be assessed, it is necessary to prepare the data. Normally this would involve the collection of data as well, however all data has already been collected in the response to Hurricane Irma from the NLRC. An overview of the available datasets can be found in section 5.2.2. These are however raw datasets and they need to be assessed and prepared before they can be used. An example of this is the productions of interferometric products using the tool Doris from the TU Delft [MGP Radar Group, 2012]. An important preparation step for all datasets is the spatial matching and geo-referencing, however the topic of an automated approach can be a thesis on it's own and for this research a manual approach will be taken. A 30 meter resolution, digital elevation model (DEM) is available from Japan Aerospace Exploration Agency (JAXA) [JAXA, 2017] to aid the correct matching of the datasets.
To better understand the existing methods for damage classification in disaster situations, the chosen methods will be prepared and executed for the case study area. These steps will provide insight in the transferability of existing methods to other disasters and provide benchmark results for automated classification. Techniques learned from the rebuilding of a method, preparation of data and subsequent results, could be transferred to the proposed method. The reconstruction of the existing methods will be done in software known and available to the author and will follow the described processes as closely as possible.
Since the result of a method is what will be needed by humanitarian organisations, it is necessary to validate and compare these. This comparison will be done between the results of the reconstructed methods and the ground

truth generated by the NLRC. This will be done in a one-to-one comparison as well as with deeper analysis. The latter will consist out of the analysis of variance of the classification and a confusion matrix as described in [Antonietta et al., 2015]. Visualisation of the results is also part of the assessment. The outcomes of the methods and analysis need to be understood by those who have not been part of the whole process.

4.3 PROPOSED METHOD

The development of a proposed method will focus on the fusion of characteristics of existing methods and datasets. Through the development of this proposed methods, the main research question will be answered. The synthesis of the best components of the previous assessed methods can lead to a more accurate, and effective approach to automated damage classification. In the process of development, the requirements towards data and tools will become clear. These might vary from those found in existing methods but will be based on similar principles.

The proposed method will not take into account the detection of buildings, as these are available from OpenStreetMap [openstreetmap.org] and have been updated shortly before the landfall of hurricane Irma on St. Maarten. These updates of the maps have been done by the volunteers of the Missing Maps network [missingmaps.org] and are validated by experienced cartographers.

Validation of the method will assess the accuracy and effectiveness. These will be compared to the outcomes of the assessment of existing methods. Similar analysis will be used on the results as described in section 4.2. The method will also be tested on the theoretical framework, which has been used for the selection of the existing models.

From all the development of the method and subsequent analysis various results will be visualised for a more accessible transfer of knowledge. The goal of the proposed method would be an accurate classification of the damage on a building level visualised on a map. These could be aggregated to higher levels, e.g. block or neighbourhood level, for other uses in the field. The results of the analysis of the methods will be more statistical and will need to be summarised in tables and percentiles.

5 ORGANISATION

5.1 PLANNING

The planning presented in this chapter is representative of the structure presented in chapter 4, the various steps and results are represented in both the tabular representation [Table 5.1] as well as the Gantt-chart [Figure 5.1], albeit under slightly altered names. The Gantt chart provides a more detailed overview of the various steps including time for writing and correction by supervisors. Leading in the configuration of the planning have been the presentation moments [or Ps]. P3 has been used as a subdivision between the work from block B and C as described in the previous chapter. This to ensure sufficient time before the final presentations for potential slight adjustments in the progress.
Biweekly meetings have been agreed upon with the supervisors; supplemented with weekly updates when necessary. This to ensure progress and to facilitate the completion of the research in the remainder of the 2017-2018 academic year.

Task	Time allocated	
	Start week	Duration in weeks
Framework development	Week 48 [2.3]	6
Methods selection	Week 48 [2.3]	6
Data preparation	Week 5 [2.10]	4
Methods assessment	Week 7 [3.1]	5
Results assessment	Week 10 [3.4]	3
Method development	Week 10 [3.4]	6
Validation	Week 16 [3.10]	3
Visualisation	Week 17 [4.1]	2

Table 5.1: Planned tasks and allocated time, TU Delft academic weeks between brackets. [From: own work]

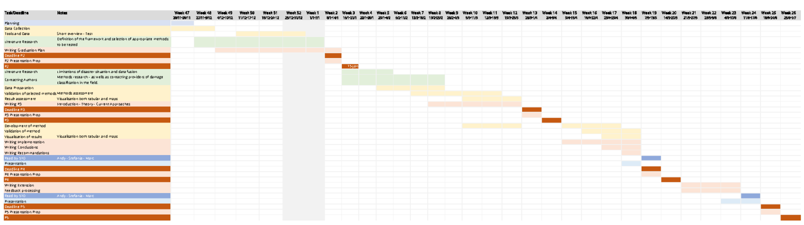

Figure 5.1: Gantt chart representation of the planning - full size attached in Appendix A [From: own work]

5.2 TOOLS AND DATASETS USED

In the following sections a short overview of proposed tools and data are presented. These relate to the methodology described in chapter 4 and methods selected in section 3.3.1.

5.2.1 Tools

The proposed tools in table 5.2 are select for the assessment of the existing methods as described in section 4.2. These are preliminary propositions and might change in the duration of the research project.

Tool	For	Notes
Doris	To prepare SAR datasets for change detection	Cywin needs to be installed; New to author
Qgis	For visualisation, change detection and Geo-referencing	–
Python	General programming language, implementation of Tensorflow available	Change detection possible as well
Tensorflow	Machine learning tool, with pre-trained networks available	Good documentation; new to author
R	Validation and statistical analysis	Has simple machine learning capabilities

Table 5.2: Tools proposed for this research. [From: own work]

5.2.2 Data

The data for the assessments of the methods and development of the proposed methods has been summarised in table 5.3. More datasets than needed for the assessment of the existing methods are represented, as the association between datasets needed for the proposed method might dependent on other datasets. The author is in possession of all datasets as described in section 4.2. It must be noted that not all UAV optical data is of the exact same resolution or from the exact date, therefore the average has been indicated for the resolution and a interval for the dates.

Platform	Technique	Resolution	Acquisition date	Source
Satellite	SAR	2.7x22 m	16-Sept-2017	Sentinel
Satellite	SAR	2.7x22 m	25-Sept-2017	Sentinel
Satellite	Optical	0.49x0.49m	14-Sept-2017	DigitalGlobe
Satellite	Optical	0.49x0.49m	20-May-2017	DigitalGlobe
Aerial	Optical	0.2x0.2 m	20-Feb-2017	IGN
UAV	Optical	0.04x0.04 m	11-Sept-2017 – 2-Oct-2017	NLRC – RescUAV
Satellite	DEM	30x30 m	unknown	JAXA
–	Ground truth	building	2-Oct-2017	NLRC
–	Building outline	building	2-Oct-2017	OpenStreetMap

Table 5.3: Datasets available for this research. [From: own work]

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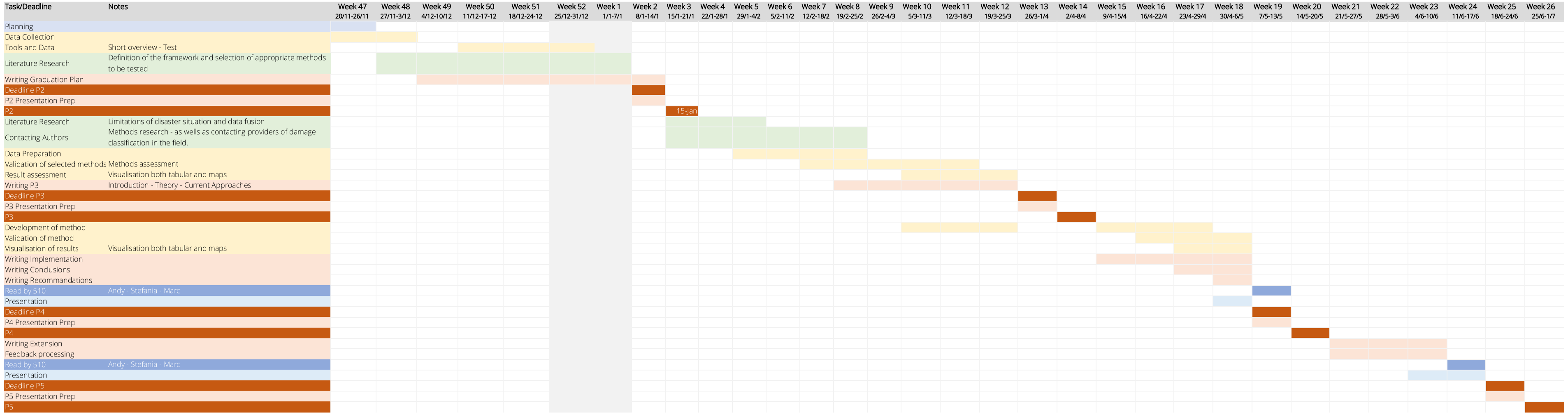
A GANTT CHART

Please find the full size Gantt chart on the next page



Task/Deadline
Notes
Week 47 20/11-26/11
Week 48 27/11-3/12
Week 49 4/12-10/12
Week 50 11/12-17-12
Week 51 18/12-24-12
Week 52 25/12-31/12
Week 1 1/1-7/1
Week 2 8/1-14/1
Week 3 15/1-21/1
Week 4 22/1-28/1
Week 5 29/1-4/2
Week 6 5/2-11/2
Week 7 12/2-18/2
Week 8 19/2-25/2
Week 9 26/2-4/3
Week 10 5/3-11/3
Week 11 12/3-18/3
Week 12 19/3-25/3
Week 13 26/3-1/4
Week 14 2/4-8/4
Week 15 9/4-15/4
Week 16 16/4-22/4
Week 17 23/4-29/4
Week 18 30/4-6/5
Week 19 7/5-13/5
Week 20 14/5-20/5
Week 21 21/5-27/5
Week 22 28/5-3/6
Week 23 4/6-10/6
Week 24 11/6-17/6
Week 25 18/6-24/6
Week 26 25/6-1/7
Planning
Data Collection
Tools and Data
Short overview - Test
Literature Research
Definition of the framework and selection of appropriate methods to be tested
Writing Graduation Plan
Deadline P2
P2 Presentation Prep
P2
15-Jan
Literature Research
Limitations of disaster situation and data fusior
Contacting Authors
Methods research - as wells as contacting providers of damage classification in the field.
Data Preparation
Validation of selected methods
Methods assessment
Result assessment
Visualisation both tabular and maps
Writing P3
Introduction - Theory - Current Approaches
Deadline P3
P3 Presentation Prep
P3
Development of method
Validation of method
Visualisation of results
Visualisation both tabular and maps
Writing Implementation
Writing Conclusions
Writing Recommandations
Read by 510
Andy - Stefania - Marc
Presentation
Deadline P4
P4 Presentation Prep
P4
Writing Extension
Feedback processing
Read by 510
Andy - Stefania - Marc
Presentation
Deadline P5
P5 Presentation Prep
P5

COLOPHON

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