Context Fusion for Driveability Analysis

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Abstract - Driveability analysis is a quite complex problem that for its solution depends on several factors. One of these factors concerns the type of vehicle for which a drive-way should be determined. Besides this, the terrain structure, the type of vegetation but also the ground type and its conditions play important roles. Driveability analysis will consequently include analysis of primarily geographical information and the outcome of this analysis can be used to support decision making in command and control systems. However, quite often the required geographical information is represented in a resolution that is either too low and/or is represented with a high degree of uncertainty that cannot be neglected. In this work, an approach to driveability analysis is presented in which geographical information is regarded as context information that eventually is fused to generate paths, that may be drivable for certain types of vehicles. This information is fused by means of a knowledge-based technique that determines the driveability from a set of qualitative driveability impact factors.

1 Introduction

Driveability analysis (also called trafficability analysis) of terrain and geographical data offers an important technique for decision support for all kinds of movements in the terrain. This type of analysis is needed for the judgement of possible movements of targets (target tracking) and for the planning of future movements. An important data source for such an analysis is a digital terrain model [1,2], which in this case is a high resolution digital terrain model generated from laser radar. In [2] is a method for finding essential terrain objects such as ditches and ridges described. The geographical data are generally represented as map data that in order to become useful need to be in a high resolution. Parts of this work has earlier been described in [3].

The research on driveability has been subject to fairly intense studies e.g. Donlon and Forbus [4] have developed a domain theory for trafficability to partition regions according to some criterion. They discuss both complex factor overlay and combined obstacle overlay partitions regions according to the type of terrain and combine them into areas of homogenous characteristics. A combined obstacle overlay characterizes the terrain according to its effect on the vehicular movement. Bonasso [5] presents a trafficability theory using first-order predicate calculus to enable reasoning about trafficable paths without the need for a detailed terrain model where only a limited set of qualitative values are used, which e.g. allows a desert to have the value SOFT given to a rigidity attribute, and FREE to a forest density attribute. Much existing work on trafficability has focused on real-time applications, mainly path planning for unmanned ground vehicles (UGVs), which move in unknown areas [6],[7],[8],[9],[10] and [11]. In the work by Johnson et. al. [12] and Kruse et. al. [13] hyperspectral or multispectral data are used to classify areas according to their surface composition, but with limited success. Kruse et. al. improve the usefulness of their approach by using data fusion to identify areas which e.g. have both high clay content and high slopes. Another fusion oriented approach is given by Glinton et al. [16]. Sapounas et. al. [15] use an object-oriented approach and cost functions to calculate bounding regions and shortest paths. The cost functions represent the effect of the terrain on the travel speed. Finally, Slocum et al. presents an approach based on a trafficability engine [14].

The rest of this paper is organized as follows. In Section 2 context fusion is defined. This section includes also a definition of the problem addressed in this paper. A discussion of existing driveability impact factors is discussed in Section 3. The digital terrain model used is described in Section 4. Driveability analysis, basically including the used measures of driveability and the final cost function with its impact factors is discussed in Section 5. Finally some results are presented in Section 6 followed by the conclusions and some further research topics in Section 7.

2 Context Fusion

The main objective of this work is to develop a method for driveability analysis that determines whether a certain path through a terrain area is...
possible to travel given a certain type of vehicle. The result of this analysis should be visualized on a map where the driveability is highlighted. To be useful in real-world applications information from a large number of sources is required. The focus in this work, however, is concerned with the overall method and basic structure of driveability. Still, in addition to the digital high resolution data model other geographical information is used as well, e.g. forest data including the density of the forest. Finally, information about the vehicle is used, both with respect to its properties (e.g. if it has wheels or tracks, its weight etc.), and its capabilities (e.g. how steep slopes it can climb). This problem turns out to be complex where the various types of information must be fused and presented to enable generation of complete driveability maps. Here context information refers to the geographical background information as well as the terrain elevation data model. The different sources of context information needs to be fused with the vehicle information to create the desired map. The result of this fusion process thus itself provide a new context, and is therefore referred to as context fusion.

To carry out the fusion, the impact factors of all the various types of context information must first be determined and then, finally, the driveability cost is determined through a cost function. The impact factor of a particular context data type refers to the factors in the context that impact driveability.

3 Driveability impact factors

Driveability is a complicated matter which does not lend itself to simple solutions. It is affected by many factors, including the vehicle type, soil, weather, slope, etc. Although outside the scope of this work, a particular problem is to collect all the required information and represent it in a reasonably high resolution. Driveability is path dependent. It may e.g. be possible to drive down a slope, but not the other way around. Most terrain features cannot be regarded in isolation. Below are some examples:

- A road barrier, a large stone, or a tree can only be seen as obstacles if it is impossible to drive around them.
- A wide ditch may be seen as an obstacle to a driver who must cross it, but not to a driver who can drive inside or around it, or use a bridge.
- A single tree may not be an obstacle, but a dense forest can be a great impediment.
- A slope may not be too steep, but if the soil rigidity is too yielding it may be an obstacle. Vice versa, a mud field may be driveable on a plane area, but not at a slope.
- A ditch may not be driveable if it is filled with water, nor if trees or other obstacles are present in its proximity.
- Vegetation and crops have an impact on the driveability of soils. E.g., grass and grain often improve the driveability, while vineyards decrease it.

There are also other features, which are not intuitively possible to represent in a geometric model, but which may still affect the driveability. For example surface roughness or vegetation may decrease the speed, damage the vehicle, or bring it to a stop. Both stickiness and sinking soil properties affect the driveability, but possibly in different ways. Sometimes the effect is not strictly physical. Mine fields and radar installations may be examples of non-terrain features which decrease the wish to drive through such areas, whereas a forest may be a good place to hide. Strictly speaking, these aspects should instead be dealt with in threat analysis, although they still deserve to be mentioned in this context.

Many terrain features change their properties over time. Forests are growing denser and higher, rivers are bending, etc. During a war bridges, roads, etc., may be destroyed.

Weather properties may affect the terrain properties, thereby affecting the driveability. For example, soil rigidity is weather dependent. During a cold period a mud field may turn into a passable field. A cold winter may turn a river, that is otherwise impossible to pass, into a frozen road. However, it is not sufficient to know what the weather is like right now; historical values must be taken into account as well. The lake will not be frozen simply because the temperature falls below -10˚ C right now; it must have been cold enough for a longer period. Hard winds or floods may also affect the driveability.

Example of vehicle properties include width, length, height, override diameter, maximum gap to traverse, ground clearance, maximum step, maximum gradient, maximum tilt, specific ground pressure, and maximum straddle. Properties such as maximum speed is not of any direct interest to the driveability reasoning performed in this work, although it can be used as a basis for driveability calculations [15]. Sometimes the terrain features and the vehicles interact in unexpected ways. E.g., even if a vehicle can override small trees, the resulting pileup of vegetation may be a too great obstacle for it to pass. This effect is greater for wheeled vehicles than for tanks [17]. The properties are also not constant for the same feature. A ditch or a road, etc., may for instance grow wider, or fork, which is due to changes across the space.

To start with, it may not be necessary to know the exact value of a property. It may be enough to use qualitative values (e.g. width is equal to large), which can later be transformed into a real value, as is suggested by Bonasso [5], or by an interval as will be suggested in this paper. As a consequence of the complexity of the problem, the complexity must be reduced with respect to basic assumptions and simplifications, which will be discussed further subsequently.

4 Digital terrain model

The data used for creation of the 3D terrain model is registered by a scanning airborne laser-radar called TopEye [1]. Uncertainties of the terrain elevation is in this case mainly dependent on the sampling density, which varies depending on flight elevation and speed. The data used in
this work has an average density between 0.3 and 0.4 m. In order to detect significant terrain features, the original sensor data is firstly pre-processed to eliminate non-terrain data, e.g. trees and buildings. The pre-processing step produces a surface defined on a rectangular grid with 0.5 m between grid points.

As a first step, the surface is partitioned regularly into tiles, which is a sub surface that covers a square with sides 2 m. The set of tiles is called $T$. These tiles are sorted into a number of categories of tiles, the spatial categories. A spatial category is a set of tiles with similar features, e.g. with similar inclination or with edges at similar locations. The categories is defined by using a set of representative tiles $REP \subseteq T$. Three different types of representative tiles are necessary to achieve a sufficiently accurate surface model. The most important of which can be described by rotations and translations of the basic category forms, shown in figure 4. In total, 115 spatial categories are used. For further characterization see [2]. A distance metric $\text{dist}: T \times REP \rightarrow \mathbb{R}$, for comparing the similarity of a tile to a representative is defined. A category $[r]$, $r \in REP$ is defined, using the metric $\text{dist}$, as the set of all tiles that are more similar to $r$ than to any other $k \in REP$.

Every category corresponds to a unique string, called a symbolic tile. A tile is compared with every representative and are substituted by the corresponding string. The tiles can be stored in a database in accordance to a relatively simple structure [1], [18] from which data can be efficiently accessed.

### 4.1 Finding and connecting segments

A filter corresponds to a particular sequence of connected symbolic tiles describing the feature that will be subject to the search. The approach taken here is to use the specific and characteristic cross-sections, which exist for all terrain formations. For instance, a cross-section of a hill can first be described with an upward directed slope followed by a slope directed downwards. At a conceptual level the cross-section of a terrain formation consist of a start segment, a possible middle segment and an end segment, see figure 2. The filters can be of different sizes depending on the requested terrain feature. Consequently, the search strategy must be sufficiently flexible to accommodate these demands.

It turns out that a two level search strategy is the most appropriate. As a result of the first matching step a large number of segments will be found. To find out which of these segments that are part of the feature, adjacent segments of similar cross-sections must first be connected. Segments found in step 1 are connected only if the segments midpoints are sufficiently close and if the orientation of the cross-section segment is similar enough. Some methods for doing so is described in [2].

The filters are specified in a plain text file that is parsed by a Java-program and applied to the symbolic tile data file. A number of filter types for different features have been developed and tested. Among them can filters for determination of ditches, ridges, hill tops and flat areas including roads be mentioned.

At the same time as determining whether an object is present or not, an initial estimate of feature area and some impact factors can be calculated. In particular, slope angles of slopes, convexities and concavities, as well as elevation difference and width of concavities, fig 3. Apart from serving as impact factors for the driveability analysis, these values are used for post-detection refutation of features to exclude small and shallow features of negligible influence. Algorithms for acquiring better estimates of impact factors are under development, some possibilities are given in [3].

### 4.2 Geographic data

The major source of data besides the 3D-data is the real-estate map, which contains data about the geographic classification of the covered area in scale 1:10000. These data are organized in overlays, where each overlay represents a certain geo-class, e.g. buildings and ground classifications are found in different overlays. Apart from providing the driveability analysis with necessary data, the map provides a highly structured representation of an area of interest (AOI), which is adequate for user presentation and interaction. Consequently, when fusing the map data with other sources it is desirable to keep most map structures that are consistent with

1. A property of TopEye AB, Sweden
the more recently collected data. Although small, the data uncertainty due to imperfections in the collection process can not be disregarded when fusion with other high-resolution sources is at hand. More importantly, generalizations due to aggregation, simplification, smoothing, exaggeration, displacement etc., [19], are typically made with consequences for the locational accuracy that is difficult to assess. Problems concerning the relative positions of the terrain features versus the map features inevitably arises, producing apparent contradictions. When serving as a basis to driveability analysis, another problem concerns the very rough, sometimes none, estimate given for most impact factors, e.g. the width of roads or the density of trees in a forest. In the absence of such values either defaults must be used or experienced users must be consulted for more specific estimates.

Even though the map is a general and important source of geo-class data there may be other sources of such data. For example [18], provides a way to locate roads, buildings and individual trees by using the elevation and intensity returns of the laser radar. Such data will improve the accuracy of some locational estimates as well as provide the driveability analysis with some of the otherwise absent values of impact factors, but will not be considered further in this paper.

5 Driveability Analysis

Driveability is a measure of the possibility of a certain vehicle to follow a path $p = (p_1,p_2)$ from the start $p_1$ to the end $p_2$. There are off course infinitely many such paths between $p_1$ and $p_2$ and there are infinitely many start and end points in a given AOI. Using a finite, but high resolution of 0.5 m still makes the analysis prohibitively expensive in computational terms. To reduce the computational complexity, as well as to lay a foundation for user interaction and spatial reasoning, another approach is suggested. Instead of viewing the AOI as an image, the AOI shall be viewed as a set of objects. These objects have attributes and belong to different classes. Consequently, in order to be able to calculate the driveability for a given AOI, a commitment to which objects, classes and attributes the driveability analysis recognizes has to be made. The objects of concern in this application will be called terrain objects (TO). The complete enumeration of the entities that constitute the terrain objects in this application differs depending on the available data sources and their implicit ontology. Any physical map entity that has a spatial extension, including roads, buildings, fences and similar line objects that direct influence driveability must be considered terrain objects. Every 3D terrain feature is also a terrain object. In analogy with the map, the result of applying a certain filter to the laser-radar data defines a separate overlay for each different filter. The terrain objects from different overlays must then be fused to construct a relevant basis for a driveability analysis, i.e. a driveability segmentation. The requirements of such terrain object fusion will be discussed below. Fusioned terrain objects will be called compound terrain objects (CTO).

A suitable driveability segmentation provides a complete segmentation of the AOI, where each CTO belong to three different types of classes. The types of classes are 3D classes, cover classes and obstacle classes.

- 3D-classes = \{Concave, Convex, Slope, Flat, Concave&Slope, Convex&Slope, Undetermined\}
- Cover-classes = \{Water, Mash, GroundVegetation, OpenGround, Road\}
- Obstacle-classes = \{Building, Forest, NoObstacle, DenseUrbanArea, Remains, LineObstacle\}

Evidently, the Cover-classes and the Obstacle-classes contain (essentially) a subset of the classes available from the map. These classes are the necessary and sufficient classes to express the map data complexity in the current version of the driveability analysis. Each classification influences which calculations that are necessary and that which makes sense at all. The classes also differ in their default properties, in the way they are influenced by weather and their compactness. Furthermore, the obstacle classes can be both elements that are considered single entities (Building, LineObstacle) and elements, which are considered aggregations of smaller obstacles (Forest, DenseUrbanArea, Remains). Building, LineObstacle and DenseUrbanArea are compact objects, whereas Forest and Remains are not. The 3D-class “Undetermined” must be included as the terrain feature filtering can not be expected, as the map, to provide a complete segmentation of the AOI.

5.1 Path selection

Driveability, as defined above, is a concept that is meaningless without a path to refer to. In this work, the focus is on the analysis of meaningfully, i.e. qualitatively, different paths that are representative of an AOI. A path is qualitatively different than another path if it traverses a different CTO or if the traversal of a certain CTO is made in a qualitatively different way. The qualitatively different ways of traversing a CTO depends on its classifications. For instance, it is only meaningful to differentiate between paths going from $p_1$ to $p_2$ and from $p_2$ to $p_1$ if the area is sloping substantially. Also, it is only meaningful to consider “leaping” over an object if it is a concavity, not if it is a convexity. In this paper, however, the same type of paths are considered for every CTO. In fact, the paths are identified with traversal directions. The possible directions are $D = \{E,NE,N,NW,W,SW,S,SE\}$, representing travelling east, north-east etc.

The directions $D$ can also be considered default paths that should be used for the 3D class Undetermined, i.e. if the CTO is labelled Undetermined, the qualitatively different paths traversing the CTO are members of $D$.

5.2 Requirements of Terrain Object Fusion

As mentioned, the data can be viewed as organized by a set of overlays, where each overlay contains a partial segmentation of the AOI. The fusion task at hand is to provide the driveability analysis with a complete, non-conflicting
segmentation of the AOI, where all areas are CTOs. An approach to constructing a driveability segmentation would be to simply intersect all overlays [4]. The problems that arise due to uncertainties and generalizations in the data, changes in the terrain and the fact that when some classifications coexist at a location a conflict is at hand. Examples of conflicts are CTOs classified as roads with crossing convexities or as concavity and water. These types of conflicts must be detected and resolved if the desired segmentations are to be achieved. As such, the terrain object fusion problem includes association, change detection and decision fusion problems commonly encountered in spatial data fusion [20]. An important consideration in this context is that the desired representation is not a driveability segmentation where the location of the objects from several sources are combined to give a more accurate locational estimate. Rather, the map representation should be kept for the earlier mentioned reasons. In particular, topological relations between TOs are of importance in the driveability segmentation. Even if not conflicting, without proper consideration, the driveability segmentation may consist of unnecessary many, small CTOs which defeat the entire idea of reducing the AOI into a manageable number of homogeneous entities. In the current version, the map are assumed to be correct and accurate in all aspects. If a conflict with 3D-data occurs, the map has precedence.

5.3 Impact Factor Attributes

Apart from determining which class of TO that are present at a certain location, some attributes, i.e. the impact factors, of the objects must be estimated as well. In this case convexity gap width, maximum slope angle, minimum cover rigidity, obstacle rigidity, maximum obstacle rigidity and minimum obstacle distance. The intended physical interpretation is indicated in table 1. Rigidity is used as a collection term for material properties, [5]. The corresponding attributes for the vehicles are gap capability, slope up capability, slope down capability, ground pressure, force limit and vehicle width. The use of maximum slope angle, minimum cover rigidity, maximum obstacle rigidity and minimum obstacle distance is connected to the fact that the slopes, covers and aggregated objects have different values at different parts of the single path under consideration. However, the value that determines the driveability of the path is the most disadvantageous value of the encountered values at any part of the path. A path between p₁ and p₂ going through a solid rock obstacle is not drivable not withstanding how easy the path part until encountering the rock may be.

<table>
<thead>
<tr>
<th>Impact Factor</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>convexity gap width</td>
<td>Obvious.</td>
</tr>
<tr>
<td>maximum slope angle</td>
<td>The maximum angle of slope for all parts of a single path.</td>
</tr>
<tr>
<td>minimum cover rigidity</td>
<td>The surface ability to withstand pressure from above. Measured in pressure units.</td>
</tr>
<tr>
<td>obstacle rigidity</td>
<td>The obstacle ability to withstand force when being driven into. Measured in force units.</td>
</tr>
</tbody>
</table>

Table 1: Interpretations of various impact factors.

5.4 Impact Factor Variation

As described earlier, driveability depends on a complex set of factors, many of which are difficult to assess and for which data is frequently missing. The actual formulation of the conditions that must be met for driveability is, however, not difficult to express once the particular case is determined. If it is the case that the path is going down a slope, through open ground and no obstacles are present, the slope angle must be compared with the vehicle capacity in this regard and the rigidity of the ground must be compared with the pressure to the ground exerted by the vehicle. The result is true or false and the driveability is thus determined. This conclusion is only appropriate if the CTO is completely uniform over the entire object in all properties, e.g. the object has the same maximum slope angle for all paths of the considered class. Clearly this is rarely the case. This is a case of spatial variation for path s at individual TOs. Also, the performance characteristics of the vehicles of the same type is not uniform, i.e. type variation exists. Apart from the type variation, the vehicle capacity is dependent on, for instance, the carried load and the maintenance of the vehicle, i.e. temporal variation exists. Type and temporal variation is typically a result of the query of driveability not being specific enough, i.e. the query is put in terms of the driveability of a certain type of vehicle at some unspecified time instant.

In order to accommodate for the variations exhibited by terrain objects, as well as by the vehicles, an extension to the approach must be considered. Instead, consider the attributes to be variational quantities, i.e. the attribute value is different at different parts of the CTO. For instance, the concavity gap width varies somewhat at different locations and the maximum slope angle varies at different parts of a slope. In this work, variation will be described by an interval, [a,b], for every impact factor. This is equivalent to saying that considering different parts of the CTO, the minimum value of the impact factor is a and the maximum value is b. The variation of the maximum obstacle rigidity and the minimum obstacle distance connected with the aggregated classes are mainly connected to the fact that there are different types of smaller objects in the area and that the obstacle rigidity and obstacle distances varies between objects.

The variations described above can not, in general, be considered to describe the uncertainty of the true value of an impact factor. An estimate of the true width of a ditch at a certain location can be subject to uncertainty depending on the resolution of the data etc., but this is not what is described by an impact factor interval [a,b]. Neither should that interval be interpreted as saying that the probability of the width at different locations is uniformly distributed.
over the interval. As already mentioned, the driveability is a measure of the possibility of travelling a certain path. Hence, it is not concerned with the length of the path, or, given a random choice of paths or vehicles, with the probability of success or with average performance. The choices are not random, but made by skilled operators. Therefore, the statistics of random choices are uninteresting, only possibilities are needed.

Still, a confidence measure that reflects the accuracy of the data and of the estimation process is useful to provide operators with an idea of the robustness of the analysis. Deciding that the variation of a width of a ditch is \([a,b]\) from measuring two locations of a 100 m long ditch would clearly justify low confidence in such a description. For the 3D data, the confidence is essentially connected to the density/resolution of data after the ground filtering step, the properties of the ground filtering process and the age of the data. Currently, no measure of confidence is calculated, but all data necessary to do so is available.

Expert users or default reasoning can often provide a qualitative value for an impact factor or a vehicle capacity as an approximation. These qualitative values can be interpreted as intervals as well, i.e. using the value SOFT for a rigidity attribute can be interpreted as saying that the rigidity is in some interval \([a,b]\). Using this interpretation, the same theory can be used regardless of the source of the estimates. Hence, the absence of specific estimates as well as unspecifically made queries and variation in individuals can be modelled using interval valued variables.

### 5.5 Impact Conditions

As already mentioned, the conditions that need to be evaluated to determine driveability are not complicated. Due to the interpretation of impact factors and vehicle capacities as varying, the evaluation of the conditions are, however, not evident. As mentioned, the variation of vehicle capacities are both class variation and temporal variation, i.e. the entity for which driveability is determined is a generic instance of a certain class of vehicles and the determination is valid in some normal, possibly temporally changing, but wide range of conditions. In accordance with the above terminology, the conditions to evaluate are called impact conditions and the resulting values are called impact costs. An impact condition is a conjunction of relations between impact factors and vehicle capacities of the type:

\((\text{impact factor}, \text{relation}, \text{vehicle capacity})\).

The only relations needed are “\(<=\)” and “\(>=\)”. The possible relations between two intervals \([a,b]\) and \([c,d]\) are 13 as described in [21]. In this case, six out of these can be given distinct interpretations regarding driveability, see figure 4 for the relation “\(<=\)”, u as an impact factor and v as a vehicle capacity. The interpretations of these interval relations are, in decreasing order of driveability:

1. All vehicles can pass at every location of the CTO.
2. Some vehicles can pass at every location, but some vehicles only at some locations of the CTO.
3. All vehicles can pass at some locations and none can pass at all locations of the CTO.
4. Some vehicles can pass at every location, some vehicles only at some locations and some vehicles can not pass at any location of the CTO.
5. Some vehicles can pass at some locations and some at no locations of the CTO.
6. No vehicle can pass at any location of the CTO.

Evaluating a single impact condition thus gives an impact cost in \([1, 2, 3, 4, 5, 6]\). Combining the values of impact costs from conjunctions of impact conditions are done by taking the maximum of the values from the individual conditions. The currently used CTO classifications and the impact conditions that are evaluated can be seen in table 2. The last entry in the table is a conjunction of the second and fifth entries.

<table>
<thead>
<tr>
<th>3D class</th>
<th>cover class</th>
<th>obstacle class</th>
<th>way of traversing</th>
<th>impact condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concave</td>
<td>Any</td>
<td>NoObstacle</td>
<td>across</td>
<td>(gap width (&lt;=) gap capability)</td>
</tr>
<tr>
<td>Convex, Concave, Convex&amp;Sl</td>
<td>Any</td>
<td>NoObstacle</td>
<td>on surface</td>
<td>(maximum slope angle (&lt;=) slope up capability) &amp; (maximum slope angle (&lt;=) slope down capability) &amp; (minimum surface rigidity (&gt;=) pressure)</td>
</tr>
<tr>
<td>Slope</td>
<td>Any</td>
<td>NoObstacle</td>
<td>on surface</td>
<td>(maximum slope angle (&lt;=) slope up/ down capability) &amp; (minimum surface rigidity (&gt;=) ground pressure)</td>
</tr>
</tbody>
</table>

For any of the traversal directions \(D\) currently under consideration, the correspondence of that direction with a certain way to traverse the CTO must be determined, e.g. whether the direction corresponds to going down or up a slope. This is solved by approximating the orientations of the TOs as one of the directions in \(D\). The 3D-class “Undetermined” must be included for the areas where no uniform feature can be determined by the filtering process. A CTO belonging to this class has e.g. different slope angles associated for the 8 directions in \(D\).

![Figure 4: The interpretation of “\(u<=v\)” when considering \(u\) and \(v\) as intervals.](image-url)
### 6 Results

An experimental tool for driveability analysis has been developed. Two types of vehicles have been used in the experiments so far. One wheeled troop carrier and one tank. The capacities of these vehicles are sometimes very difficult to obtain. This fact can be modelled by using a qualitative approximation. The value of a driveability analysis is of course dependent on the estimation accuracy of vehicle capacity but, as shown in for instance [4] and [5], qualitatively valued approximations can still be valuable.

As examples of driveability, a square AOI of sides 200 m is given in figures 5, 6 and 7. The area contains a road and some open areas in connection with these. The road is colored green in the figures because of its low driveability cost. Following the road on each side is ditches. Other concavities and slopes can also be seen. Visualization of the driveability is handled by color coding of the tiles belonging to the terrain objects. In this case impact costs = 6 are colored red and impact costs = 1 are colored green. All other impact costs are white.

### 7 Conclusions and Further Work

Many data sources are necessary if successful driveability determination shall be possible. In particular, 3D data in high resolution is important to determine terrain features and their attributes. Fusion of context sources and vehicle information is required to enable adequate analysis of the properties of the context in which the vehicles move, i.e. context fusion is needed. Requirements on data sources and processes are described. A formulation of driveability
analysis in terms of terrain objects, impact factors and impact conditions is presented. The suggested method accounts for the dependence on both path and vehicle characteristics. Most terrain features and vehicles exhibits variation that cannot be neglected. An approach to handling this phenomenon is presented. Handling confidence measures in the estimate of such variational qualities is still to be resolved. A prime candidate for locational uncertainty representation in this context is rough set theory, which is increasingly popular in handling geographic information.

References


