Plan of Action PhD-research

Hiddo Velsink

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1 Introduction

Almost thirty years ago I was a student of Geodesy in Delft and did for five months an internship at the German Geodetic Research Institute in Munich. During the internship I was concerned with designing a geodetic network in the Italian Alps to detect movements of the earth's crust. There started my interest in geodetic deformation measurements. I wrote my first scientific article with a collegue in Munich, Mr. Boedecker (Boedecker and Velsink, 1982) and they asked me to write a technical report on the subject (Velsink, 1982).
After finishing my study in Delft (see Velsink (1983)) I worked at the Cadastre in Apeldoorn and at the Delft University of Technology (TU Delft). For my work at the Utrecht University of Applied Sciences (called hereafter by its Dutch name: Hogeschool Utrecht), that hired me from TU Delft, I wrote a series of lecture notes on adjustment theory (Velsink, 1998b,c). In Velsink (1998c) I treated the definition of coordinates and their transformation, including their stochastic behaviour, which is an important basis for deformation analysis. I noticed then that application of these theories in practice was limited, although the possibilities were quite promising.
After ten years in management at Hogeschool Utrecht I was given the opportunity to start a PhD-research, as Hogeschool Utrecht wants to enlarge the amount of PhD's among its staff. To choose geodetic deformation measurements as topic was quite natural and that was reinforced when talks with many parties in practice showed that after ten years the field concerned had developed considerably, but not the dissemination of knowledge and application of fundamental theories. My experience in management and knowledge of management theories made me question why practice deals with geodetic deformation measurements the way it does and if it is possible to make things work better. The research question as it is formulated furtheron evolved from the questions posed by myself and from fruitful discussions with my supervising professor and co-supervisors.
In the following an overview is given of persons involved in my PhD-research, a definition and elaboration of the reseach envisaged and the research question. The scientific and practical context of the research is sketched and background literature is given.

2 Persons involved

2.1 PhD-candidate

Name:	Hiddo Velsink
Date of birth:	26 September 1958
Place of birth:	Groningen, the Netherlands
Highest diploma awarded:	Delft University of Technology, Faculty of Geodesy: MSc (Geodetisch ingenieur (ir.)), 1983
Employer:	Hogeschool Utrecht

2.2 Supervising professor

Name supervising professor:	Prof.dr.ir. Ramon F. Hanssen
Position:	Professor, Head of Section for Mathematical Geodesy and Point Positioning, Delft University of Technology

2.3 Co-supervisors

Co-supervising professor of Hogeschool Utrecht:	Dr.ir. Johan Versendaal, professor Extended Enterprise Studies
External co-supervisor:	Prof. Dr.-Ing. habil. Wolfgang Niemeier, Technische Universität Braunschweig

3 The research and its context

3.1 Preliminary title of the research subject

The preliminary title of the PhD-research is: "Adding value to geodetic deformation measurements" and its subtitle: "A model to facilitate communication on geodetic deformation monitoring and analysis".

3.2 Problem statement

The Dutch professional practice in geodesy and geo-informatics uses several pragmatic methods to determine and analyse the differences in the geometrical description of objects with respect to each other and with respect to the surface of the earth (hereafter called geo-objects) that however frequently seem to lack a good (scientifically proven) foundation, which was noticed during several interviews that were held in preparation of this Plan of Action. And if a scientific foundation does exist, the methods are not fully understood and accepted by non-experts.

It should be possible to make communication about goals, possibilities and analysis results of geodetic deformation measurements substantially better. To achieve this an analysis of the techniques of deformation measurements, the social-organisational circumstances and the communication between parties involved (principal and contractor (both mining/building and monitoring), responsible government bodies, those who might suffer from deformations, general public) is necessary. To make the problem more tangible two explorative practical case studies in the Netherlands and one explorative case study on theory will be analysed. The first case is about subsidence caused by mining activities in the Netherlands, i.e. the exploitation of salt, gas and oil reserves. One well-chosen example of such an exploitation will be investigated. The second case is about monitoring an infrastructure facility as it is put out to tender for example by Rijkswaterstaat (executive arm of the Dutch Ministry of Infrastructure and the Environment), Prorail (the Dutch company responsible for the railway network in the Netherlands) or another large principal in infrastrucure. These two case studies should provide information on geodetic deformation measurements both under strict legal regulations (mining activities) and without such regulations (infrastructure). The third case study studies theoretical geodetic models to handle deformation measurements and their practical implementations as they can be found in literature (in Dutch, English, French, German and Russian).

From these cases general conclusions will be drawn how the application and analysis of existing and new techniques, taking into account the social-organisational circumstances, can find their place in a succesfull communication between parties involved.

The additional problem of an insufficient scientifically proven foundation of the professional practice in geodetic deformation measurements will be accounted for in the research analysis and the conclusions drawn.

3.3 Short description of the research

The research is characterised in the following.

1. In the research a model will be developed to describe the goals, possibilities and results of analysing geodetic deformation measurements. The conditions are given that have to be fulfilled technically and organisationally in society to allow the model to be applied successfully.

2. The model will be developed on the basis of three case studies that were mentioned in section 3.2 and will elaborated in section 4.1.3.

3. The model will take into account the possibilities of kinematic and, as far as necessary and feasible within the framework of the research, dynamic analyses for assessing deformations of geo-objects.

4. The model will take into account ways to organise geodetic deformation measurements (e.g. by inviting to tender).

In constructing the aforementioned model it is foreseen:

- to give a systematic description of the Dutch professional practice with respect to determining and analysing the differences in the geometrical description of geo-objects; this description is both technical and social-organisational by nature;

- to examine systematically how the professional practice could make better use of the possibilities of mathematical geodesy and to describe and deepen the required mathematical geodesy;

- to explore by means of the case studies how an improved professional practice should look like as far as it concerns the technical aspects;

- to give recommendations concerning desirability, possibilities and alternatives of standardisation of deformation measurements, also in relation to the way in which deformation measurements are insured against risk financially.

- to give recommendations how the social-organisational implementation could take place; they should treat the organisational structures within and between the companies concerned.

The research has a technical component (describing the known and possibly to be developed parts of the domain of mathematical geodesy, analysing applications of it and offering new solutions) and a social-organisational component (the way in which the professional practice organises the solution of the technical problems concerned and how knowledge is developed and disseminated).

3.4 Relevance for the professional practice

Determining modifications induced by physical causes in spatial geometry with geodetic methods has a large social importance (e.g. land subsidence by oil, gas and salt extraction from the underground and the financial compensations that are linked to it, sea level change and climate change, subsidences and distortions of civil engineering and architectural structures (construction of North-South Underground Line in Amsterdam, construction of underground railway in Delft, engineering works in ports and locks, industrial installations, etc.)). For the realisation of durable solutions for the (re)planning of the Netherlands knowledge of the spatial situation and its changes are of substantial importance. Risk management during this (re)planning is not possible without a good control of the used mathematical and geodetic models.

3.5 Scientific relevance

The importance of the research is large, because the traditional scientific basis in the Netherlands for the application areas meant has disappeared for an important part by the termination of activities of the Faculty of Geodesy of Delft University of Technology and as a result a noticeable loss of knowledge has taken place, whereas at the same time in quick tempo new technologies are developed and introduced in the professional practice. Because the so-called Delft School in Geodesy had an international influence, see van der Hoek (1982); van Daalen (1985), the loss is also felt beyond the borders of the Netherlands.
The scientific relevance manifests itself in two areas, mathematical geodesy and business administration. By systematic research and scientifically founded proposals, as described in the problem statement, a contribution is provided to mathematical geodesy, whereas the social-organisational aspects of the problem statement make a contribution to the scientific field of business administration.

3.6 Connection with education

The course in geodesy/geo-informatics, the ict-courses and the course technical business administration is the natural educational setting for the research. Students and lecturers of these courses can fulfil important functions for the research and results of the research will find its place in the courses.

3.7 Position within the research programme of Hogeschool Utrecht

The research programme of the Faculty of Science and Technology of Hogeschool Utrecht for the period 2010-2015 (version 3.1) prescribes that in 2011 a professorship Design Tools and Methods (Virtual Worlds) should be started. From the description of the professorship that has to be set up, it shows that its subject concerns among others simulation studies, BIM and

GIS (BIM = Building Information Model, GIS = Geographical Information Systems). The subject of the PhD-research falls within these subjects. It concerns obtaining information, with which a virtual model of reality is made, whereupon by mathematical analysis, simulations and the use of BIM and GIS conclusions are drawn. The PhD-research has relations with several professorships: Microsystem Technology /Embedded Systems (for deformation measurements among others this type of systems is applied), Extended Enterprise Studies (the research concerns processes of digital information processing within and between organisations), New Culture in the Construction Chain (the phenomenon culture in a project setting is studied).
Some experienced researchers within Hogeschool Utrecht, possessing a PhD-degree and not yet involved in any research programme, could participate in this research. Explicit interest from other lecturers has already been registered. Students from the course in Geodesy and Geo-informatics can easily be involved in the research. A research question for a fourth year student has already been issued.

3.8 External parties involved

The supervising professor, prof. Hanssen, is professor at Delft University of Technology.
From the two co-supervisors Mr. Versendaal is professor at Hogeschool Utrecht and capable of supervising the organisational questions linked with the research question. Prof. Niemeier is professor at Technische Universität Braunschweig in Germany and will be very valuable as he fulfills important international functions in the scientific area of interest and has an outstanding track record. He can also mediate in contacting parties in Germany, where the level in this scientific field is high.
Interviews were held with several engineering companies, NAM (a subsidiary of Shell) and Rijkswaterstaat (Directorate General for Public Works and Water Management). From the interviews it has become clear that all of them consider the PhD-research of large value for their company and they are prepared to take action to regulate financial and organisational contributions. The sub-committee Land Subsidence and Sea Level Change of the Netherlands Geodetic Commission, part of the KNAW (Royal Netherlands Academy of Arts and Sciences), examines the possibility of contributing financially.

3.9 Organisation and financing

The nominal duration of the PhD-research is estimated to be four years. The intention is to finish the research within a period of three years, as from September 2011, in which period three days per week are used for the research. Such an acceleration must be possible because of the knowledge and experience the PhD-candidate already possesses. The costs of the research are split up in four components.

1. remuneration costs, including the associated employer costs and travel and subsistence expenses for the research

2. overhead costs for the employer, such as housing, costs of facilities and such
3. costs for supporting activities and appliances for the research
4. costs for making up and publishing digital and paper versions of the thesis

The proposal is to cover the costs as follows:

1. to be financed by interested parties in the professional field, hereafter called the participants, and Hogeschool Utrecht. The costs are € 60,500 per year (price level February 2012) during a minimum of three and a maximum of five years. It is foreseen to be covered by:
   - Nederlandse Commissie voor Geodesie; requested is € 12,500 per year in 2012 and 2013;
   - Principals of geodetic deformation measurements as Rijkswaterstaat, NAM, Shell, Prorail; requested is a total of € 20,000 per year;
   - Geodetic Engineering Companies as Fugro Geoservices, Oranjewoud, Arcadis, Grontmij, Advin/IV-infra, etc.; requested is a total of € 17,900 per year;
   - Hogeschool Utrecht to an amount of € 10,100.
2. to be financed by Hogeschool Utrecht; it amounts to € 18,200 per year.
3. to be financed on the basis of agreements, which are made for each situation separately.
4. to be financed by participants; the amount will be estimated in due course.

The participants and Hogeschool Utrecht form jointly an advisory body, in which every participant and Hogeschool Utrecht are represented by one person. The advisory body meets at least twice a year, at which meeting also the PhD-candidate, the supervising professor and the co-supervisors are invited. The advisory body gives recommendations concerning everything that pertains to the PhD-research.

4 Set up of the PhD-research

4.1 Research question

4.1.1 Subject

Before formulating the research question the environment of the research question is sketched.

Geodesy

Fixing position and position change of objects with respect to the surface of the earth and with respect to each other is one of the tasks of geodesy. The result of fixing is indicated as geometrical geo-information or spatial geometry. The objects can be for example buildings, cadastral bounderies, underground gas reservoirs, and also means of transport as ships and cars, or satellites. Fixing takes place in general by means of one-, two- or three-dimensional Cartesian or geographical coordinates (x, y, z respectively φ, λ, h). These coordinates fix the geometry of the objects in relation to each other and to the surface of the earth.

Deformation measurements

The PhD-research occupies itself with the measurements of changes of the geometry of geo-objects, particularly those changes which bring about only restricted differences and which are determined by geodetic measuring techniques and result in Cartesian or geographical coordinates. These measurements are called deformation measurements. For the analysis of the measurements techniques from mathematical geodesy are applicable, among which the network connection adjustment. A central item of the PhD-research is mathematical geodesy and the application of it for determining and analysing the differences in the geometrical description of objects. Monitoring is considered as a (semi-)continuous form of deformation measurements and as such as a subdomain of the domain of deformation measurements.

A difference is made between geodetic and geotechnical deformation measurements. Under geotechnical deformation measurements are understood the measurements of tensions and differences in pression, slope changes, deflection, changes in distance and altitude by means of specialised instruments (see Verhoef (1994)), which frequently reach submillimeter level. Measurements of changes in distance and altitude with total stations and spirit level instruments are considered geodetic deformation measurements. Also photogrammetrical measurement methods, GPS, SLR, VLBI and INSAR are considered as geodetic (Verhoef, 1994). The research aims at geodetic deformation measurements. To the extent that for solving deformation problems both geodetic and geotechnical measurement methods qualify, geotechnical methods are also taken in consideration, but the research concentrates on geodetic measurement methods.

4.1.2 Formulation of the research question

The problem statement as formulated in section 3.2 is translated into the research question.
How can communication about goals, possibilities and analysis results of geodetic deformation measurements be improved substantially, taking into account and, if necessary, proposing improvements to the techniques of deformation measurements and analysis, the social-organisational circumstances and the communication between parties involved (principal and contractor (both mining/building and monitoring), responsible government bodies, those who might suffer from deformations, general public)?

Bounderies The research limits itself to consider deformation measurements only within certain bounderies.

1. Type of deformation measurements
   (a) subsidence
   (b) shifts, rotations
2. Time
   (a) from several days to tens of years
   (b) *not*: seconds, centuries
3. Space
   (a) from a minimum of 100 m to a maximum of 1000 km
   (b) *not*: less than 100 m and continents
4. Techniques
   (a) leveling
   (b) total stations
   (c) gps
   (d) laser scanning
   (e) radar
   (f) etc., see overview in Niemeier (2011)

4.1.3 Case Studies

To arrive at general conclusions concerning the research question three casestudies will be elaborated.

Case Land Subsidence:

- The model that is developed for the analysis of land subsidence measurements integrates different measuring techniques in a transparent way and divides the information that can be discussed with all parties concerned from the information that can be qualified as internal to the model. The model offers the possibility for parties to modify the "external information" and to judge the consequences for themselves.
- The model developed to describe the social organisational aspects of land subsidence measurements and modes of cooperation and interdependance gives an insight in parties concerned and gives alternatives for the modes of cooperation and the interdependance.

Case Infrastructure:

- The model developed for the analysis of geodetic deformation measurements in infrastructure engineering indicates how different measuring techniques can be integrated and how on the basis thereof tenders can be formulated.
- The model developed to describe the social organisational aspects of deformation measurements describes how a procurement can be organised.

Case Integrated set-up of deformation measurements:
The model developed for the integrated set-up of deformation measurements describes how measurements acquired with different measuring techniques, with different intervals, in different dimensions and at different geographical locations, can be combined and how conclusions should be drawn.

4.1.4 Elaboration of the research question

4.1.5 Sub Questions

The research question is developed into sub questions. The sub questions are divided over five areas of interest.

1. Inventory and analysis of domain (technologically/organisationally and Netherlands/abroad)
   (a) How can the field of geodetic deformation measurements in the Netherlands be defined for the PhD-research? Which areas can be distinguished?
   (b) How is the field defined abroad and what are the important differences with the Dutch situation?
   (c) By which companies and institutions deformation measurements are devised, carried out, analysed and presented? What is its turnover?

(d) Which roles do parties play in this (principal, provider, consultant, knowledge institute, legislative organisation, standardisation institution, etc.) and which advantages and disadvantages do parties experience in this system of roles?

(e) Other systems of roles can be found abroad: which experiences have been gained with those systems?

(f) How is communication on measurements and analysis organised?

2. Mathematical geodesy applied to deformation measurements

   (a) Which components of mathematical geodesy are used for deformation measurements? The modelling by means of adjustment models, the network connection adjustment and the kalmanfilter are among others possible components. How does a synoptic description of these components look like?

   (b) What are the unsolved problems in these components? What is the qualitative and quantitative importance in the professional practice of these problems?

   (c) Which answers can be given to the qualitatively or quantitatively important unsolved problems within the framework of the PhD-research? How can mathematical geodesy be complemented for this purpose?

   (d) Is it possible to review theory and implementation of the questions above in practice in practice examples? What does this show?

3. Organisation of deformation measurements

   (a) What is a good taxonomy of the companies and institutions which are active in deformation measurements and what role do they play?

   (b) Which alternatives for a system of roles can be formulated and which advantages and disadvantages stick to those alternatives?

   (c) Which alternative for an effective communication can be formulated?

4. Parameterisation, credibility and acceptability

   (a) Can the choices that are needed for the parameterisation of the models of mathematical geodesy, be presented in a user friendly manner and can these choices be made in dialogue with users (taking into account the terms credibility and acceptability, see van der Molen (1999))?

5. Standardisation

   (a) Which forms of standardisation exist and how are they used in practice?

   (b) How is standardisation organised? Are alternative organisation forms possible and how do they perform seen against the existing practice?

5 Basic literature

The research envisaged will be based on knowledge and research in different scientific areas. The following areas are seen as essential:

- Geodetic Deformation Measurements and Model Building
- Statistics, Testing Theory and Adjustment Theory
- Mechanics, Geotechnique and Geophysics
- Public Governance, Principal, Provider and the Extended Enterprise

Some basic literature is mentioned in the following subsections.

5.1 Geodetic Deformation Measurements and Model Building

- A book with a good overview of deformation measurements and their treatment is Welsch et al. (2000). It also contains an extensive overview of relevant literature upto the year 1998.
- Models and terminology of deformation measurements are treated in a report of the International Federation of Surveyors (Welsch and Heunecke, 2001).
- A good overview in recent advancements in deformation measurements with a focus on satellite radar interferometry is the PhD-thesis of Ketelaar (2008).
- A valuable overview on land subsidence gives Barends et al. (2008).
- Useful information on the technique of Radar Interferometry, important for deformation monitoring from satelites, gives Hanssen (2001).
- A recent thesis on the application of deformation analyses to detect and analyse height changes in Northern Germany, including an overview of applicable models is Tengen (2010).

5.2 Statistics, Testing and Adjustment Theory

A good overview of statistics, testing and adjustment theory and a superficial reference to deformation measurements is given in

- Niemeier (2008)
- Teunissen (2007).

5.3 Mechanics, Geotechnique and Geophysics

A basic introduction in geotechnique to assess its role with respect to deformation measurements is

- Barends (2011).

5.4 Public Governance, Principal, Provider and the Extended Enterprise

What public and private goals are achieved by performing deformation measurements? How do government and private business organise initiative, design, execution and evaluation? Some thought-provoking literature is:

- Bloemendaal and Van der Geest (2011), on alternative organising methods for building a new highway
- Versendaal and Wiersema (2009), on extended enterprises
- Dicke et al. (2011), on how markets function in the Netherlands

5.5 Articles from my hand

Articles from my hand related to the subject of the PhD-research are Boedecker and Velsink (1982), Velsink (1982), Velsink (1987), Velsink (1990), Velsink (1991), Velsink (1997), Velsink (1998a), Velsink (1998b), Velsink (1998c).

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