OBJECT BASED IMAGE ANALYSIS:
A NEW PARADIGM IN REMOTE SENSING?

Thomas Blaschke, professor
University of Salzburg
Department of Geoinformatics
Hellbrunner Str. 34
5020 Salzburg, Austria
thomas.blaschke@sbg.ac.at

ABSTRACT

The amount of scientific literature on (Geographic) Object-based Image Analysis – GEOBIA or OBIA in short – has been and still is sharply increasing. The term OBIA is herein used for generic image processing tasks. OBIA researchers with backgrounds in geology, geography or mineralogy are joining forces with colleagues from cell biology, molecular biology, medicine, pharmacy or nanotechnology. More narrowly, *GEOBIA's* objective is the generation of geographic information (in GIS-ready format), from which new spatial knowledge can be obtained. GEOBIA is a relatively new field of research based upon two major concepts: a) dissecting images or any (pseudo-)continuous multidimensional fields of data, and b) allowing for multiple scales when organizing and utilizing the resulting objects. Analyses of the amount of scientific literature reveal that not only the number of articles is increasing, but that the rate of growth is also noticeably accelerating. Finally, it is discussed whether or not GEOBIA can be considered as an important paradigm in remote sensing.

KEYWORDS: Object Based Image Analysis, OBIA, GEOBIA, GIScience

INTRODUCTION

Remote Sensing for a better understanding of the Earth

Contemporary Remote Sensing (RS) has brought technological advances and has certainly contributed to a better understanding of the natural world, and – to a much smaller degree – to the understanding of humans and societies inhabiting the world. The full integration of RS and Geographic Information Systems (GIS) has widely become reality as envisioned in the 1990s (e.g. Ehlers et al. 1991; Estes 1992; Hinton 1996; Star et al. 1997; Blaschke et al. 2000). We may claim that today these technologies – in principal, although not automatically – offer the opportunity to gain important insights into biophysical systems through the spatial, temporal, spectral, and radiometric resolutions of remote sensing systems and through the analytical and data integration capability of GIS. The two former separate technologies can be seen as being linked together into a synergistic system that is particularly well suited for the examination of environmental and landscape conditions, as well as for anthropogenic patterns (Chase et al. 2012). Together with the nearly ubiquitous use of positional information, scientists are increasingly often able to directly address objects of interests in images and in data sets in general – which hopefully correspond to real world objects (Burnett and Blaschke 2003; Lang et al. 2004).

Pixels are bound to the scale of observation

The ultimate goal of remote sensing is to mirror, elucidate, quantify and to describe surface patterns, in order to contribute to an understanding of the underlying phenomena and processes. Blaschke and Strobl (2001) claim that since the first Landsat satellite was launched in 1972, we achieve this in more or less the same way: We measure some reflectance at the Earth's surface. The smallest unit is called a 'pixel'. Blaschke and Strobl do not question the pixel as a necessary entity as such. They argue for a somewhat different handling of our entities, introducing the concepts of neighbourhood, distance and location, since using the pixel as the basic scale of analysis may have certain drawbacks. Aplin and Smith (2011) state that perhaps the most significant one is the potential for mapping error as a result of noise in original imagery (i.e. erroneous pixel values, often referred to as the 'salt and pepper' effect), or through misrepresentation of Earth-surface features because pixels are too large (mixed pixels) or too small (within-feature variation) to characterize the features of interest effectively (Aplin et al. 1999). Also, pixel-based mapping products are not universally favoured by users of spatial information, with raster representation sometimes considered artificial and noisy, and a common preference among geographical information system (GIS) operators for vector data.

A need for multi-scale

Lang et al. (2004) have elaborated on how the traditional approach of aerial photograph interpretation is being adopted to examine high-resolution data with modern technology and advanced methodologies. It was demonstrated how findings of complex system theory and hierarchy system theory, coupled with traditional aerial photography interpretation techniques, can form the basis for cutting-edge methodologies for the semi-automated classification of high-resolution digital data. Following the ideas of Burnett and Blaschke (2003), Lang et al. introduced a novel and flexible multiscale segmentation / object-relationship modelling methodology used to extend the scientific understanding of landscapes as hierarchies of patterns and processes. Today we may claim that the interrelationships of scale, pattern, and process, somehow form a paradigm that has gained prominence in the fields of biogeography and landscape ecology (see also Lang 2008).

We may think that concepts of scale, pattern, and processes are widely used and well elaborated. Nevertheless, when critically analysing many journal articles, these concepts are surprisingly rarely substantiated. In RS articles, scale, level of detail and the methods used are often not justified in regard to any underlying theory. One may call this attitude logical positivism. This type of reality is the way it is since the laws we believe to exist really do exist. Consequently, we can know about this reality by observing or sensing the interactions of entities through the operation of laws (Inkpen 2005, p.28).

The critique of the limited RS theory is not substantiated herein either. The point made for this article is: Satellite image processing, change-detection analyses, digital elevation models, GIS-derived landscape indices and variables, composition and pattern metrics of landscape organisation – just to name a few established concepts and methods – are widely used, although not always unambiguous. There are still many conceptual problems with scale-dependent analyses and subsequent up- and downscaling. My hypothesis is that some of these concepts are used in landscape ecological studies at least as guidelines to explore landscape relationships, but are not well reflected in RS literature.

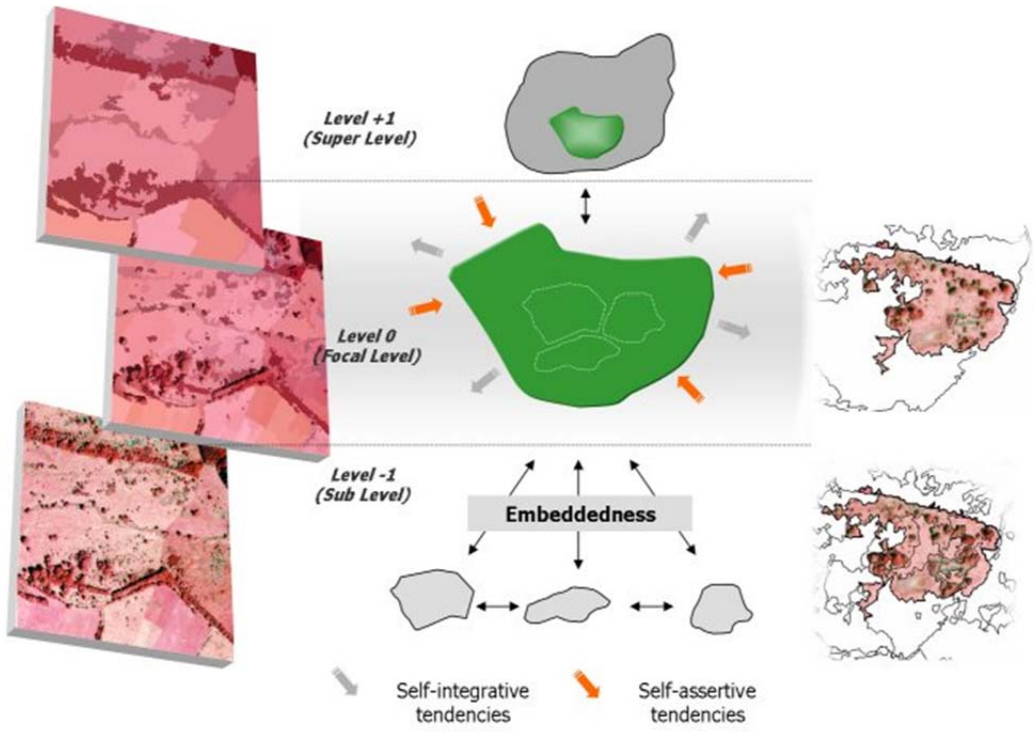

Figure 1. Multi-scale hierarchical representation of a landscape. According to our understanding of the systemic organization, scientists may want to derive appropriate levels of division which may be achieved through segmentation (*above*). The resulting image objects are associated with landscape elements at various scales (*below*), from Lang et al. (2004).

In the remainder of this article I will briefly discuss what a paradigm is, I will analyse the scientific literature and I will propose some conclusions in an attempt to answer the question if GEOBIA is a new paradigm in RS.

GEOBIA

GEOBIA claims to overcome problems of traditional pixel-based techniques of high spatial resolution image data, by firstly defining segments rather than pixels to classify, and allowing spectral reflectance variability to be used as an attribute for discriminating features in the segmentation approach (Blaschke and Strobl 2001; Benz et al. 2004; Blaschke 2010; Johansen et al. 2010). GEOBIA allows inclusion of additional information to guide the classification and modelling processes. This can be external information – usually from GIS data sets – or information intrinsically evident in the image and its constituents, but not necessarily achievable at the level of a single pixel. This can be as simple as the use of: object average reflectance; object reflectance standard deviation; object maximum, minimum and median reflectance values; area and shape of objects; texture of objects; location of objects in relation to other objects. It can be a complex combination of individual parameters and a 'hierarchical' view: relation of objects to 'super-objects' or the image scene characteristics.

It is repeatedly stated that image segmentation is not new but has gained new momentum when incorporated in object based image analysis (Blaschke and Strobl 2001; Blaschke 2010). When performing image segmentation a complete set of image objects is created. This is usually done for one specific object scale but it is increasingly recognized that GEOBIA accommodates multi-scale data handling (Blaschke et al. 2002; Blaschke et al. 2004; Blaschke 2010). One ambiguous discussion is whether the user should pre-define scales he or she is aiming for, or if this task should be left to the computer. Regarding the popular software "eCognition", target scale parameter and the way users often address it is sometimes criticized. The recent development of tools (Drăguţ et al. 2010) which support the definition of such scales through statistical analysis is a major step towards transparent rules.

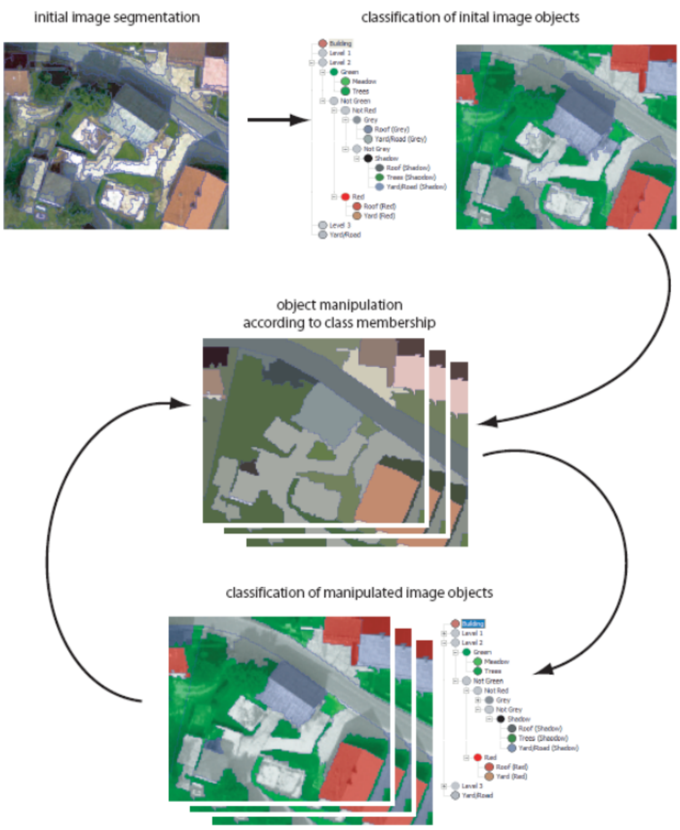

Figure 2. GEOBIA principles: Iterative process of knowledge-based image segmentation and classification (from: Hofmann et al. 2008)

In an effort to define an explicit GEOBIA framework, Hay and Castilla (2008) provided a number of tenants or fundamental guiding principles. They described GEOBIA as exhibiting the following core capabilities: (i) data are earth (Geo) centric, (ii) its analytical methods are multi-source capable, (iii) geo-object-based delineation is a pre-requisite, (iv) its methods are contextual, allowing for 'surrounding' information and attributes, and (v) it is highly customizable or adaptive, allowing for the inclusion of human semantics and hierarchical networks. Lang (2008) also describes a selection of OBIA guiding principles for complex scene content, so that the imaged reality is best described and the maximum (respective) content is understood, extracted and conveyed to users (including researchers). For details see Lang (2008, pp. 14-16).

I may summarize that GEOBIA is associated with multi-scale segmentation. Segmentation as such is only a means and not an end in itself. Multi-scale segmentation deserves to be linked with hierarchy theory (Lang 2008). Hierarchy theory is an appealing concept and the link seems evident, as both hierarchy theory and multi-scale segmentation deal with hierarchical organization. One problem here is that hierarchy theory proposes and requires the decomposability of complex systems (Simon 1973), but imagery is just a representation of such systems. An imaged representation is in several aspects reductionist: it is a plane picture only revealing reflection values. Following Lang (2008) we may claim that hierarchy theory can provide a conceptual framework for GEOBIA.

IS GEOBIA A PARADIGM?

In recent literature (Blaschke 2010; Johansen et al. 2010) it is claimed that OBIA/GEOBIA enables a hierarchical multiple spatial scale approach when mapping, which takes advantage of characteristic nested scales of environmental features occurring across different spatial scales in all environments. In cartography, scale refers to size on the map relative to size in the world - small-scale maps show large regions. Map scale interacts with geometry of the world and requires map generalization. In the physical sciences, such as geomorphology tackled in this research cluster, the term scale is used to indicate the size, extent, or characteristic length of physical processes (Mark 2003). Interactions between size, shape, and function will be further explored systematically with the help of 'newer' technologies such as LiDAR or field geophysics. Using the metaphor of scale as a 'window of perception' (Marceau 1999), cognitive aspects of scale have been highlighted (Fabrikant 2001) and need to be incorporated in the GIScience curriculum and in the research agenda. Particular new research questions (Blaschke 2010; Hay and Castilla 2008; Hay and Blaschke 2010) are focussing on multi-scalar analyses and transfers (Reitsma and Bittner 2003; Burnett and Blaschke 2003), or transferability and reusability of classification rule sets (Walker and Blaschke 2008, Hofmann et al. 2011). Such claims seem to be justified by many respective references.

Likewise in recent literature, it is often claimed that GEOBIA is a paradigm. The Oxford English Dictionary defines the basic meaning of the term paradigm as "a pattern or model, an exemplar". The historian of science Thomas Kuhn (1962) gave it its contemporary meaning when he adopted the word to refer to the set of practices that define a scientific discipline at any particular period of time. In his book "The Structure of Scientific Revolutions", Kuhn defines a scientific paradigm as a universally recognized scientific achievements that, for a certain time, provide model problems and solutions for a community of researchers, i.e., what is to be observed and scrutinized, the kind of questions that are supposed to be asked and probed for answers in relation to this subject, how these questions are to be structured, how the results of scientific investigations should be interpreted and how is an experiment to be conducted.

In Kuhn's view, the key concept – if extremely condensed and simplified – is that common practice may be regarded as normal science whereas new concepts when clearly contradicting established thoughts may be called revolutionary science. In remote sensing, the pixel seems to be the common denominator of the vast majority of concepts and methods. Although occasionally criticized (Fisher 1997; Blaschke and Strobl 2001), it may be regarded as the unspoken paradigm in RS and it fulfils Kuhn's definition that a scientific paradigm is: "... what is shared by members of a scientific community, and conversely, a scientific community consists of those who share a certain paradigm." More generally, a paradigm may also be described as a constellation of findings, concepts, values, techniques etc. shared by a scientific community to define legitimate problems and solutions. As such, a paradigm has a fundamental influence on the methodology and the validity of experiments or scientific descriptions, and then defines what is significant and what is not, what is considered science and what is not. Kuhn defines a scientific revolution as a paradigm shift. The transition from a science experienced as paradigmatic belief stems from a subsequent appearance of "anomalies" theoretical and/or experimental, leading to questioning of the paradigm and the development of a broader science.

If we hypothesize that GEOBIA is a new paradigm, what is then the 'old' or 'dominating' paradigm? Intuitively, one would answer that the classic approach is the 'per-pixel paradigm'. Interestingly, a literature search reveals very few articles which call this a paradigm. A few exceptions include Walker and Blaschke (2008), Bhaskaran et al. (2009), Blaschke (2010), or Wuest and Zhang (2009), who claim that "Although pixel based methods have proven to be a generally successful method for classification of lower resolution satellite imagery, the advancements in image spatial resolutions have placed limitations on pixel" (p. 55). The modest use of the combination of the words 'pixel' and 'paradigm' may be surprising, since already Fisher (1997) argued in a well perceived article that integration of remote sensing and GIS can only possibly advance if we develop methods to address the conceptual short-comings of the pixel as a spatial entity, and stop pretending that it is a true geographical object. We can only speculate why the "paradigm hasn't been named a paradigm". A surprisingly simple answer could be the following: if something is taken for granted – like eating with a fork and a knife – one does not need a name for this habit – or paradigm, respectively. In figure 3, I position the two "paradigms" according to Kuhn's theory of paradigm shifts.

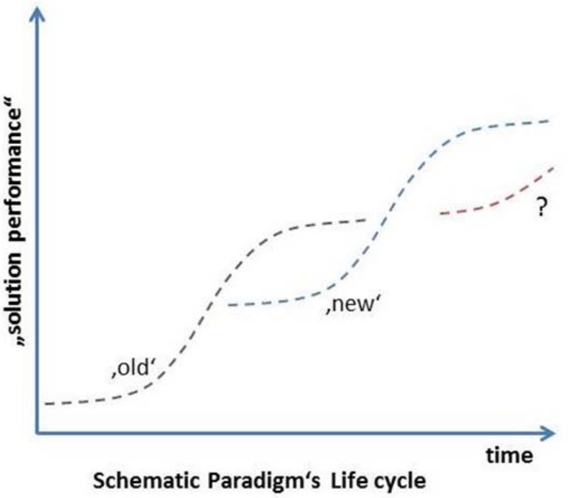

Figure 3. A schematic sketch of a paradigm shift according to Kuhn (1962). The per-pixel paradigm would refer to the 'old' and GEOBIA to the 'new' paradigm, respectively.

LITERATURE ANALYSIS

A brief search using Google Scholar (GS) in December 2012, reveals 346 articles which include the word "paradigm" AND either of the terms "object based image analysis" or "object oriented image analysis". Interestingly, a similar search but restricted to title, abstract and Keywords in Scopus only reveals 10 hits. When briefly analysing the more important articles – mainly journal articles – it becomes obvious that extremely few of these articles discuss what a paradigm is or try to substantiate claims they make in regard to the paradigm discussion. Most commonly it is simply argued that GEOBIA is a (new) paradigm in RS. How can a number of scientists claim that GEOBIA is probably one of the most significant developments in RS over the last ten to twenty years (Benz et al., 2004; Blaschke 2010; Johansen et al. 2010)? One possible explanation is that scientific literature is lagging behind the market success of some commercial products in this field (Blaschke 2010). Around the year 2000 – coincidentally with the advent of commercial high resolution satellite sensors – a software called eCognition had a great market success. Other products followed, partially by the more established RS software vendors, partially by new companies.

A small literature study was carried out in late December 2012. The study was conducted to find out if we can quantitatively support the hypothesis that GEOBIA can be considered as an important trend or even a paradigm in remote sensing. The literature survey utilized three different literature portals, namely GS, WebofKnowledge (WoK) and SCOPUS (Elsevier). Results show that not only is the number of articles increasing, but also that the rate of growth is dramatically accelerating. Blaschke (2010) identified 145 journal papers relevant to GEOBIA. Since more and more GEOBIA methods are integrated into application papers, it is difficult to provide an exact number. However, in the newly conducted literature survey, which analysed the number of relevant journal articles as of 31 December 2012, WoK found 311 articles when using different combinations of "object based image analysis" *OR* "object oriented image analysis" *OR* GEOBIA. The same search in SCOPUS yielded 366 hits. These figures represent a 213% or 250% increase, respectively, over the intervening three years.

Are these 311 or 366 quality-ensured publications – as opposed to GS searches – significant or negligible? Or is at least the growth rate higher than the respective growth rate of the RS literature? A comparative search for the term remote sensing and the years 2000 to 2012 yields roughly 84.000 hits, both for WoK and SCOPUS. Therefore, GEOBIA literature only accounts for some 0.3 to 0.4% of the scientific literature indexed in these two major scientific portals.

CONCLUSIONS

GEOBIA is increasingly recognized …. and is believed to have some advantages

By many measures, contemporary developments in object-based image analysis have been a resounding success, particularly when one considers the impressive number of applications. Market success may be one part of the overall story. However, when looking at the number of publications, there is not much ammunition to quantitatively support the hypothesis that GEOBIA is of growing importance in RS.

Although many, if not most, scientists are drawn into this field of RS and GIScience by the curiosity about analysing and classifying real world objects in images and auxiliary geospatial data sets, and hardly any involved scientist began from a theoretical or even paradigmatic perspective, there are many signs that the GEOBIA approach can today be considered as a paradigm.

Why is the sheer numbers of scientific publications rising, but not adequately supporting the claim that GEOBIA is a paradigm in RS? In this short paper I can only speculate, but I want to motivate colleagues to systematically investigate this paradox in more detail. If I may speculate, I will attribute it to the market-driven development and the factor time. We may draw the analogy to GIS and the late theory offensive starting in the late 1980s with the NCGIA Initiatives (Star et al. 1991). Another explanation could be the multi-disciplinary composition of the references found. There are not too many 'technical' papers and papers published in the core RS journals. Figure 4 shows the composition of the publication outlets for the search in SCOPUS. About 30% of the identified GEOBIA publications fall into the category "Earth and Planetary Sciences", about 19% in "Computer Science" and another 10% each in "Engineering" and in "Environmental Science". In combination, these four major fields account for 70% of the publications. The rest is splintered into many different fields.

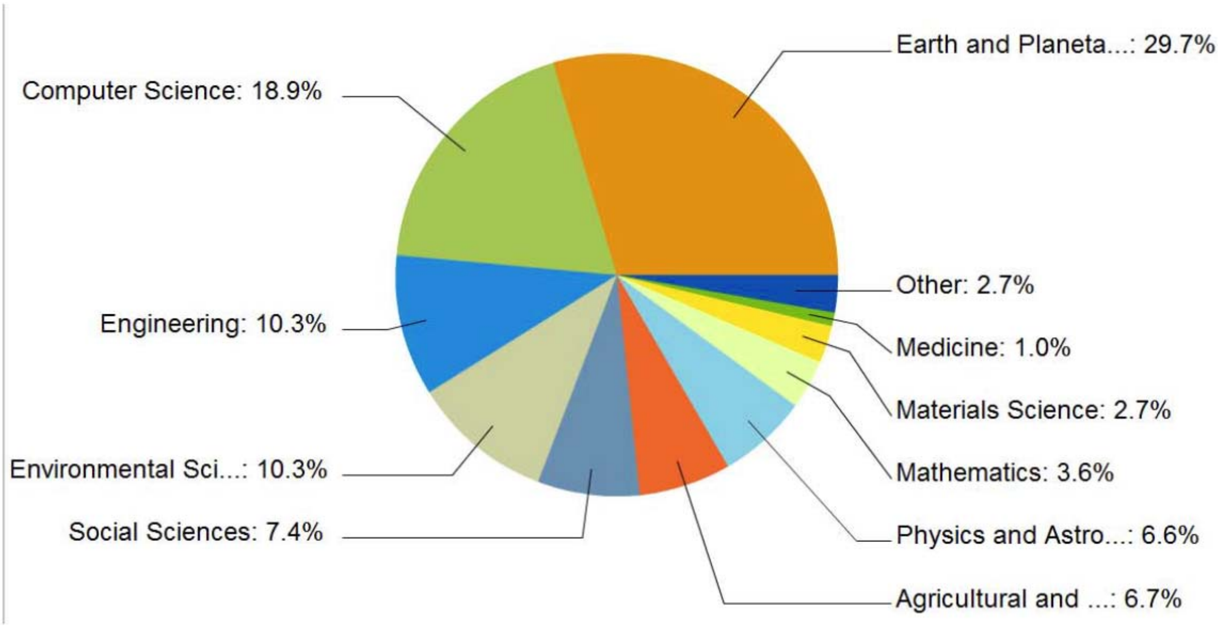

Figure 4. The 366 GEOBIA publications identified in SCOPUS and the disciplines of the respective publication outlets.

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