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GEOMATICS IN PHYSIOGNOMIC LANDSCAPE RESEARCH

A DUTCH VIEW

4.1 INTRODUCTION

Starting a chapter by this title implies a lot of explanation to the reader. Terms like 'geomatics' and 'physiognomic landscape research' promise a wide interest in a diversity of scientific domains, especially when the geomatics component is the main focus.

In the pioneer stage of conducting physiognomic landscape studies by use of automated procedures most scientists discerned the limitation of computer capacities and the availability and accuracy of data. However, they affirm positively the role of computations; geo-information was already mentioned. This chapter surveys the expected role by the key-word geomatics. The geomatics definition evolved for the last decennium into "Geomatics is a field of activity which, using a systematic approach, integrates all the means used to acquire and manage spatial data required as part of scientific, administrative, legal and technical operations involved in the process of production and management of spatial information. These activities include, but are not limited to, cartography, control surveying, digital mapping, geodesy, geographic information systems, hydrography, land information management, land surveying, mining surveying, photogrammetry and remote sensing [url 1]" (Roswell and Tom, 2009).

However, the scope of this chapter is narrowed. For that reason the definition of physiognomic research as given in the introduction chapter is a starting point and will be used as a reference.

The geomatics definition from the Dutch perspective is given. Followed by a stepwise description of the geomatic items: *geodata*, *geodata processing* and *geodata visualisation*. Afterwards, geomatics and physiognomic landscape research will be linked again twice, firstly, from the geomatics perspective, and secondly, from the physiognomic landscape perspective. The final section concludes the relation between both domains and sets an outlook. However, the chapter is greatly based on the experiences in the Netherlands, but references will be made to an international setting.

4.2 GEOMATICS – AN EXPANDING DOMAIN

The current ISO definition of geomatics shows that the original focus on spatial information/ geodata "a technology and service sector focusing on the acquisition, storage, analysis and management of geographically referenced information for improved decision-making" (Canadian Council of Land Surveyors, 2000) has been changed in favour of management and decision-making by integration and systematic approach items. Besides, ISO uses geomatics and geographic information science as synonyms.

A Dutch textbook on Geographic Information Systems and Spatial research (Hendriks and Ottens, 1997) presents Geomatics as the domain that integrates modelling on the levels of conceptual and logical representation of the spatial reality by developing geo-information methodologies and theory. The analysis of conceptual and logical models, as well as their relations of interest of different application domains, fuels these developments (Molenaar, 1997).

As we may understand from the more recent definitions, and notice from the reported inventions and developments (Fisher, 2006), the domain has dramatically changed and is still changing since the early days of Canadian GIS, CGIS [url 2], as did, and does, this sector in the Netherlands (Bregt and Van Lammeren, 2000). All these changes have an impact on the Dutch physiognomic landscape studies.

4.2.1 Data sources

In the relation with physiognomic landscape research the acquisition of geodata is still of primary importance, because the nature of the input datasets the scope of the analysis outcome. For that reason, first an overview of present data of interest is shown. Second to that, the ways to visualise the input and derived data needs a thorough look, after all we are dealing with the visible landscape. Finally, the (automated) functions to analyze these geodata needs will be exploited.

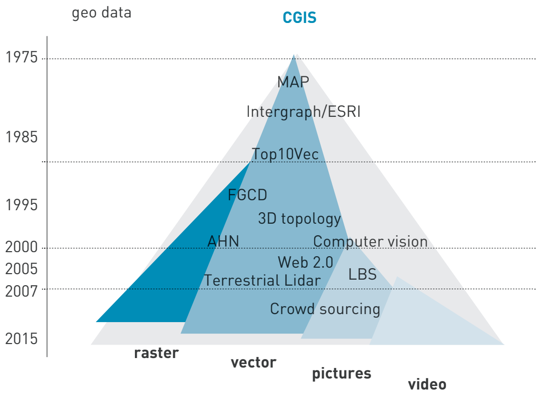


Figure 1
Geomatics events of importance for geodata availability

A geomatics-time line (figure 1), which shows awareness of reported evolutions and is partly influenced by the GIS timeline [url 3], gives an overview of the change in available geodata.

Looking at the acquisition of geodata it is obvious that from the study of De Veer and Burrough (1978) and in line with the CGIS setup, the first geodatasets were manually made by a procedure that was very similar to the raster approach as used for physiognomic landscape research. This rasterising way of getting geodata was based on the definition of a variable (for example 'space-mass difference'), the spatial extent and a spatial resolution (the raster-cell size). Via a physical overlay of a pellucid paper, with a drawn raster on it, over a hard copy map ("*don't forget the fiducial marks!*"), per raster cell a value related to the variable was written down.

4.2.2 Data availability

The introduction of vector-based geodata started as early as the raster approach originated by the work of Sutherland (2003). However, in contrary to CGIS it took a while before it strongly pushed, in a more practical sense, data developments in Computer Aided Design, and as originally developed. However, in the Netherlands, the role of vector geodata was serious from 1987 onwards, when the first versions of GeoPakket in relation to SiCAD (in 1987) and ArcInfo (in 1983) were introduced in the offices of the Dutch Administrations. Since that moment the map series of the Dutch Topographical Service of the Land Registry (*Topografische Dienst Kadaster*) began to become available as geodata (Top10Vec). Also, the early satellite images gave a boost to geodata in the early 80's, by Landsat-TM images [url 4].

Since the well-known Geodata Act of the Clinton government (FGDC, 1994 [url 5]) the interest in authorised geodata became globally a serious item. In the Dutch Ministries in cooperation with their departments, like Dutch Topographical Service of the Land Registry and Census offices, started rapidly to develop standardised geodatasets of national concern, that gradually replaced the hard copy maps. The last hard copy topographic map series of the Netherlands, scale 1:50,000, dated from 1984 [url 6]. Besides the description of position based data was no longer a primarily a real map case, but instead geodata many organisational aspects change gradually. For example, the latest, 2008, Dutch Act on landscape planning demands the use of geodatasets in the procedure of creating and deciding upon municipality zoning plans (by January 2010, [url 7]).

Driven by the EU Inspire initiative (2009, Annexes) more of these enactments will follow. The guiding role of the Inspire Annexes is interesting in the case of physiognomic studies. What type of geodata has been described, and, may support such studies?

As soon as the airborne Lidar technology was available, the Dutch Ministry of Public Works (*Ministerie van Verkeer en Waterstaat*) started a campaign with this technology, to map, during the period 1997-2003, the elevation of the Dutch land area. This 'actual state of the Dutch land elevation' (*Actueel Hoogtebestand Nederland (AHN-1)*), was the first high-resolution digital elevation dataset [url 8]. The national authorities of Europe are encouraged by the European Inspire directive [url 9], which defined 34 spatial themes to develop geodatasets for. A closer look at the appendixes that describe these themes shows that the majority of the themes are about orthogonal two-dimensional geo-referenced (2D) geodata. However, many new developments with respect to CAD and 3D visualisation have been initiated to capture and deliver three-dimensional geo-referenced (3D) geodata. Experiments in these directions are on-going and are most promising (Xu et al, 2010; Döner et al 2010). Yet,

Figure 2
Point cloud that represents a forest stand (by Van Leeuwen, 2010)

the debate on feasible data structures and flawless topology rules is still on. Especially in relation to the (combination of) airborne and terrestrial Lidar (Tang et al, 2008; van Leeuwen, 2010), 3D referenced data will offer more geometric details of real world phenomena, which may suit physiognomic landscape studies. Currently, the translation from point clouds, the measured points of reflection, into 3D objects for landscape visualisation remains challenging (figure 2).

4.2.3 Occasional geographic data

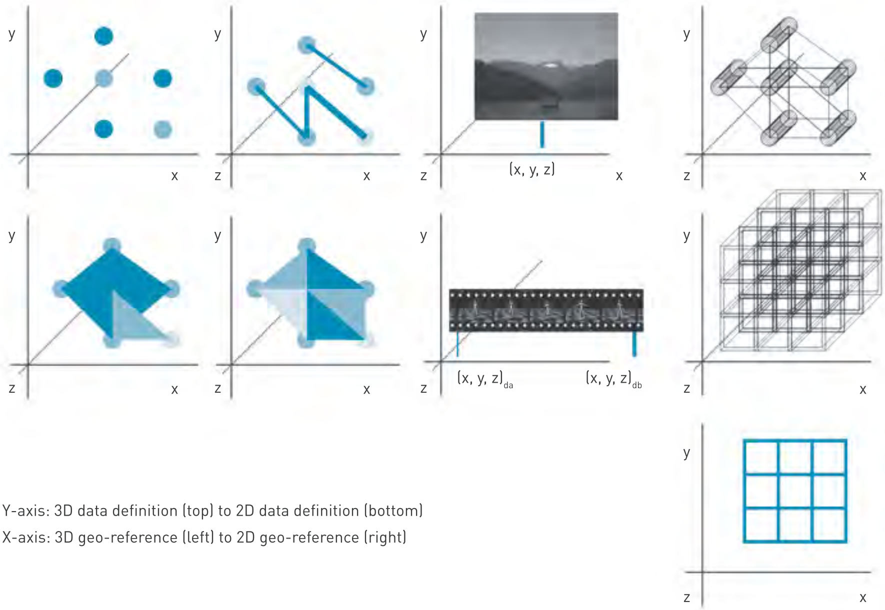
The Internet, on the other hand, has gradually become the main source of data. Wherrett (2000) presented the Internet as a medium to send out questionnaires in relation to landscape perception studies. Particularly the concept of participation and interaction by the Internet, as promoted by the concept Web 2.0 [10], has brought forward many Internet communities who store and share data. Mobile phones and digital cameras make it possible to geotag all data types ranging from mobile messages to photographs and videos, and once done, these data objects can be easily tracked by location based services (lbs)(Raper, 2007).

Successively applications like Flickr [url 11], Panoramio [url 12], Locr [url 13], Google Earth [url 14] and Bing [url 15] offer the many dedicated volunteers to geotag their photographs and put these on the Internet. The huge amounts of photographs do offer a great 'crowd source' of data that may be of use for physiognomic landscape studies (Jones et al., 2008). Of interest with these photographs is the variety of perspective projections. Sometimes orthogonally projected photographs are available.

One data type that is not mentioned in the time line is the set of 3D rasters, based on volume image elements, and mostly called voxels. Though it started as a promising development in a GIS setting (Marschallinger, 1996), the interest seems to have faded out. However, in some geological and geomorphologic studies the data type as such is still in use (Clevis et al., 2006), as in some remote sensing studies. Computer gaming and medical studies, like CT-scan analysis, still favour these data types [url16].

4.2.4 Trend watch

With respect to the previous sketch of the geomatics development it is obvious that the variety of available and accessible digital geodata has increased dramatically. This variety does offer many options to be used in physiognomic landscape studies (figure 3). Yet, drawbacks still exist. Geodata can be 2D or 3D referenced and the reference systems can vary. The VGI datasets may be biased. An Internet search for photographs of the *Eiffel tower* (keywords in English, German and Dutch) on July 26th 2010 showed 1,550,000, 256,000 and 24,400 photographs respective-



Y-axis: 3D data definition (top) to 2D data definition (bottom)
X-axis: 3D geo-reference (left) to 2D geo-reference (right)

Figure 3
Available data types for physiognomic landscape studies

ly. For the *Hoge Veluwe*, a Dutch National Park, the total of available photographs was 65,300. In any case not all datasets are accessible due to commercial or privacy reasons.

The role of all previously mentioned data types is to describe current, recent past and present states of the visible landscape and as such it could be useful.

It seems that rarely geodata is produced for the function of physiognomic landscape research. Consequently available data is not always optimal, and needs to be transformed or interpreted before it can be used in this kind of research.

4.3 TWO OR THREE DIMENSIONAL GEODATA

The subject of physiognomic studies has been defined before as 'the visible landscape'. Visibility in this case meant from the human's eye perspective. As Mark (1999) explained, geodata is merely a representation of the things that exist and represent, in our case, the 'visible landscape'. Comparable with his approach in this text (Mark, 1999), the words 'phenomena' and 'entities' point at the things that exist. The words 'objects', 'features' and associated words like 'attributes' and 'values' refer to the representations of phenomena and entities in the formal system of the digital world.

4.3.1 Digital landscape model attributes

The representation of the visible landscape phenomena and entities includes minimally a topographic surface. The surface represents the continuous phenomena elevation. This surface however may include more delineated features like pits, tops, ridges, edges, faults and stream patterns. This representation is known as a *digital elevation model* (DEM). However such a DEM is not a representation of the visible landscape. Man-made entities like buildings, roads, canals, plantings, as well as natural vegetation, have to be clearly represented as well. Gathering and adding these definable delineated objects to the DEM will generate finally a *landscape object model* (LOM) or *digital landscape model* (DLM). Such models may be understood as the representation of the visible landscape (figure 4). Wassink (1999) labelled the visible landscape by the nowadays old fashioned annotation 'landscape as a whole'. This label originated from a more static and fixed physiognomic landscape approach.

The different types of geodata, as presented in the second paragraph, could support the representation of the visible landscape in many ways. The 2D or 3D referenced geodata (raster and vector) could offer, for example after an interpolation process, a DEM coverage of a certain geographical extent [url17]. For example in a 2D geo-referenced setting the terrain layer (of figure 4) can be represented via surface, vector or raster definition. Besides the terrain layer, the volume layer (of figure 4) can also be generated in this way. In a 3D geo-referenced setting the terrain layer as well as the volume layer can be constructed by a 3D geometry and topology of morphologic objects. By adding 2D and 3D referenced objects, like representations of build-

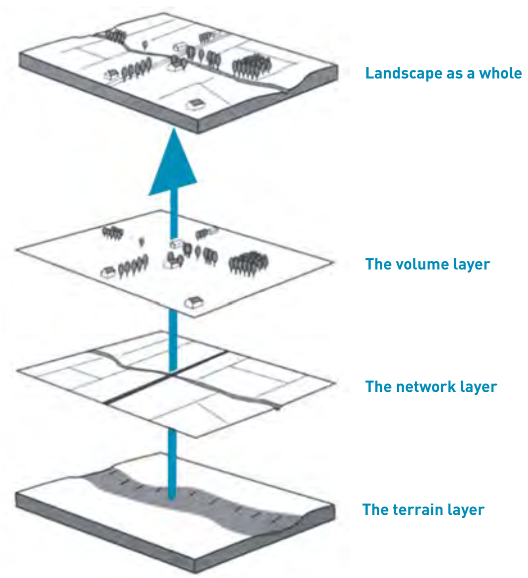


Figure 4
A visible landscape representation (source: Wassink, 1999)
On bottom the DEM (terrain layer). Successive layers like network (line and area objects) and volume layer (3D objects) put forward a DLM (on top)

ings, trees and other artifacts, a DLM will be created out of the DEM. For example a 2D geo-referenced elevation dataset, like the Dutch AHN, can be supported by a selection of vertically extruded 2D objects to generate a DLM out of a DEM as presented in figure 6.

If a 'complete' DEM or DLM coverage doesn't exist then many other software functions are available to create these models by a number of processing steps.

In many visible landscape studies in which a DLM is used, the spatial resolution or precision of the model that suits the study is problematic. Many studies refer to this item as a scale issue. However, this item deals, in fact, with the geometric precision and accuracy of the point, line, area and volume features defined in a vector structure, and the granularity of the raster cells and voxels. As well as the geodata representations of the terrain layer, the network layer and volume layer are also problematic, as the relations between these layers is still under exposed. Currently, it looks like the only solution to tackle this issue seems to be additional data sampling and adding ancillary geodata.

Photographs have a number of attributes that are implicitly related to the image. These graphic attributes like colour hue, colour saturation (grey value) and colour brightness are related to the smallest feature of a photograph, the image element (pixel). The combination of such pixels offers patterns and structures. These patterns and structures are cognitively understood by humans. In the domain of computer vision researchers try to mimic algorithmically these facilities of the human brain (Szeliski, 2010). Videos also have the same basic implicit variables per frame (Zhou, 2010), as a video consists out of series of related stills (scene) and series of scenes (video narrative).

Geodata however consists mostly of geometrically well-defined features like points, lines, polygons, volume objects (vectors) and raster cells or voxels. One or many thematic variables can be linked to these features to explain the meaning of the features in terms of characters and numbers. The values, the range of numbers and characters, of the attribute domains are constrained by a measurement scales (Gibson et al., 2000; Open GeoSpatial Consortium inc. [url 18]). In landscape physiognomic studies these graphic and thematic variables fulfil an important role.

4.3.2 Digital landscape model visualisation

The previously introduced DLM has many digital expressions. The visualisation of such DLM expressions is the most important interface to discuss landscape physiognomy in most studies.

Geovisualisation has to be understood as defined by Dykes et al. (2005): "Geovisualisation can be described as a loosely bounded domain that addresses the visual exploration, analysis,

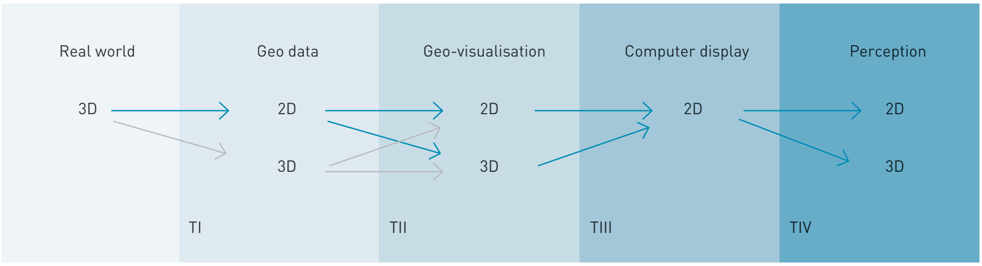


Figure 5
Transformations in the Geovisualisation process (source: Van Lammeren, Houtkamp, et al., 2010)
TI geodata acquisition; TII geovisualisation definition; TIII display rendering; TIV perception triggers in 2D and 3D (parallax and/or depth cues). Light grey arrows refer to 3D referenced geodata types

synthesis and presentation of geospatial data by integrating approaches from cartography with those from other information representation and analysis disciplines, including scientific visualisation, image analysis, information visualisation, exploratory data analysis and GI Science."

Figure 5 shows how real world phenomena, the visible landscape as perceived in reality, is represented and influenced by four different transformations before we can perceive the visualisation of it (Lammeren, Houtkamp, et al, 2010). The figure expresses the importance of transformations. The first transformation has been discussed in the previous paragraph. The second transformation (TII) shows the preparation of the data for visualisation. Different combinations of 2D and 3D defined objects and layers may need to be generated to finally result in a visualisation. All types of figure 5 can be combined, for example, Google Earth examples may illustrate such visualisations by the historical landscape paintings of Florence [url 19] and the 3D buildings layer of Amsterdam [url 20]. The latter (figure 6) shows different 3D house geometries (3D) plus mapped textures (images used to show the 'realistic' facades of the buildings). The former shows geotagged images of historic paintings of Florence and located into the original view direction. Photo's and paintings like in the example of Florence, put forward the subject of atmospheric conditions that's not yet covered by geodata and only gradually by geovisualisation (Daniel and Meitner, 2001).

We may conclude that the issue of missing and imprecise geodata, in the case of physiognomic landscape studies, can be partly dealt with by including other data types, especially geotagged photographs and videos in the visualisation of such data. The automated processing of such combined datasets is much harder however.

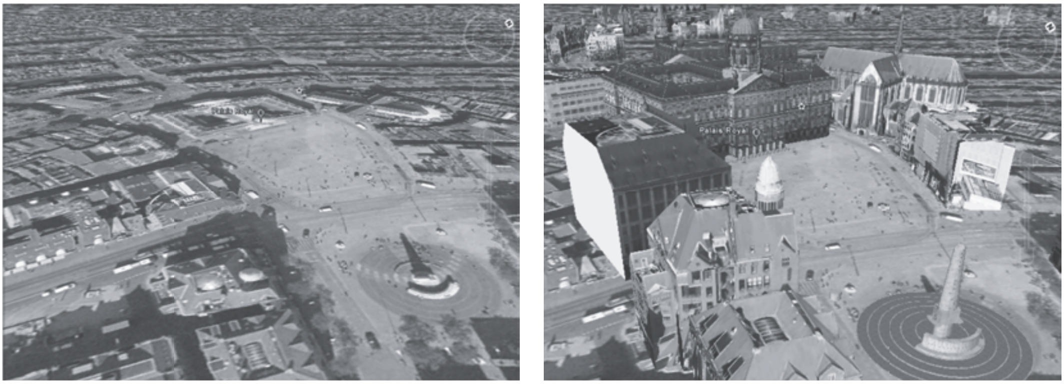


Figure 6
Amsterdam Royal Palace without (left) and with (right) 3D models

4.4 GEODATA PROCESSING

All geodata types and the options to visualise these have previously been discussed with the meaning to show the variety of options to represent the visible landscape. The sheer variety relates to the fact that that a dataset, which will be used to analyse physiognomic landscape items, must be prepared by pre-processing before the more analytical processing can be performed.

4.4.1 Pre-processing

Pre-processing includes the transformation of geo-references (map projection, 3D into 2D, 2D into 3D), of geodata (like from vector into raster, raster into vector, geotagged images into vector) and of feature classes (for example points into lines, points into areas, points into volumes). It could also include (re-) classification of attributes and attribute domains to better fit to the physiognomic landscape analysis (like ratio measurement class variable classified as an interval measurement class variable).

A very special class of transformation is related to the data of volunteers, also known as voluntary geographic information. These geotagged photographs and videos can be used, thanks to the results in pattern recognition by computer vision research to stitch or construct photogrammetrically multi-facetted scenes like those offered by Microsoft Photosynth [url 21] and even 3D-models and -scenes [url 22] (Snavely, 2006; Pollefeys, 2002). These very promising developments must lead to an integration of horizontal and vertical definitions of reference.

4.4.2 Re-classification and interpretation

After finishing the geodata pre-processing, the processing in line with the physiognomic landscape analysis may be started. Depending on the pre-processed data types available these processing steps may be as different as the physiognomic landscape interests.

The simplest analysis seen from a computational point of view may be the re-classification of 2D- or 3D-geodata layer, geotagged image or video. Re-classification could support for example user interpretation and appreciation by ranking or ordering, user understanding of classes of interest for policy making and user labelling of features (e.g. Wascher, 2005). Such classification may also follow after other types of processing. In more detail the re-classification can comprehend feature classes or thematic class values (Chrisman, 2003).

4.4.3 Simple geometric analysis

As mentioned before, most analysis in the domain of physiognomic landscape research is basically starting with a digital landscape model. Besides classifications, a number of new attributes may be described and calculated describing visual properties of the landscape model (e.g. Ode et al., 2010). Geometric attributes of interest that may be used are: location, direction, distance, altitude, size (length, area, volume), shape and topological relation. All these attributes can be calculated for a single object, multiple objects and interrelated objects. Besides attributes like spatial density, distribution and variability can be derived as a next step. Most algorithms available by geodata processing software will support this type of geometric and topologic analysis functions.

4.4.4 Visibility oriented analysis

An interesting dispute is always what type of object initiates the data processing. It always means that a second geodataset is involved by which point, line, area and volume objects have been described that will be used as the starting objects for the physiognomic landscape analysis. For example the algorithmic principles of visibility studies, is typified as visibility querying on a digital landscape model (Batty, 2001; De Floriani and Magillo, 2003). Before the real querying the continuous visibility mapping by TIN (vector) and discrete visibility mapping by raster is started from point objects that represent vantage points.

In a raster format the range of local, focal, zonal and global functions, as originally defined by Tomlin (1990), work in this way. For the voxel format there are comparable classes to be found (Marschallinger, 1996; Clevis et al., 2006).

4.4.5 De Veer and Burrough revisited

Current geodata types are, in other words, able to be processed in many ways. If we take into consideration the examples of de Veer and Burrough (1978), then we may conclude that finding 'concave objects' is a matter of pre-processing (especially classification) 2D geodata, querying the area objects that represent spaces and ordering afterwards on size and shape of the selected objects.

The 'breadth of view' approach is able to do this via the isovist field's concepts of Benedikt (1979), which have been implemented. After pre-processing and defining the points that represent vantage points, a number of attributes may be calculated like lines of sight, fields of sight and derivatives like the shape of the field of sight. Also the viewshed techniques could be categorised as such an approach.

The third approach, 'raster' as they called it, is in fact a combination of classifications of attributes belonging to the objects and a transformation from vector based objects into a raster geometry. The resolution of the raster cell size will be a most critical factor in a correct ascribing the intended values to each individual raster cell. Many studies still use this approach.

4.4.6 What validity?

In this paragraph the main classes of geodata processing have been introduced in short. Each class delivers data output by which characteristics of the landscape physiognomy are descriptively explored, quantitatively explained or qualitatively predicted. In the academic research tradition the main question concerns the validity of these results.

From the position of this section in this chapter it could falsely be understood that the validity of the results is just a matter of selecting appropriate processing tools, like cross-validation of the used and resulted data. Or, on the other hand, the processing tools themselves could be also subject to validation, as has been illustrated by the study of Riggs and Dean (2007) about viewshed processing.

However, as put forward in the previous paragraphs, the variety of geodata that helps to represent the study of landscape physiognomy, are suspects themselves. Some geodata is generated by given definitions and procedures within the context or praxis of a certain application domain. A formal definition of visual landscape entities and phenomena seems an irrefutable issue. Fisher (1999) already explained that the nature of uncertainty is based on the well or poor defined classes of objects and their spatial delineations. In well-defined situations uncertainty is caused by errors and is probabilistic. In poorly defined situations uncertainty could be a matter of vagueness (weak definition) or ambiguity (confusing definition).

Indeed occasionally geodata has been generated without any given definition or procedure. Most geotagged photographs and tweets bear this origin. But does it mean that it is vague or ambiguous data? The enormous amounts of such geodata, accessible and available by social networks, do unveil vagueness and ambiguity. Perhaps expert validation of physiognomic landscape findings will be followed up by validation via social networks and E-communities. The works of Sheppard (e.g. Sheppard and Cizek, 2009), promoting the ethics of visualisation, also give clues for such more contextbased validation. The conclusion of Ode et al. (2010) that *"The results show that the different data sources were more or less adequate to use in different contexts and for different purposes"*, fuels this perspective.

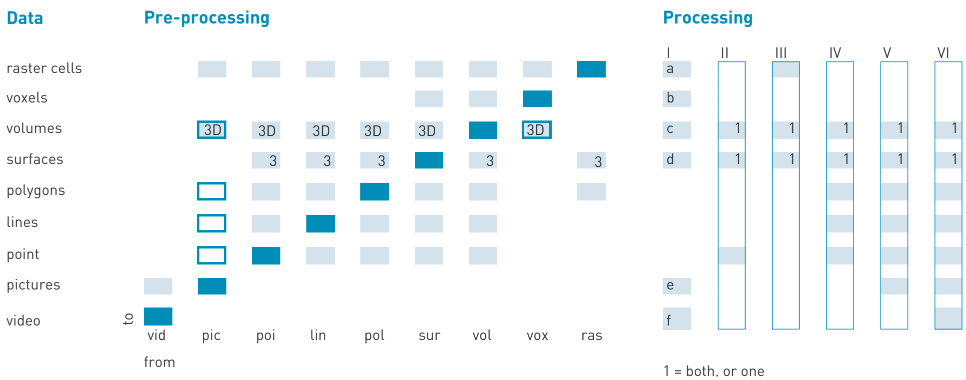
4.5 GEOMATICS MEETS PHYSIOGNOMIC LANDSCAPE RESEARCH

From a geomatics perspective the link with physiognomic landscape studies may be based on the extent of the geodata types and related variables to be used as input, to be processed into a certain output variable, and to be visualised. The data types, as introduced in the second section, may be a starting point. The way this data could be combined, processed and finally visualised offer a combinatory set of options that may be of relevance for physiognomic studies (figure 7). It will show clearly that the methodological soundness is a tough case.

4.5.1 Geodata ensembles

Figure 7 consists of three blocks. The first block, entitled data, shows all data types as introduced in section three of this chapter. The second block, pre-processing, summarises all

Figure 7
Geodata ensembles
dark blue = original data; light blue = created data; box = based on photogrammetric functions



transformations available to realise a specific type of digital landscape model as introduced in section four. The third block, processing, ranges groups of data ensembles that may support physiognomic landscape studies. The ensembles are based on original data types (block one) or originated from the pre-processing results (block two) and take into consideration the processing options as introduced in the fifth section.

4.5.2 Ensemble-related pre-processing

The focus of the second block is on transformation options. The x-axis shows the *from data* and the y-axis the *to data*. The first column of the block presents the transformation of a video into an image via a frame or still. Images can be used in many forms of transformation. As such the pixels of an image may be converted into a grid. However in case of an image made via a perspective projection the geo-referencing may be a difficult topic to handle. Yet, the many pattern recognition functions, resulting from computer vision research, could support the transformation from specific objects of an image into specific points, lines and polygons. Such derived data may be used for a photogrammetric construction of a 3D-model, which in the figure is labelled as volume data (indicated by 3D).

Transformations of points into lines, polygons and surfaces that finally represent elevation, by the terrain and/or volume layer (figure 4), as well as lines into points, polygons and surfaces and polygons into points, lines and surfaces, are very common functions in a 2D-reference system. The transformations of these vector-based data types into raster datasets are also common. The transformation of points into volumes is possible in case of 3D referenced point sets. Examples of such data are given by terrestrial Lidar data, that show transformation is also possible in cases of datasets with line and polygons objects defined by a 3D reference. Surfaces, sometimes described as 2.5D-referenced because once visualised they give a three-dimensional impression even though the geo-reference is still 2D, offer transformation options into both directions. Creating points, lines and polygons in a 2D or 3D reference are possibilities. Besides, surfaces could be transformed into a 3D (volumes), voxel and raster model. In fact, the volume data type (3D) offers the same classes of transformations. However these transformation functions have to include the conversion of 3D topology. Depending on the algorithm there is not a single result. However that's often the case in many of these transformations.

The seventh column presents the transformation of voxels. The creation of a volume model needs an intermediate step in which 3D referenced points and lines of significance have to be found in favour of the construction of polygons and volumes. The last column presents the transformation of raster data into polygons and surfaces.

4.5.3 Processing of single data ensembles

The third block of figure 7 gives an idea of the data ensembles that may be the object of processing options related to physiognomic landscape studies. The first column (figure 7: I) of the third block points at the processing of a single data type. Examples of physiognomic landscape applications that can be found by studies with raster cells (figure 7a) are very familiar with the raster approach of de Veer and Burrough (1976). A raster cell is, in most of these studies, the location identifier for a number of variables of interest for a specific analysis. These variables may originate from thematic themes and geometric items. For example McGarigal et al. (2002) introduced landscape metrics; a number of variables originally thought useful for landscape ecology studies. However, the concept of the matrix-patch-corridor model can be understood metaphorically and used in physiognomic landscape studies (Kamps and Van Lammeren, 2001; Palmer and Hoffman, 2004).

Voxel analysis (figure 7b) is not often found in physiognomic landscape studies. However, if geomorphology Clevis et al., 2006) or layered Isovist fields are included, the so-called Minkowski model (Benedikt, 1979), then voxel analysis has a lot to offer. The role of volume models (figure 7c) is at the moment mainly related to studies of perception and assessment. The lack of well-defined data structure and 3D topology blocked the availability of suitable analysis methods, like 3D Boolean operators, that offer immediately quantitative numbers of the calculated results. Surface analysis (figure 7d) is available in many ways, especially for the discovery of height derivatives like contours, slope types, slope aspect, edges and drainage patterns. At the moment the tools to process images (figure 7e) and videos (figure 7f) are mostly related to perception and appraisal by assessing single, pairs and series of images. Such studies are still in line with the studies like Schroeder (1988). Besides usability, analysis, like navigation and orientation, in relation to the visualisation of the above data types are of interest for physiognomy studies.

4.5.4 Processing steps of multiple data ensembles

The other columns of the third block (figure 7: II up to VI) show the ensembles that make use of integrated datasets. In all cases the DLM may be based on a surface (2.5D) or volume (3D) data types or a combination of both. The most common combination by now is the one where volume objects are placed on a surface. Depending on the physiognomic landscape analysis, in this example visibility, the data model could be extended by:

- Points, in the case of view point based visibility studies;
- Lines in the case of route based visibility studies;
- Polygons in the case of neighbourhood or specific landscape unit based visibility studies;
- Rasters in the case of all previously mentioned types of studies.

In fact all 'visualscapes' analysis tools as introduced by Llobera (2003), including isovist and viewshed, are look-a-likes. All of them derive values related to visibility variables from the above mentioned data ensembles. A serious 3D approach is suggested by the ViewSphere approach as discussed by Yang et al. (2007).

Recently, new combinations of data show the surplus of options of how geomatics meets physiognomic landscape studies. What seems promising is the integration of surface (2.5D) or volume (3D) data with:

- Images in case of (semi-) photo realistic renderings via texture mapping or having location based billboards or panoramic views in the digital landscape model for example like Streetview [url 23] to capture specific visibility items;
- Videos in case of dynamic renderings of objects or location based video streams also to capture visibility items.

4.6 PHYSIOGNOMIC LANDSCAPE RESEARCH MEETS GEOMATICS

Another approach to show how both domains meet may be given by the four landscape perspectives of Antrop (2007). A landscape perspective is defined as the way that human are confronted with the landscape. The four perspectives are the vertical, the horizontal, the mental and that of the meta-reality. The first two perspectives are mainly related with the primary cognition and definition as a human may sense. The latter two are more related to derivation and inference from the first two perspectives. For that reason the first two are primarily linked to data as input for processing and the latter two as output data of processing (figure 8). All derived variables are group-listed in the column furthest right in figure 8.

Figure 8
Physiognomic landscape perspectives (based on Antrop, 2007)

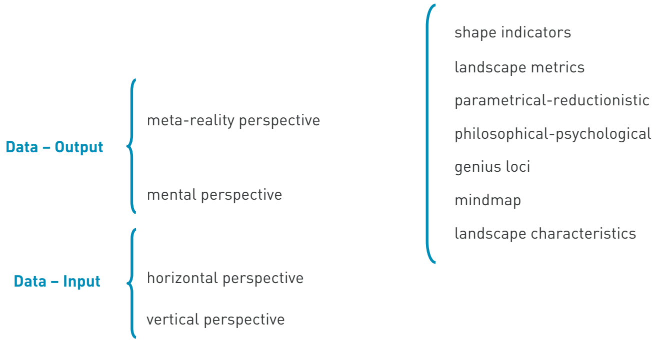


Table 1
Tentative summary of differences in human-landscape interaction paradigms.

	context	liability	sensitivity	validity	usability
expert - ecological	research preference	medium	medium	medium-low	low-medium
expert - formal esthetic	artist view	low	medium-high	low	high
psychophysical	mutually well defined	high	low	medium-good	medium
cognitive - psycological	differ : cognitive, perceptive, affective	high-medium	high-medium	medium-low	medium-high
experiential-phenomological	inside/outsideness	low-medium	high	pm - personal	local

The meta-reality and mental perspectives are recognisable in the studies of Zube et al. (1982) and Daniel and Vining (1983). 30 years later such an extensive literature review, as they did, could be of serious interest to find out how human-landscape interaction studies have been developed since and how these paradigms have evolved. Dutch studies of the past decennia have checked, and it may be considered, that the paradigms (table 1) are detectable and, in each of these applied geomatics, are traceable.

4.6.1 Expert approach

The expert-ecological approach may be recognised in the dissertation of Wassink (1999). The dissertation presents a methodological attempt on a qualitative landscape classification to define landscape form transformations of the Dutch landscape. A landscape morphological model has been developed, based on a layered concept (figure 5) of terrain forms (digital elevation), network pattern and vertical landscape features like buildings, trees and shrubs. The methodological framework was applied for the brook valley landscapes of the Pleistocene areas of the Netherlands. The study shows that this multilayered model may visually support the insight in specific relations between geomorphology, networks and vertical features in relation to landscape forms. The geodata in case of networks and vertical features were derived from the Dutch topographical data. Kamps (2001) repeated the analysis of Wassink's study by using raster data and landscape metrics (McGarigal et al., 2002). Steenbergen et al. (2009) made the same type of study for the Dutch polder landscapes.

The works of Wassink (1999) and Steenbergen et al. (2009) bridges the expert-ecological approach with the formal-esthetical approach. The latter is much more detectable in Steenbergen et al. (2003, 2008), with the use of architectural variables like vista, rhythm, symmetry and order in a variety of landscapes (like Italian Renaissance villa landscape and Dutch Polder landscape). Kerkstra et al. (2007) analysed vista's to find a leading architectural design principal for designs of the undulating Zuid Limburg area in the south of the Netherlands.

4.6.2 Psychological and psychophysical approaches

In the psycho-physical approach the Dutch research groups show still many interests. These studies still start with defining space and physiognomic character by the type and amount of landscape features (Werkgroep Helmond, 1974; Blaas, 2004; Roos Klein-Lankhorst et al., 2002, 2004, 2005; Van Lammeren et al, 2010; Weitkamp, 2004, 2007, 2010). These types of studies are still grounded in an expert tradition but do validate the results by expert and respondent tests. These types of studies also bridge the expert-ecological approach and the psycho-physical perception approach. Most of these studies are based on stated references and not on revealed ones (Sevenant, 2010).

The psychological approach does have some Dutch examples. These are still in line with the previous studies of Coeterier (1996). Especially photo and video montages have been used as input data. The link with geodata is not always the case (Tress and Tress, 2003).

4.6.3 Phenomenological approach

The more recent studies, in relation to Web 2.0 developments and as promoted by Coeterier (2002), which are in line with the humanistic or phenomenological, have been performed. These are especially studies (Lammeren et al., 2009) in which an attempt at classification of landscape photographs, which were taken by tourists, has been made, in relation to tourist landscape interest and their in-situ behaviour. In that study volunteer data (geodata as well as geotagged photos) has been used.

The Web 2.0, including the trends of geotagged photographs and augmented reality, heavily supports the challenging future of this research approach.

4.7 TENDENCIES AND PERSPECTIVES

In the previous sections the connection between the expanding domain of geomatics and the variety of physiognomic landscape studies have been outlined. Tendencies and perspectives are derived from the Dutch studies. One item is very sure and in line with previous writings of Ervin and Steinitz (2003). The nature of ongoing physiognomic landscape studies is not only dominated by strict ecological, formal-esthetical, psycho-physical, psychological and phenomenological approaches. The studies that show a cross-reference approach are increasing and seem very promising, thanks to geomatics.

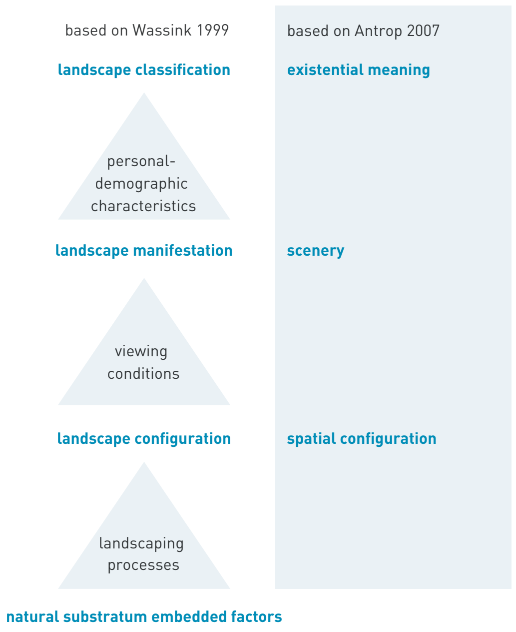
4.7.1 Increase of geodata

The increase of geodata as result of institutional, societal and technology developments, show a variety of physiognomic landscape representations and, by creating data ensembles, there are many options to have geodatasets that fulfil the definition of landscape entities and the intended processing results. The most striking trends discovered are the increased precision of data, three-dimensional geometry of objects, data type integration (supported by computer vision), 3D references (horizontal plus vertical references), 3D geo-scenes (due to 3D reference) instead of 2D geodatasets, time series (initiated by digital photography and ground based Lidar) and even real-time geodata based on GPS tagged photos and video enabled smart phones. These trends will bring forward the need for geodata standards for physiognomic landscape studies including a related ontology.

4.7.2 Outcome of data processing

Geo-computational innovations improved options to calculate many thematic, geometric and topology-based variables, and, even time-series based variables have dramatically increased. Besides listing the variables they could be linked to the type of physiognomic landscape studies (figure 9).

Figure 9
Physiognomic landscape research and landscape studies



In relation to the availability of data ensembles the following types of variables are used:

- Basic vector and raster analysis tools based, including density and distribution variables (description substratum and embedded factors; configuration, classification);
- Landscape metrics (configuration, classification);
- DEM derived, like slope, aspect, curvature (description substratum and embedded factors; configuration);
- 3D Boolean operators that support geometric and topologic variables (configuration; manifestation; (re)classification);
- Viewsphere, Viewshed and Isovist derived variables (manifestation; configuration, classification);
- Interface perception variables based on eye tracking, time responses, interface tracking (manifestation; classification).

4.7.3 Impact of visualisation

Important research stimuli came from the many ways to visualise geodata and the variety and simplicity of interfaces. Based on the type of physiognomic landscape studies (figure 9) that each have their peculiar sets of variables, it is obvious that a high variety of visualisations are in use. These visualisations are primary based on the traditions of cartography.

In the perception-oriented studies' landscape manifestation, geomatics have been used to create (dynamic) landscape visualisations. Based on these visualisations derived variables related to usability and affective appraisal have been the subject of studies.

The nature of the interface for both, derived variables visualisation and landscape visualisation, have become the subject of studies too.

4.7.4 Improving methodologies

The increase in data and new variables, the latter as result of processing options, has influenced methodology. Most striking are the options to compare variables in relation to measured, perceived and simulated data. Even (cor)relations between variables can be generated like viewing graphs and visibility paths. In all of them, landscape configuration, manifestation and classification studies, an increase of variables can be discovered. There is an increased interest in the nature of a data due to the role of volunteers to collect, to review and to respond on landscape data. Specifically, the demographics of users underpin the findings of studies via demographic group based variables.

As noticed by Ervin and Steinitz (2003), even the so-called "viewer predisposition, or purpose" and the impact of other senses-related variables to measure landscape characteristics and perception, like noise, smell and crowdedness, become part of studies.

However one of the most important gains of geomatics is the automated reporting function. This function captures datasets and processing steps by flow diagrams and meta-datasets, which supports the discussion of results and makes an easy adaptation of the methodology possible.

4.7.5 Meeting previous demands

Let's finish with the study of De Veer and Burrough (1978), who asked policy makers and consultants to score applications of physiognomic landscape studies. Those days five categories scored high: vulnerability designation (e.g. visibility of a new building, road or power line); suitability designation (e.g. for different recreation activities); public landscape preferences (e.g. as determined by a questionnaire using colour photographs of selected landscapes); landscape evaluation (using parameters such as diversity, rareness, or replacement possibilities) for conservation planning and landscape design (the creation of new, or modification of old landscapes).

The main conclusion from the questionnaire was that users' demands for physiognomic landscape mapping vary enormously, both in terms of mapping scale and map content (De Veer and Burrough, 1978). With the contribution of geomatics we may notice that the variation of physiognomic landscape studies does increase. Applied geomatics in physiognomic landscape research will dramatically increase by the availability of mobile Internet services that will support citizens to become more aware of their surrounding environment and to participate in spatial planning procedures.

As mentioned by peers from many application domains (Tucci, 2010), the contribution of geomatics does not only consist of the application of the latest information technology based data and data processes, but it helps to create new methodological pathways, especially related to data acquisition and processing. Alongside that, geomatics proffer new and innovative ways of describing reality, which offers a wider spatial range related to more precision and accuracy of physiognomic features. Examples are: the enormous quantities of data relating to a single geographic location and generated at different times (past, present and future), the possible addition of extra variables to each of the representations during the research, the powerful extent to which topology rules spatial analysis, the variety of visualisation options, the fact that data can be created via volunteer sessions and Internet services and the acquired data, information and knowledge can be widely disseminated on-line via external databases in the 'cloud' and Internet sites.

All together geomatics doesn't only provide important contributions to physiognomic landscape studies, but it also create more awareness, different appreciation and more sustainable utilisation of landscapes. At least that's what may be proved in the near future.

The Dutch-Flemish physiognomic landscape research community tends to follow, and sometimes initiate, most of the here fore mentioned global geomatic developments. However this community is not afraid of using data ensembles and variables in line with cross-reference approaches to evolve and challenge physiognomic landscape studies.

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