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Schriftenreihe des Studiengangs Geodäsie und Geoinformatik 2012,1

Highly Precise Positioning and Height Determination using GPS

Results of a PROBRAL project
by Universidade Federal do Paraná (UFPR, Curitiba, Brazil) and
Karlsruhe Institut für Technologie (KIT, Karlsruhe, Germany)

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In remembrance of

Jair Silveira Da Silva Jr.

Dank

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Preface

CLÁUDIA PEREIRA KRUEGER[1] *AND BERNHARD HECK*[2]
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This book presents some representatively selected results and experiences gained within the bilateral PROBRAL program funded by the academic exchange services CAPES (Brazilian academic exchange service) and DAAD (German academic exchange service). During the time period 2006-2009 the joint international research project entitled “Precise positioning and height determination by means of GPS: Modeling of errors and transformation into physical heights” was established between the Postgraduate Programme in Geodetic Sciences of the Department of Geomatics of the Federal University of Paraná (UFPR, Curitiba, Brazil) and the Geodetic Institute of Universität Karlsruhe TH (now KIT, Karlsruhe Institute of Technology, Karlsruhe, Germany).

This compilation is composed of five sections. We will start with a block of two papers focusing on the fundamental basis of the success of our cooperation – the historical background. In the context of planned future cooperation sustainability seems to be fundamental as well, therefore, the second paper of the block “History and Sustainability” deals with this topic. The following section is reserved for the “Final reports of the project coordinators”. Section 3 gives a representative overview of the “Research” carried out in the framework of our PROBRAL initiative. The improvement of the “Intercultural Competence” of all participating researchers is an important goal of the here described joint venture. This is taken into account within section 4. The last section of this book lists the “Scientific Output”. The close cooperation of the participating institutions proved to be very successful, not only with respect to the number of jointly supervised doctoral students, but also due to the remarkable number of joint publications generated throughout the project.

The project coordinators Cláudia Pereira Krueger and Bernhard Heck first of all acknowledge the international cooperation teams of CAPES and DAAD, for the competent and efficient service at all times and for all project participants. Without CAPES and DAAD we would not have been able to achieve full success in our research.

Both project coordinators would like to express their sincere thanks to their colleague Michael Mayer (KIT) who read most parts of the written material critically, gave suggestions, solved problems, and made this compilation possible due to his obstinate inquiries. Both, Cláudia Pereira Krueger and Bernhard Heck, would like to acknowledge all other Brazilian and German colleagues and friends who directly or indirectly contributed to the great success of this outstanding transnational project; particular mention is given to Jorge Centeno (UFPR) and Silvio Freitas (UFPR), who acted as co-coordinators.

There exists a strong wish and hope from both institutions for a future continuation of the fruitful Brazilian-German cooperation in the field of Geodesy.

“*As for the future, your task is not to foresee it, but to enable it.*”
Antoine de Saint-Exupery

Historie und Nachhaltigkeit

History and Sustainability

História e Sustentabilidade

Das Geodäsieprojekt der GTZ in Curitiba 1981-1995: Eine nachhaltige Investition deutsch-brasilianischer Zusammenarbeit

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1. Vorbemerkung

Brasilien übt auf Deutsche eine ganz besondere Faszination aus, vielleicht gerade deshalb, weil Land und Leute doch so aufregend anders sind als das Gewohnte. Das gilt im übertragenen Sinne auch für das Arbeitsfeld des Geodäten, der in Brasilien Herausforderungen in einer anderen Größenordnung vorfindet als in seiner Heimat. Das Wirken deutscher Geodäten in Brasilien und die überaus freundschaftlichen Kooperationen haben einen lange Geschichte und sind z. B. in (ERWES UND BÄHR 2004) dokumentiert. Bereits Ende der 30er Jahre war es Vinzenz Pölsler, ein Schüler Richard Finsterwalders/Hannover, der im Auftrage der Lufthansa in Rio de Janeiro Photogrammetrie aufbaute (WINKELMANN 1984). Die ersten damals gegründeten Luftbildfirmen existieren teilweise noch heute. In den 1960er Jahren begannen dann die Arbeiten der „Deutschen Kartographischen Mission“ in Olinda bei Recife mit maßgeblichen Anteilen von Herbert Erwes (vgl. BÄHR 2009) und vielen anderen deutschen Vermessungsexperten. Aufgabe dieser Mission war, die Produktion „amtlicher“ topographischer Karten besonders für den brasilianischen Nordosten zu befördern und zu sichern; die damals entwickelten Strukturen haben sich bewährt und gelten bis heute.

Zu den beiden wirtschaftlich-technisch geprägten Schwerpunkten geodätischer deutsch-brasilianischer Kooperation kam Anfang der 1980er Jahre ein Projekt der akademischen Zusammenarbeit zwischen den Standorten Curitiba und Recife einerseits und deutschen Universitäten andererseits. Über dieses Projekt wird im vorliegenden Aufsatz berichtet, wobei einschränkend die Kooperation am Standort Curitiba im Zentrum stehen soll. Eine vollständige Darstellung von Verlauf und Ergebnissen gibt (BÄHR 1996). Die folgenden Ausführungen sind daher teilweise dieser Literaturstelle entnommen und wenn nötig modifiziert.

2. Vorgeschichte

Am Anfang steht eine weitere Persönlichkeit, welche die Zusammenarbeit zwischen der Geodäsie an der Universidade Federal do Paraná (UFPR) in Curitiba und deutschen Universitäten begründete: Prof. Camil Gemael – „Professor K1000“, wie er bisweilen scherzhaft schrieb. Camil Gemael hatte in Brasilien Bauingenieurwesen studiert und anschließend ein Masterstudium der Geodäsie an der renommierten Ohio State University in Columbus absolviert. Dabei lernte er nicht nur die besten Köpfe der internationalen Geodäsie persönlich kennen – W.A. Heiskanen, U. Uotila, I. Mueller… – sondern auch die Strukturen von internationaler Forschung und akademischer Lehre. Die überaus erfolgreiche Einrichtung eines entsprechenden geodätischen Studienganges an der UFPR ab den frühen 1970er Jahren entwickelte sich zu seinem Lebenswerk.

Mit großer Energie baute Camil Gemael zunächst eine Masterausbildung auf („Curso de Pós-Graduação em Ciências Geodésicas“). Dieses war der erste geodätische Studiengang in Brasilien, welcher bereits umfänglich Forschungselemente umfasste und damit eine anspruchsvolle akademische Ausbildung garantierte. Möglich wurde dies durch den Aufbau einer modernen geodätischen Bücherei einerseits und regelmäßige Einladungen von internationalen Gastprofessoren andererseits; aus den USA (z. B. Uotila), Kanada (z. B. Vanicek), Bundesrepublik Deutschland (z. B. Grafarend) oder Portugal (Vicente). Als weiterer stabilisierender Faktor kam hinzu, dass einige Professoren ihren PhD in Nordamerika machten und anschließend nach Curitiba zurückkehrten (José

Bittencourt de Andrade, João Bosco Lugnani…). Ab den 1970er Jahren bis heute „liefert" Curitiba den so dringend benötigten akademisch ausgebildeten geodätischen Nachwuchs für Brasilien und darüber hinaus.

Aber für eine Persönlichkeit wie Camil Gemael musste die Entwicklung nach Einrichtung eines MSc. weitergehen bis zum PhD. Dazu schrieb er also 1978 einen Antrag an das Bonner Auswärtige Amt – nota bene auf dem Dienstwege über die brasilianische Regierung – auf fachliche und finanzielle Unterstützung durch die Bundesrepublik Deutschland. Hier schließt sich der Kreis mit den beiden oben erwähnten wirtschaftlich-technisch geprägten Projekten aus den 1930er und 1960er Jahren, Aufbau von Photogrammetrie und Kartographische Mission. Bemerkenswert ist dabei, dass von der UFPR in Curitiba aus zu diesen beiden Projekten zunächst keine direkten Verbindungen existierten; die Initiative zur neu beantragten akademischen Kooperation entstand vielmehr in Curitiba unabhängig als Ausleger des „Curso de Pós-Graduação em Ciências Geodésicas".

Der Antrag nahm seinen weiteren bürokratischen Weg vom Auswärtigen Amt zum BMZ (Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung) und von dort zu dessen Tochter GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit) in Eschborn, welche sich fachlichen Rat bei der DGK (Deutsche Geodätische Kommission) holte. Ihr damaliger Vorsitzender war Alois Heupel, Professor für Kartographie an der Universität Bonn und gleichzeitig ihr Rektor. Dieser erkannte sofort die interessanten Aufgaben, die sich der deutschen Geodäsie in Curitiba boten, und so wurden 1979 zwei Bonner Geodäten zur Projektprüfung im Auftrage der GTZ nach Brasilien entsandt, Dr. Dieter Morgenstern und Prof. Dr. Günter Seeber, der damals bereits seit einigen Jahren in Hannover wirkte. Ihr Gutachten kam zum Ergebnis, dass Curitiba ein geeigneter Standort für den Aufbau einer Doktorandenausbildung wäre. Zusätzlich wurde vorgeschlagen, am Standort Recife (Universidade Federal de Pernambuco) am dortigen Departamento de Cartografia (DECART) einen Masterkurs aufzubauen in Abstimmung mit Curitiba. Damit war der Rahmen vorgegeben, der durch die beiden Kooperationspartner Brasilien und Bundesrepublik Deutschland akzeptiert wurde und für das Projekt bestimmend blieb.

3. Ziele des GTZ-Projekts

In der Projektvereinbarung der Regierungen von Brasilien und Deutschland vom 22. Dezember 1980 heißt es: *„Die Regierung der Bundesrepublik Deutschland und die Regierung der Föderativen Republik Brasilien kommen überein, gemeinsam für die Dauer von bis zu drei Jahren die Bundesuniversität von Paraná in Curitiba beim Aufbau des Institutes für Vermessungswesen zu unterstützen mit dem Ziel, die Postgraduiertenausbildung in Lehre und Forschung zu fördern und durch die Einrichtung von Promotionskursen zu erweitern. Damit soll eine Ausbildungsstätte hoher Qualität eingerichtet werden, die eine Leitfunktion für Brasilien übernehmen und langfristig zur Lösung der kartographischen Probleme des Landes beitragen soll".*

„Vermessungswesen" und „Geodäsie" werden in den Vereinbarungen und Übersetzungen synonym gebraucht. Auch das brasilianische „cartografía" ist inhaltlich weitgehend deckungsgleich. Aus den zunächst vereinbarten drei Jahren wurden schließlich 15, und zu Curitiba kam bei Projektbeginn Recife hinzu. Die Projektvereinbarungen blieben indes Leitlinie für alle Projektmaßnahmen. Im Jahre 1991 wurde folgendes Projektziel definiert:

„Die Universitäten von Pernambuco und Paraná bilden entsprechend den Erfordernissen Brasiliens praxisorientiert qualifizierte Fachkräfte im Vermessungswesen aus und nehmen ihre Aufgaben in anwendungsbezogener Forschung und Beratung wahr".

Inhaltlich erscheint diese Formulierung gegenüber der von 1980 weicher, weil der Promotionskurs (der 1991 in Curitiba bereits lief) nicht explizit genannt wird. Andererseits zeigt der Hinweis auf Praxisorientierung und anwendungsbezogene Forschung und Beratung, dass man keine akademischen

Elfenbeintürme bauen sondern für die entwicklungspolitischen Herausforderungen des Landes gerüstet sein wollte. Was die Formulierung von 1991 angeht, so folgt sie übrigens sehr charakteristisch den Vorgaben aus der „Zielorientierten Projektplanung (ZOPP)“, ein transparentes Planungswerkzeug mit Beteiligung aller Akteure, wie es damals bei der GTZ neu eingeführt worden war.

4. Verlauf und Maßnahmen im Projektteil Curitiba

Der Projektname lautet: „Postgraduiertenausbildung Geodäsie an den Universitäten Curitiba und Recife / Brasilien“. Unter „Postgraduiertenausbildung“ versteht man in Brasilien die auf einen berufsqualifizierenden Abschluss („Graduierung“) folgende weitere Qualifikation zu einem „mestrado“ und einem „doctorado“. Es handelt sich also um das zweistufige System, welches von den USA übernommen wurde, nur dass der Begriff „Postgraduierung“ dort die Phase *nach* dem PhD bezeichnet, ein Umstand, der bei internationalen Diskussionen häufig zu Konfusion führt.

Das Projekt begann praktisch mit der Ausreise des ersten Langzeitexperten (LZE) H.-P. Bähr/ Hannover im Mai 1981 und endete formal mit Abschluss der Förderung Ende 1995. Als Vorsitzender der DGK hatte sich der Projektkoordinator (PK) A. Heupel die Auswahl des LZE vorbehalten und gleichzeitig die Bedingung aufgestellt, dass dieser habilitiert sein müsste, denn schließlich ginge es ja um Einrichtung und Abnahme von Promotionen. Der „Markt“ an habilitierten geodätischen Nachwuchswissenschaftlern, die zusammen mit ihrer Familien bereit waren nach Brasilien zu gehen, war damals naturgemäß sehr beschränkt, was die Auswahl sicher vereinfacht hat.

Die erste Projektphase lief von Mai 1981 bis Dezember 1986 mit LZE H.-P. Bähr bis zu seinem Weggang nach Karlsruhe im April 1983, anschließend mit LZE E.-U. Fischer/Bonn, der bereits ab 1982 im Projekt in Curitiba arbeitete; PK in der ersten Phase war A. Heupel. In einer zweiten Projektphase von Januar 1987 bis Juli 1991 war E.-U. Fischer LZE und H.-P. Bähr / Karlsruhe PK. Eine Nachbetreuungsphase schloss sich an von August 1991 bis Dezember 1994 mit Konsolidierungsphase Januar 1995 bis Dezember 1995, jeweils mit PK H.-P. Bähr.

4.1 Maßnahmen in der Lehre

Die Projektinhalte umfassen praktisch die ganze Geodäsie. Fachliche Unterstützung musste daher von vielen Personen geleistet werden. Anders etwa als beim GTZ-Forstprojekt der Universität Freiburg mit der Forstfakultät Curitiba war beim Geodäsieprojekt die Zusammenarbeit nicht auf eine einzige deutsche Hochschule beschränkt. Allerdings ergaben sich Schwerpunkte mit der Universität Bonn und Hannover. Im Verlaufe des Projekts strahlten die Verbindungen dann weiter aus nach Karlsruhe, Darmstadt und Wien.

Folgende Professoren haben im Rahmen von Kurzzeiteinsätzen (KZE) am Aufbau des Projekts mitgewirkt: Konecny, Pelzer, Seeber, Torge (Hannover); Bonatz, Heupel, Morgenstern (Bonn); Bähr, Wenzel (Karlsruhe); Groten, Schlemmer (Darmstadt); Kahmen (Hannover und Wien). Die Aufgabe von KZE ist zunächst eine Unterstützung in der Lehre, denn staatliche Anerkennung von Ausbildungsgängen („cursos“) im Postgraduiertenbereich setzt Lehre auf hohem Niveau voraus. Eine Schwierigkeit ist natürlich die Sprache: Bis auf Ausnahmen tragen Gastprofessoren in Englisch vor, obwohl brasilianische Studenten des Englischen meist noch weniger mächtig sind als deutsche. Neben theoretischen Vorlesungen sind praktische Übungen hochwillkommen, was allerdings am Anfang der Projektlaufzeit wegen fehlender Geräte- und Rechnerausstattung schwierig war. Alle Beiträge von KZE waren ins das Postgraduierten-Curriculum integriert, es gab also „creditos“.

Bereits im ersten Jahr der Projektlaufzeit hatte sich eine Maßnahme besonders bewährt: der Einsatz von sogenannten „Tutoren“. Das sind Studenten höherer Semester, welche auf die Übernahme einer speziellen Aufgabe bereits an ihrer Heimatuniversität vorbereitet wurden. Sie gingen dann für etwa drei Monate nach Brasilien und konnten in dieser Periode natürlich in einer anderen Weise wirken als ein Gastprofessor, der in der Regel nur zwei Wochen bleiben kann. Alle Tutoren waren immer hoch motiviert und haben auch gut Portugiesisch gelernt. Die meisten Tutoren-Einsätze hatten zum Ziel, neue Hard- und Softwarekomponenten einzuführen und brasilianische Studenten und Professoren darauf zu trainieren. Anders als in anderen Ländern verursachte es übrigens in Brasilien keine Probleme, wenn hier der „Student" den „Professor" unterwies.

4.2 Beschaffung von Geräten

Dieses Thema liegt an der Schnittstelle deutscher und brasilianischer Verwaltungsbürokratie und ist entsprechend komplex. Positiv ist zunächst, dass bei der Auswahl, jedenfalls während der Projektlaufzeit, keine Bevorzugung deutscher Produkte vorgegeben war. Der Aufwand für eine Beschaffung, vom LZE durchgeführt, ist jeweils immer derselbe, egal ob es sich um die Schreibmine für einen Zeichentisch handelt oder um ein photogrammetrisches Auswertesystem. Ein besonderes Thema ist die Entzollung. Zollgebühren dürfen entsprechend der Regierungsvereinbarung nicht erhoben werden, aber die Auslieferung kann sich unter Umständen auch mehrere Monate hinziehen.

Folgende Labors und größere Geräte sind in der Projektlaufzeit für Curitiba beschafft worden (in Klammern fachlich betreuender deutscher Counterpart). Die Reihenfolge ist etwa chronologisch:

- Photogrammetrisches analytisches Auswertesystem Zeiss-Planicomp C 100 mit HP 1000 Rechner; 1995 umgebaut (Bähr)
- Rollei 6 x 6 Réseau Kamera sowie Digitalkamera (Bähr)
- Einrichtung einer Erdgezeitenstation (Bonatz)
- 2 GPS-Empfänger mit Software (Seeber)
- Einrichtung eines Eichlabors (Schlemmer)
- Software für die Kartographie (Morgenstern)
- 2 Workstations, mehrere PCs

Alle Labors und Geräte haben Lehre, Forschung und Projekte ganz erheblich bestimmt und gefördert.

Ein grundsätzliches Problem ist die Wartung und Erneuerung der Gerätesysteme, sowohl Hard- als auch Software. Dies ist ein Thema, was ja auch an deutschen Universitäten bekannt ist und welches sich in den vergangenen drei Jahrzehnten von Spezialgeräten verlagert hat auf Rechnersysteme und Software. Erfreulicherweise gelang es den Kollegen in Curitiba, den wertvollen Bestand der modernen Labors auch über die Projektlaufzeit hinaus betriebsfähig zu halten.

Die Einführung des Zeiss-Planicomp im Jahre 1982 war für Brasilien ein Novum. Das Gerät wurde zunächst weniger als „rechnergesteuertes photogrammetrisches Auswertesystem" gesehen und genutzt, sondern primär als relativ moderner Digitalrechner verwendet. Digitalrechner – PCs existierten noch nicht – waren damals an brasilianischen Universitäten den Rechenzentren vorbehalten. Mit dem Planicomp erhielt man in Curitiba im Department nun einen unabhängigen Zugriff auf einen eigenen Digitalrechner. Der HP 1000 Steuerrechner begann Anfang der 1990er Jahre Probleme zu zeigen; daher wurde er noch ganz am Ende der Projektlaufzeit gegen eine PC-Steuerung ausgetauscht.

4.3 Fortbildungsmaßnahmen für brasilianische Dozenten

Hinter dem Begriff „Fortbildung" verbergen sich sehr unterschiedliche Alternativen. Die Palette reicht von kompletten Promotionsverfahren in Deutschland (organisiert vom DAAD) über Forschungsaufenthalte bis hin zur Präsenz auf internationalen Kongressen. Bis 1995 promovierten allerdings nur relativ wenige brasilianische Geodäten in Deutschland; die meisten Fortbildungsaufenthalte konzentrierten sich auf spezielle technisch-wissenschaftliche Themen in Zeiträumen von zwei bis vier Monaten an Instituten in Hannover, Bonn, Karlsruhe und Darmstadt.

Während im ersten Teil der Projektlaufzeit diese Aufenthalte mehr informativen Charakter hatten, wandelten sie sich später zu Forschungsaufenthalten in Verbindung mit gleicher oder ähnlicher Hard- und Software bei Gast- und Heimatuniversität. Fast in jedem Fall gestalteten sich solche Aufenthalte als äußerst fruchtbar, besonders dann, wenn der betreuende deutsche Professor einen guten Einblick in das brasilianische Umfeld hatte. Es wurde darauf geachtet, dass die Arbeiten anschießend in Curitiba weitergeführt wurden, möglicherweise dazu noch mit Unterstützung eines studentischen Tutors. Dies führte, zusammen mit brasilianischen Masterkandidaten, bisweilen zu Keimzellen von späteren Forschungsgruppen.

Folgende Professoren aus Curitiba haben im Berichtszeitraum 1981 bis 1995 Fortbildungsmaßnahmen unterschiedlicher Art absolviert: José Bittencourt de Andrade, João Bosco Lugnani, Alvaro Doubek, Celso São João, Romualdo Wandresen, Oziel Leite, Milton Campos, Henrique Firkowski und Quintino Dalmolin.

4.4 Ausgewählte Forschungs- und Entwicklungsprojekte 1981 bis 1995

Im Folgenden werden kurz Schwerpunkte und einige ausgewählte Projekte aufgelistet, welche das GTZ-Projekt auszeichneten:

- Arbeiten mit GPS, vor allem Kooperation zwischen Prof. Dr. Milton Campos und Prof. Dr. Günter Seeber/ Hannover:
    - Untersuchung des Einflusses der Ionosphäre in äquatorialen Breiten (mit Unterstützung von BMZ/DFG)
    - GPS für kinematischen Einsatz bei Überwachung von Transporten (zusammen mit Bundesbahnverwaltung in Curitiba/RFFSA)
    - Nutzung von GPS zur Abmarkung von Indianerreservaten in fünf Bundesstaaten im Auftrage der Nationalen Stiftung für Indianerfragen FUNAI (hier auch Kooperation mit dem DECART /Recife)
- Gravimetrie und Messtechnik, vor allem Kooperation von Prof. Dr. Oziel Leite und Prof. Dr. François Rosier mit Prof. Dr. Manfred Bonatz/Bonn:
    - Betrieb einer Erdgezeitenstation (Fundamentalstation) und Einbindung der Messergebnisse in ein internationales Beobachtungsnetz
    - Inklinometermessungen mit Anwendungen in der Geophysik und bei Bauwerksüberwachungen (Stadtverwaltung Curitiba)
- Photogrammetrie, vor allem Kooperation von Prof. Dr. José Bittencourt de Andrade, Prof. Mary Olivas und Prof. Dr. Quintino Dalmolin mit Prof. Hans-Peter Bähr/ Curitiba und Karlsruhe:
    - Einrichtung des Planicomp für die Auswertung von LANDSAT-MSS-Bildern (Acre/ Amazonas, Ilha do Mel/ Paraná)
    - Einsatz terrestrischer Photogrammetrie zur Herstellung digitaler Fassadenpläne brasilianischer Gebäudeensembles (mit Unterstützung von BMZ/DFG)
- Kartographie und Geoinformationssysteme, vor allem Kooperation zwischen Prof. Henrique Firkowski und Prof. Dr. Dieter Morgenstern/Bonn:
    - Umsetzung kartographischer Daten für die Stadtentwicklungsplanung Curitiba

5. Weitere Ergebnisse und Bewertung der Nachhaltigkeit

Während von 1971 bis 1995 in Curitiba bereits 111 Kandidaten den Mestrado-Grad erreicht hatten, waren es im Doktoratskurs von 1985 bis 1995 lediglich acht. Die Postgraduierten-Ausbildung blühte zwischen 1971 und 1987, bis sich eine Krise abzeichnete, welche etwa 1991 dadurch ihren

Höhepunkt erreichte, dass gleichzeitig vier Ordinarien in den Ruhestand gingen. Es blieben nur noch zwei promovierte Professoren im Postgraduiertenkurs übrig sowie drei Studenten im Mestrado- und zwei im Doktoratskurs. Dank einer großen Kraftanstrengung ging es von da ab aber wieder bergauf: Am Ende des Berichtszeitraums 1995, nach einem Generationenwechsel, waren 18 Studenten im Mestrado-Kurs immatrikuliert und sieben im Doktoratskurs. Es lehrten wieder sechs promovierte Professoren, unerlässlich für die staatliche Genehmigung der Ausbildungsgänge und für die Zuteilung von Stipendien. Ohne das Stipendiensystem würden die meisten brasilianischen Postgraduierten-Kurse wegen Studentenmangel schließen müssen.

Insgesamt hat das Geodäsieprojekt der GTZ an der UFPR in Curitiba zu folgenden grundsätzlichen Erkenntnissen geführt:

- Ausbildungsprojekte sind Investitionen in die Zukunft; es darf kein schneller Erfolg erwartet werden. Sie müssen Durststrecken überwinden können und langfristig angelegt sein, eingebettet in ein übergeordnetes Bildungs- und Berufskonzept
- Neben einer gut fundierten theoretischen Ausbildung ist ebenso wichtig das Training an praktischen Aufgaben, auch und gerade an Universitäten. Dies setzt den stabilen Betrieb von Labors mit modernen Hard- und Softwareeinrichtungen voraus.
- Kooperation zwischen Universität einerseits und privatem und öffentlichen Sektor andererseits ist von fundamentaler Bedeutung. Speziell in Brasilien gab es hier im Berichtszeitraum häufig eine seltsame Art von „Berührungsangst", aber auch bürokratische Hürden.
- Von Kooperation profitieren alle Seiten. Eine Promotionsmöglichkeit im eigenen Land ersetzt keineswegs internationale Kontakte und Zusammenarbeit, im Gegenteil. Wissenschaft war und ist immer international.
- Die Randbedingungen für ein Projekt der technischen Zusammenarbeit sind für Erfolg und Misserfolg mindestens ebenso hoch zu bewerten wie die eigentlichen Maßnahmen selbst: Die Ausbildung muss weitgehend geschützt sein vor willkürlicher politischer oder wirtschaftlicher Einflussnahme. Schlechte Ausbildungsbedingungen, zumal an Universitäten, halten ein Volk langfristig unmündig und abhängig.

Im Jahre 2010, nach weiteren 15 Jahren, kann die Geodäsieausbildung in Curitiba mit Genugtuung und Stolz auf eine sehr erfolgreiche, stabile Entwicklung zurückschauen, welche die vor 30 Jahren formulierten Projektziele voll erfüllt hat und fortführt. Über die Arbeiten zwischen 1995 und 2010 wird an anderer Stelle berichtet (z. B. KRUEGER ET AL. 2005). Das GTZ-Projekt in Curitiba war eine nachhaltige Investition par excellence, weil es über 30 Jahre gelungen ist, die Generationenwechsel bei Menschen, Themen und Werkzeugen für die Weiterentwicklung der Qualität von Lehre und Forschung zu nutzen.

Literatur

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Sustainability in higher education and research within the transnational project PROBRAL

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1. Introduction

In order to improve the education of young researchers (master degree, PhD, PostDoc) a cooperation between the Department of Geomatics, Federal University of Paraná (UFPR), Curitiba (Brazil) and the Geodetic Institute (GIK), University Karlsruhe (TH), Karlsruhe (Germany) aiming for higher education and research was established. The transnational and intercultural joint venture was called “PROBRAL: Precise positioning and height determination by means of GPS: Modelling of errors and transformation into physical heights” and focused on research and higher education within the field of satellite geodesy. PROBRAL was funded by the Brazilian academic exchange service CAPES and the German academic exchange service DAAD.

The geodetic main goal of the cooperative research project was to validate and improve the quality of 3-D positions derived from observations related to Global Navigation Satellite Systems (GNSS) like GPS. In order to fulfil this ambitious goal sustainably, research had to be carried out in close cooperation. At the same time, e.g., to guarantee continuous success, a coordinated education had to be ensured. Besides technical geodetic education aspects, key competences (e.g., language, capacity for teamwork, project management skills) were trained.

This paper will focus on tools and techniques to guarantee sustainability. This is done based and the UFPR and GIK background (sections 2-3). Within the sections 4 and 5, most important principles of cooperating sustainably are presented. Section 6 concludes this paper.

2. Background of higher education in Curitiba (Brazil)

The international cooperation with Germany has a long and prosperous tradition at the UFPR in Curitiba, starting in 1978. Many research projects have been developed and carried out in close cooperation. Besides research, one important goal of the cooperation is related to the transfer of the gained experiences into study courses (e.g., postgraduate course). Within the framework of German-Brazilian research cooperation, Brazilian students are enabled to stay abroad. Since 1996, at least 15 doctoral sandwich students visited Germany.

The Department of Geomatics is responsible for the postgraduate course in Geoscience. This study course was implemented in 1971. The curriculum consists of the following focus areas:

- Geodesy and Surveying,
- Photogrammetry and Remote Sensing and
- Cartography and Geographic Information Systems.

There are two main goals this study course is aiming for: Firstly, next generation teachers for teaching geodesy in national Latin American institutions have to be qualified. Secondly, new and innovative technologies should be developed within and integrated in geodetic and neighbouring sciences. Therefore, a multi-disciplinary approach in higher education was chosen.

The basis of the postgraduate course lays in the basic agreement on scientific and technical cooperation signed on the academic training project in geodesy between the federal governments of

Germany and Brazil under the Agreement 53/81 - ABC/GTZ/UFPR on the 17th of February 1981. For details see BÄHR (2011). One objective of this agreement was the establishment of a Ph.D. program in Geodesy at UFPR. This was the first Ph.D. program in Brazil.

Between 1985 and 1988, six different scientific projects were carried. Their main objectives were the popularization and introduction of the GPS technology in Brazil. This opened up a new era and led to a paradigm shift in Brazil. The projects were carried out between the Brazilian Institute of Geography and Statistics (IBGE), the Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), the Federal University of Parana (UFPR), the Institut für Erdmessung (University of Hannover), the Land Institute, Cartography, Forestry (ITCF), the Coordination of the Metropolitan Region of Curitiba (COMEC), and the Energy Company of Parana (COPEL). Various sponsors such as GTZ, UFPR, CNPq, COPEL, COMEC and FINEP founded these projects.

Since 2001, the cooperation between the Department of Geomatics (DGEOM), Federal University of Parana, Curitiba (Brazil), and the Geodetic Institute (GIK) resp. the Institute of Photogrammetry and Remote Sensing (IPF), University Karlsruhe (TH), Karlsruhe (Germany) was intensified. This joint venture was carried out the framework of the international academic cooperation project GEOMACK-I, a pioneer initiative, focussing on Cartography and Geoinformatics. See BÄHR (2005) for details. The project was financially supported by CAPES (Brazilian Exchange Service) and DAAD (German Exchange Service). The main objective was to promote exchanges and cooperation at the level of academic degree in the particular field of geodetic science.

One result that could not otherwise have been achieved, was the approval of the PROBRAL project “Precise positioning and height determination by means of GPS: Modelling of errors and transformation into physical heights” funded by CAPES resp. DAAD. This project started in 2006. Selected results of this fruitful cooperation are shown within this compilation.

3. Study course “Geodesy and Geo-Informatics” at Karlsruhe (Germany)

The Geodetic Institute of the University of Karlsruhe (Germany) is responsible for the study courses “Geodesy and Geo-Informatics” (Bachelor, Master, Diplom-Ingenieur) in close cooperation with the Institute for Photogrammetry and Remote Sensing. On October 01, 2009, the Karlsruhe Institute of Technology (KIT) was founded by a merger of Forschungszentrum Karlsruhe and Universität Karlsruhe (TH).The KIT bundles the missions of both precursory institutions: Within these missions, KIT is operating along the three strategic fields of action of research, teaching, and innovation. The Geodetic Institute (GIK) consists of three chairs. Prof. B. Heck is responsible for research and education dealing with Physical and Satellite Geodesy.

Besides of teaching fundamental and highly modern learning objectives, the higher education carried out at the GIK aims on the personal growth of the learners in an individual and flexible way with respect to their background, their preferences, and the constraints of the learners. One very successfully used tool to fulfil this ambitious goal is to give the learners the possibility to stay abroad. This tool has a long tradition at the GIK. A stay abroad could be done in the framework of studying one or more semesters in a foreign country or learners could gain experiences as an academic assistance within a project carried out abroad. Both ways broaden the student’s mind and view wider. Within the last decade South America and especially Curitiba (Brazil) became the focus of attention based on established research cooperation (e.g., UNIBRAL).

4. Sustainability – backbone of the PROBRAL and future cooperation

Within the "IV Simpósio Brasil-Alemanha / 4. Deutsch-Brasilianisches Symposium" held in Curitiba in 2009 it was found great accordance that sustainability is the most important aspect of CAPES-funded resp. DAAD-funded cooperation. In order to guarantee sustainability within the geodesy-related cooperation between UFPR and GIK a cycle of sustainable knowledge transfer (Fig.1). Applying this method, research advance as well as personal growth of all participants can be guaranteed within transnational cooperation.

Within the PROBRAL initiative, the focus was set on detailed and widely spread information for all members of the participating institutions. Therefore, not only the cooperating researchers but also their colleagues as well as the students were informed; presentations and lecture courses as well as integration of research results into the regular study and lecture courses were realized as appropriate tools for this purpose. By means of these tools, well-prepared follow-on generations of researchers are existing, who will be able to keep this fruitful cooperation alive.

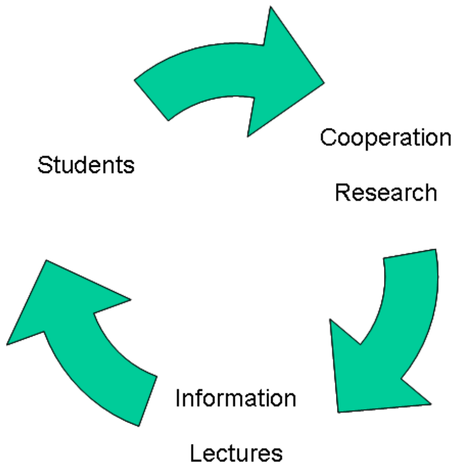

Figure 1: Cycle of sustainable knowledge transfer.

5. Lessons learnt

Within this section, the most important lessons, which were learnt during the here described PROBRAL cooperation are going to be presented.

The fundamental basis of scientific as well as individual gain is the ability of communication. Therefore, it is highly recommended that all participants of such an intensive research and social exchange initiative should be able to communicate with each other. To be able to speak and read the English language fluently is a must. This should be checked in detail in the forefront of a stay abroad. In addition, it is recommended to be able to communicate in the foreign language, especially due to the fact that one important goal of the here described exchange program is to improve the social and intercultural skills of the participants. This could only be guaranteed based on communications with persons which are not part of the scientific community.

Another important contribution to a fruitful cooperation is a careful selection of the exchange candidates. This has to be done in close cooperation of the participating institutes resp. project directors. Both should have various experiences in studying resp. researching abroad. In addition, there should also be deeply insights into the circumstances which exist abroad. The selection of appropriate exchange candidates should be carried out open and above board, respectfully, faithfully, and truthfully in order to guarantee sustainability of the knowledge transfer. In addition, it is very important to keep contact, which was possible within the IV Simpósio Brasil-Alemanha / 4. Deutsch-Brasilianisches Symposium.

Especially when learners are exchanged, appropriate guidance from the participating institutes resp. project directors is needed. This statement is also correct when young scientists are exchanged for long time spans (e.g. one year). In the beginning, when there are no social contacts outside the universities existing, then some faithful contact persons should be able to be contacted at any time. In order to guarantee best options for high quality learning resp. research results, the exchange person should be fully integrated into a research group.

Working together (team work) in order to fulfil one big (research) goal (be part of it) seems to be a good way to keep the motivation of each participant as well as the motivation to participate high. It is very important to collaborate in an equal, active, and cooperative way. The results of joint ventures should be as concrete as possible (e.g. publications, further cooperation, symposia). In the cooperation described here, one concrete result is the establishment of the GNSS antenna calibration field (HUNICA ET AL. 2011, KRUEGER ET AL. 2008). The results should also be integrated into (other) lecture courses in order to guarantee sustainability.

After returning to their home country, all participants should try to stay in contact (networking). It was realized that even within a short cooperation period many additional research possibilities were opened up. Especially, if something went wrong or unexpected problems occurred the circumstances should be reflected within a quality management process.

6. Conclusions

Physical and satellite geodetic engineering knowledge was used as a bridge between science and society. The cooperation within UNIBRAL and PROBRAL between the Geodetic Institute, University Karlsruhe (TH), Karlsruhe, Germany and the Department of Geomatics, Federal University of Paraná, Curitiba, Brazil ended in December 2009. A lot could be learned and a lot of experiences could be gained – geodesy-specific as well as related to so-called key competences. As a measure of the geodesy-specific outcome PhD dissertations (7), master dissertations (3), graduated jobs (9), publications (18), oral presentations in congress (36), oral resp. poster symposium presentations (18) could be used. The measure of the improvement of key competences of the participants is more difficult. Therefore, some keywords are listed finally: friendship, personal engagement, helpfulness, hospitableness, social competence, intercultural competence, social involvement, sharpness of details, lingual competence, negotiation competence, improvisation skills, handling of time, team competence, open-minded, cosmopolitanism, and interdisciplinarity.

Acknowledgement

PROBRAL was funded by the German academic exchange service DAAD and the Brazilian academic exchange service CAPES. Thanks for supporting us.

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Abschlussbericht der Projektleiter

Final report of the project coordinators

Relatório final dos coordenadores

The transnational cooperation between CPGCG and GIK in the framework of PROBRAL

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Abstract: This report presents the main results achieved in the international cooperation project established between the Postgraduate Programme in Geodetic Sciences of the Department of Geomatics of the Federal University of Parana (UFPR, Curitiba, Brazil) and the Geodetic Institute of Universität Karlsruhe (now KIT, Karlsruhe Institute of Technolgy) in Karlsruhe, Germany. During the period 2006-2009 the transnational research project entitled "Precise positioning and height determination by means of GPS: Modeling of errors and transformation into physical heights" was funded in the framework of the bilateral PROBRAL programme by the academic exchange services CAPES (Brazilian academic exchange service) and DAAD (German academic exchange service). After finalizing the PROBRAL project successfully, the cooperation between the two institutions is still going on.

1. Introduction

The program PROBRAL provides coordinated and collaborative training of human resources on a high level in Brazil and Germany in several areas of knowledge. It is funded by CAPES (Brazilian academic exchange service) and by DAAD (German academic exchange service). It aims to promote, through joint research projects, exchange of scholars and researchers, linked to Post-Graduate Education Institutions (IES). Another important aspect of PROBRAL projects is to transfer technology between the two cooperating institutes.

In 2005 the Postgraduate Programme in Geodetic Sciences (CPGCG) of the Department of Geomatics (DGEOM) of the Federal University of Parana (UFPR, Curitiba, Brazil) and the Geodetic Institute (GIK) of Universität Karlsruhe (now KIT, Karlsruhe Institute of Technology), Germany, submitted a proposal to CAPES and DAAD concerning a joint research project entitled "Precise positioning and height determination by means of GPS: Modeling of errors and transformation into physical heights". Funding of this transnational research project was granted by CAPES and DAAD for the full period of four years in the time span 2006-2009. In the following the main results of the PROBRAL project will be presented.

2. Objectives

The joint research project had been subdivided into three sub-projects related to

I. Investigation of important error sources in precise GNSS positioning aiming for an improved modeling of these errors
II. Analysis and improvement of the Brazilian vertical network and integration into SIRGAS
III. Application in three-dimensional monitoring of the Earth's surface

The specific goals of this cooperation are related to research as well as to higher education. At the beginning of the PROBRAL project the following goals have been defined:

- Increase of human resources at the post-graduate course in Geodetic Sciences and especially in Geodesy
- Improvement of teachers in the field of Geodetic Sciences

- Intensification of the exchange of scientific information
- Contribution to the definition of vertical datum SIRGAS and its materialization in Brazil
- Investigation of errors in high-precision GNSS positioning
- Understanding and modeling of errors in high-precision positioning using artificial intelligence
- Joint publishing of scientific as well as technical papers (poster and oral presentations included)
- Increase substantially the scientific productivity of the post-graduate program in Curitiba
- Establishing joint research in priority areas in Geodetic Sciences
- Improvement of intercultural competences of all participants

In particular, the stated goals aimed to:
- Contribute to solving problems dealing with precise GNSS positioning
- Contribute to solutions for environmental monitoring in Brazil
- Provide the 1st calibration site for GNSS antennas in Brazil and South America
- Complement the education of sandwich-doctoral and post-doctoral students with experience in international centers of excellence
- Improve (quality, quantity) the portfolio of fields under research
- Consolidate the exchange (personal, correspondence) with German institutions

3. Missions performed by Brazilian participants

The Brazilian participants have carried out several study and work missions within the funding period of four years, see Table 1 for details. Table 1 shows the names of the team members, their title resp. position within their institutions, the mission (work resp. study) that was performed (incl. duration of stay abroad) and the geodetic field of expertise.

Table 1: Brazilian participants in the PROBRAL project

Name	Title / Position	Mission, duration	Field of expertise
2006			
Cláudia Pereira Krueger	Doctor / Lecturer UFPR / CPGCG	Work, 30 days	Satellite Geodesy / Marine Geodesy / Environmental Monitoring / Surveying
Sílvio Rogério Correia de Freitas	Doctor / Lecturer UFPR / CPGCG	Work, 21 days	Geodesy / Geodynamics
Roberto Teixeira Luz	Doctor / former student of CPGCG / IBGE	Study, sandwich doctor, 8 months	Geodesy / Geodynamics
2007			
Mauricio Ihlenfeldt Sejas	Doctor / former student of CPGCG / UTFFB	Study, sandwich doctor, 12 months	Satellite Geodesy
Juliana Moulin Fosse	Doctor / former student of CPGCG / UFRRJ	Study, sandwich doctor, 5 months	Remote Sensing
2008			
Cláudia Pereira Krueger	Doctor / Lecturer UFPR / CPGCG	Work, 21 days	Satellite Geodesy / Marine Geodesy / Environmental Monitoring / Surveying
Rodrigo Mikosz Gonçalves	Doctor student of CPGCG	Study, sandwich doctor, 12 months	Environmental Monitoring / Satellite Geodesy
Vagner Gonçalves Ferreira	Doctor student of CPGCG	Study, sandwich doctor, 9 months	Geodesy / Geodynamics
2009			
Sílvio Rogério Correia de Freitas	Doctor / Lecturer UFPR / CPGCG	Work, 15 days	Geodesy / Geodynamics
Jorge Antonio Silva Centeno	Doctor / Lecturer UFPR / CPGCG	Work, 55 days	Remote Sensing / Environmental Monitoring

Roberto Teixeira Luz was supervised by Prof. Dr. B. Heck of the GIK and by Prof. Dr. S.R.C. de Freitas in Brazil. The student developed his sandwich doctorate in sub-project II "Integration of the Brazilian vertical network into SIRGAS". The activities carried out by this student, in general, have focused on the analysis of gravimetric and leveling data. These data were analyzed in an integrative and combined way, using data of leveling lines of the Brazilian Fundamental Vertical Network (BFVN). Several tide gauges along the Brazilian coast have been connected by leveling and gravity, after an effective procedure for the interpolation of gravity data had been developed; furthermore, satellite altimetry tracks have been used for connecting tide gauges via the ocean side. The work of R.T. Luz has enabled important discussions, exchange of ideas, and development of activities in cooperation with other German research institutions such as the German Geodetic Research Institute (DFGI, Munich, Dr. W. Bosch) and the Geodetic Institute of the Leibniz University Hannover (Prof. Dr. J. Müller). R.T. Luz defended his doctor thesis in 2008 successfully.

Maurício Ihlenfeldt Sejas was supervised cooperatively by Prof. Dr. B. Heck and Dr. M. Mayer – both members of the GIK – and by Prof. Dr. C.P. Krueger in Brazil (coordinator of the PROBRAL project). His research topic was linked to sub-project I "Investigation of error sources in precise GPS positioning and modeling of these errors”. The main goal of his thesis deals with the improvement of the regional ionospheric modeling with a special focus on networks of double-frequency receivers. Therefore, he developed an approach based on epoch-wise satellite-specific independently estimated ionospheric coefficients for GPS. Within this approach, one fundamental assumption is: The errors for each satellite are approximately linear in an area covered by the network. This enables to use an efficient and fast approach to describe the ionospheric effects. As network coefficients are generated for each epoch, quick changes in the total electron content can be easily monitored. Case studies were carried out in regions with different ionospheric conditions and different site coverage within the network: e.g. Central Europe, mid-latitudes and South Brazil, and equatorial regions. The developed model was tested using code observations. Precise products (orbits, clocks) were taken into account, too. The results showed that the model removes 92% of all ionospheric effects for European stations and 87% for Brazilian stations, on average. The doctor thesis was successfully defended in 2009.

The third study mission was developed and performed by Juliana Moulin Fosse. She was supervised by Prof. Dr. H.-P. Bähr (Institute of Photogrammetry and Remote Sensing (IPF), Karlsruhe, Germany) and in Brazil by Prof. Dr. J.S.A. Centeno. The student worked in the subproject III "Application in three-dimensional monitoring of the Earth's surface”. J.M. Fosse studied interactive three-dimensional representations, which are tools for modeling and visualization, virtual reality (VRML), so these maps are assessed for the elements of the cartographic language, through a user perception test. Among the various types of virtual reality, the augmented reality, which is a visualization tool for virtual models, becomes more and more important (e.g., monitor and mouse are replaced using camera systems and special glasses). During the doctorate stage abroad, the achievement of the final phase of implementing the 3D map was made, making use of laboratories of the IPF, that also contributed to relevant bibliographic material for her research.

Rodrigo Mikosz Gonçalves carried out the fourth research study mission in the framework of the PROBRAL project. This research is related to sub-project III "Application in three-dimensional monitoring of the Earth's surface". Monitoring and management of shoreline is an important task along the coast, but remains also difficult. The goal of this research study was to carry out comparisons and assessments between three different shoreline prediction models: robust parameter estimation, neural network, and linear regression. The region for this case study is located at Matinhos beach in the state of Paraná (Brazil). Data related to the years 1954, 1963, 1980, 1991, and 1997 were used for shoreline extraction in a 6 km section. One important and difficult issue of his work dealt with the precise shoreline extraction. One problem which had to be overcome was related to poor quality of photographs (esp. 1954 and 1963). Besides that, it was rather difficult to interpret the correct positions of the feature set (limit between sea and ocean). In the research of R.M. Gonçalves uncertain photogrammetric data and GPS data (years 2001, 2002, 2005, and 2008) were used in a combined way. GPS data was used as reference data. An improved weight matrix for the case of linear regression and robust estimation was analyzed. In all cases, the robust estimation gave the most promising results. Different tests based on neural networks were performed using setting parameters like: architecture, number of neurons in hidden layers, and training algorithms. The doctor exam was finalized in February 2010. He was supervised by Prof. Dr. B. Heck (GIK) and in Brazil by Prof. Dr. C.P. Krueger and Prof. Dr. L. Coelho.

The 5th doctoral candidate Vagner Gonçalves Ferreira also was supervised by Prof. Dr.-Ing. B. Heck (GIK) and by Prof. Dr. S.R.C. de Freitas in Brazil. The student developed his sandwich doctorate in sub-project II "Integration of the Brazilian vertical network into SIRGAS". Actually, ellipsoidal heights can be determined by GNSS (Global Navigation Satellite Systems) with centimetre accuracy. Combining GNSS positioning with gravity field determination can replace the traditional leveling in many situations. Since gravity measurements can be performed with a precision of the order of some µgal, the gravity disturbance can be easily obtained with a high accuracy. At the end of the 1960s, Martin Hotine proposed a solution of the disturbing potential (Hotine's formula), which uses gravity disturbances as input data. A strategy for achieving this goal is determining the disturbing potential on the geoid surface by an iterative solution according to the gravity disturbance given on the ellipsoid. This approach is in line with the solution of the fixed Geodetic Boundary Value Problem (GBVP). One practical problem is how to find a solution of the fixed GBVP in real situations related to a poor distribution of gravity information, as usual in South America. This is the case, especially over long distances and throughout the steep terrain encountered in many parts of those countries (e.g., Brazil). The doctor thesis of V.G. Ferreira was successfully defended in February 2011.

In addition to the so-called study missions, Table 1 shows five so-called work missions. Two were carried out in 2006, one in 2008, and two in 2009. Within these missions, many additional activities have been performed. Some highlight topics of this very important part of the PROBRAL cooperation are listed below:

- Coordinative meetings with Prof. Dr. B. Heck and members of the GIK working group
- Discussions concerning research topics in general
- Detailed discussions concerning research topics of Brazilian doctoral candidates
- Debates about scientific papers
- Coordination of further project aspects
- Supervision of Brazilian students during their stay abroad in Germany

4. Missions performed by German participants

In table 2 some details of the missions performed by the German researchers in the PROBRAL project are summarized in the same way as in table 1 for the Brazilian participants.

Prof. Dr. B. Heck has developed various activities including: meetings with researchers, discussion with Brazilian colleagues about the progress of the PROBRAL project and future collaboration; participation in doctoral theses and exams of J. Freiberger Jr., R.T. Luz and M.I. Sejas; qualification exam (Seminario III) of Alessandra Palmeiro. He also gave an advanced lecture course on Geodetic Reference Frames and Systems.

Dr. M. Mayer has developed various activities, among them are participation and discussion related to: establishment of a GNSS receiver antenna calibration field, called First Baseline Calibration station for GNSS Antennas in Brazil (BCAL/UFPR); investigations in multipath effects and calibration of GNSS antennas; joint development of the modeling of the troposphere in the state of Parana. Also, the researcher presented lectures on, e. g., „Using GNSS observations in order to detect highly precise deformation rates" and "Experiment: Using GPS as soil/moisture" sensor to the Post-Graduate Program in Geodetic Sciences (CPGCG). Dr. M. Mayer and A. Knöpfler also organized a workshop for the researchers of LAGE (Laboratory of Space Geodesy) at UFPR dealing with antenna calibration.

Table 2: German participants in the PROBRAL project

Name	Title / Position	Mission, duration	Field of expertise
2006			
Michael Mayer	Doctor / GIK	15 days	Satellite Geodesy
Franziska Wild-Pfeiffer	Former doctor student of GIK	21 days	Geodesy
Andreas Knöpfler	Doctor student of GIK	30 days	Satellite Geodesy
2007			
Bernhard Heck	Doctor / Director of GIK	17 days	Satellite Geodesy, Geodesy, Geodynamics
Norbert Rösch	Doctor / GIK	15 days	Geodesy, GIS
Xiaoguang Luo	Doctor student of GIK	30 days	Satellite Geodesy
2008			
Bernhard Heck	Doctor / Director of GIK	10 days	Satellite Geodesy, Geodesy, Geodynamics
Michael Mayer	Doctor / GIK	15 days	Satellite Geodesy
Andreas Knöpfler	Doctor student of GIK	30 days	Satellite Geodesy
Xiaoguang Luo	Doctor student of GIK	30 days	Satellite Geodesy
2009			
Bernhard Heck	Doctor / Director of GIK	10 days	Satellite Geodesy, Geodesy, Geodynamics
Michael Mayer	Doctor / GIK	15 days	Satellite Geodesy
Andreas Knöpfler	Doctor student of GIK	15 days	Satellite Geodesy
Xiaoguang Luo	Doctor student of GIK	30 days	Satellite Geodesy

In 2007 Dr. N. Rösch visited the UFPR and presented the lecture “On the transformation of co-ordinates and implementation aspects concerning the computer-aided transformation of coordinates”. He also participated in a meeting with a group of CPGCG researchers interested in future cooperation.

The doctor candidate Dipl.-Ing A. Knöpfler took part in the same activities listed for Dr. M. Mayer and presented the lecture on “Collaborative Research Center 461 Strong Earthquakes: A Challenge for Geosciences and Civil Engineering” in addition.

The doctor student Dipl.-Ing. F. Wild-Pfeiffer gave a lecture in the scope of Physical Geodesy to the Post-Graduate Program in Geodetic Sciences (CPGCG) and participated in discussions about the progress of the PROBRAL project.

The doctoral candidate Dipl.-Ing. X. Luo also participated in meetings with researchers from the Laboratory of Space Geodesy (LAGE) and gave seminars on: “Determination of High-Resoluted Water Vapor Fields from GNSS Double Difference Residuals“ and “Effect of SNR-based weighting on the Results of GNSS Phase Observations”. He also provided an advanced course on the background and use of the Bernese GPS software.

5. Personnel training within PROBRAL

In the framework of the PROBRAL project, five Brazilian PhD students working in the joint research programme could finalize their theses and successfully defend them, see Table 3.

In addition, the master student Suelen Cristina Movio Huinca also completed her master thesis in February 2009, entitled “Relative calibration of GNSS antennas in the BCAL/UFPR”. This work was also developed within the PROBRAL cooperation, as well as the doctoral thesis of J. Freiberger Jr., entitled “Investigations into the relative calibration of GNSS receiver antennas”; Dr. Freiberger spent some time at the GIK within a PhD sandwich programme.

Furthermore, two German graduation students from Karlsruhe had been integrated in the PROBRAL project. Bernhardt Schäfer developed a research project in LAGE (Laboratory of Space Geodesy) entitled “Investigations on multipath effects of GPS reference stations in Paraná and the First Baseline

Calibration Station of Brazil (1aBCALBR) in Curitiba, PR“, and Pascal Knoch worked in a research project at LAGE entitled “Influence of different sets of antenna calibration values on point positioning”.

The subjects of the doctoral theses of the German PhD students (F. Wild-Pfeiffer, A. Knöpfler, and X. Luo) are not directly related to the themes of the PROBRAL project. During their stays at UFPR they could gain intercultural and language competencies, but also extend their capacities in teaching.

Table 3: PhD theses of Brazilian doctor students resulting from the PROBRAL project

Name	Title of thesis	Examination	Supervisors
Jaime Freiberger Jr.	Investigações para a Calibração Relativa de Antenas de Receptores GNSS. Investigations into the relative calibration of GNSS receiver antennas.	28.02.2007	Krueger / Heck
Roberto Teixeira Luz	Estratégias para Modernização da Componente Vertical do Sistema Geodésico Brasileiro e Sua Integração ao SIRGAS. Strategies for the modernization of the vertical component of the Brazilian Geodetic System and its integration into SIRGAS.	14.03.2008	Freitas / Heck
Mauricio Ihlenfeldt Sejas	Modelagem Ionosférica Local em Redes GPS para o Posicionamento Absoluto de Estações de uma Frequencia. Local ionospheric modeling in GPS networks for absolute station positioning with single frequency receivers.	25.08.2009	Krueger / Heck
Rodrigo Mikosz Gonçalves	Predição de Mudanças a Curto-Prazo da Movimentação de Linha de Costa Utilizando Dados Geodésicos Temporais. Prediction of short-term variations of motions of the coastline using temporal geodetic data.	Feb. 2010	Krueger / Heck
Vagner Gonçalves Ferreira	Solução do tipo Brovar para o Segundo Problema de Valor de Contorno da Geodésia com Vistas à Modernização de Sistemas de Altitudes. Brovar type solution of the second geodetic boundary value problem considering the modernization of height systems.	Feb. 2011	Freitas / Heck

6. Production of publications

The project proved to have been very successful, not only with respect to the number of jointly supervised doctoral students, but also concerning the number of joint publications, oral and poster presentations, see table 4. The title of these publications can be found in the contribution “PROBRAL Publications – Papers, Oral Presentations, Poster Presentations” of this compilation.

Table 4: Publication activity within the PROBRAL project

Type	Numbers
Papers in scientific journals	05
Accepted articles in scientific journals	02
Chapters of books published and accepted for publication	09
Summaries published in congress proceedings	26
Papers published in congress proceedings	09
Graduate works	02
Master theses	03
PhD theses	05

The high productivity is on the one hand founded by the good personal relations between the project partners in Brazil and Germany, on the other hand by the balanced complementarity of the contributions of both sides: While the German side focussed on methodological aspects related to GNSS observation processing and gravity field determination, the practical application of these approaches is emphasized on the Brazilian side, on the basis of real data. Incidentally, the finalization of the PROBRAL project coincided with the 4th German-Brazilian Symposium organized by UFPR in October 2009. In the framework of this symposium a workshop on cooperation in the field of Geodesy was jointly organized by Prof. Dr. C. Krueger and Dr. M. Mayer.

7. Main results achieved

The sub-project "Investigation of error sources in precise GPS positioning and modeling of these errors" started with the research on calibration of GPS antennas together with the analysis of the effect of multipath produced by the surrounding of the stations. One main goal of this cooperation in this sub-project was to establish a relative receiver antenna calibration field for GNSS instrumentation on the roof top of the "Astronomical Laboratory Camil Gemael" called BCAL/UFPR (http://www.lage.ufpr.br/), situated on the Polytechnic Campus at UFPR in Curitiba (Brazil). Within this project three stable pillars (1000, 2000, and 3000) could be constructed consisting of a long expected lifetime material based on experiences concerning the establishment and monumentation of geodetic network sites gained at the GIK. The pillars were constructed following the rules of Brazilian authorities responsible for surveying and mapping (IBGE: Brazilian Institute of Geography and Statistics). This calibration field and the studies undertaken are important and will continue contributing in solving problems regarding GNSS precise positioning in Brazil. The calibration of GNSS antennas by the proposed method (relative calibration) has advantages in terms of performance and precision considering the basic investments for the installation of equipment, measurements, and maintenance. The operational efforts are reduced since the measurements are performed automatically. By this efficient method the azimuth- and elevation- dependent antenna phase centre variations can be determined with high resolution and considerable reduction of multipath effects. The first experiments showed that by calibration of GPS antennas with respect to an individually absolutely calibrated antenna the same level of precision as in absolute calibration can be achieved. The relative antenna calibration field was the first one established in Latin America. The experiments carried out in Brazil showed the influence of multipath acting with similar intensity on the calibration pillars 1000 (West) and 2000 (North). The results obtained in Germany proved that the influence of the multipath effect is extremely important and should be considered in high precision GNSS measurements, particularly in the GNSS satellite receiver calibration. Experiments were carried out applying the relative calibration method in order to acquire and compare different calibration parameters for the TRM 22020.00+GP antenna. This antenna was calibrated in three sessions of 24 hours, with a data-sampling rate of 15 seconds. The software WaSoft/Kalib was used to process the GPS phase observations. Carrier phase center offset and variation values were determined relatively with respect to a Leica choke ring antenna. Additional experiments using absorber material in order to reduce pillar-reflected multipath effects are in preparation.

In the sub-project "Integration of the Brazilian vertical network to SIRGAS" studies undertaken by the Group of Laboratory of Geodetic Reference and Satellite Altimetry (LARAS), associated with the doctoral thesis of Dr. R.T. Luz, allowed to define procedures for integrating data from geometric leveling, gravity, tide gauge stations and satellite altimetry. These procedures were materialized in software, written in Fortran and Octave, taking into account the peculiarities of the Brazilian context, emphasizing the importance of semi-automatic assembly of the vertical network in geopotential numbers, implemented using the program IDNOS. Gravity and leveling data from IBGE were analyzed with respect to problems related to forming up geopotential differences; for this purpose, a subset of recently observed RAAP (Brazilian Fundamental Vertical Network) lines was identified, in which all benchmarks possess direct gravity information. Simulating various scenarios concerning the lack of gravity observations, the results indicated an overestimation of the quality of gravity interpolation. A rigorous adjustment of the leveling network showed excessive distortions in the height values, as well as problems arising from heterogeneities in the region of Imbituba. A subnetwork of RAAP connecting three tide gauge stations (Imbituba, Macaé, and Salvador) has been selected as a reference for the study of the sea surface topography at the Brazilian coast. These tide gauge stations have been interconnected by suitable satellite altimetry tracks, chosen to be virtually colinear to these tide gauge stations. The first attempts in height transfer via satellite altimetry proved to be promising, although major inconsistencies at crossover points had been detected.

In the doctoral thesis by Dr. V.G. Ferreira a novel procedure of GNSS leveling was founded and tested, based on the fixed GBVP. This procedure uses GNSS ellipsoidal heights in combination with gravity disturbances for the determination of geopotential numbers. For a topographical Earth surface the fixed GBVP cannot be solved analytically; therefore a series expansion of Molodensky-Brovar type has been derived. The theory has been applied to two case studies, one in the Federal State of Baden-Württemberg, Germany, and the other in Paraná State, Brazil. The results showed that the achievable precision strongly depends on the resolution of the gravity data coverage; lack of gravity data in Brazil has been identified as the major error source.

The sub-project "Application in three-dimensional monitoring of Earth's surface" started with the organization of spatio-temporal data and building a CGIS (Coastal GIS) with data composed by historical maps using remote sensing and satellite geodesy to extract the shoreline. The goal of this study in the framework of the doctoral thesis by Dr. R.M. Gonçalves was to carry out a comparison and assessment between three different models of shoreline prediction: robust parameter estimation, neural network, and linear regression. A section of the Brazilian coast in the vicinity of Matinhos Beach in the State of Paraná has been selected for a case study using old material from analogue photogrammetry (years 1954, 1963, 1980, 1991, and 1997) and new GPS data (year 2001, 2002, 2005, and 2008) for control. For the case study the best results concerning prediction of the shoreline kinematics have been obtained using the robust estimation model.

Both, the Brazilian and German partners within the PROBRAL project wish to continue the scientific cooperation. Also from the side of the Universities, the UFPR (Curitiba) and the KIT (Karlsruhe), great interest in further collaboration is present, which is manifested in an official cooperation agreement signed in 2006.

Acknowledgements

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Wissenschaftliche Arbeiten

Research

Pesquisa

Establishing a Baseline Calibration Site for GNSS Antennas at UFPR/Brazil: First Results from TRM22020.00+GP antenna

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Abstract: One main goal of the transnational research project "PROBRAL: *Precise positioning and height determination by means of GPS – Modelling of errors and transformation into physical heights",* was to establish the first relative antenna calibration field of Brazil and Latin America. The calibration field BCAL/UFPR is situated on the Polytechnic Campus of the UFPR (Federal University of Paraná, Curitiba, Brazil) on the roof top of the "Astronomical Laboratory Camil Gemael" (http://www.lage.ufpr.br/). The status of the establishment of BCAL/UFPR and the first results are going to be presented within this paper. The TRM22020.00+GP antenna was calibrated in three sessions of 24 hours, with a data sampling rate of 15 seconds in order to derive antenna calibration values. The software WaSoft/Kalib was used to process the GPS phase observations. Phase centre offset values (PCO) were determined relatively with respect to a Leica Choke Ring antenna LEIAT504 NONE. This article will be focussing on the analysis of the derived PCO.

1. Introduction

The subject "GNSS antenna calibration" has been investigated and analysed by different international working groups for nearly two decades; various studies, e.g., on receiver and satellite antenna phase centre modelling (MADER, 1999; WANNINGER, 2002; WÜBBENA ET AL., 2002; SCHMID ET AL., 2007) have been carried out. As these site-specific effects are playing nowadays a more important role in GNSS positioning and there was no GPS antenna calibration service in Latin America existing, studies dealing with these effects have been performed in Brazil by the Federal University of Paraná (UFPR), Curitiba (Brazil) in the framework of the international project PROBRAL since 2006. This project was funded by the Brazilian academic exchange service CAPES and the German academic exchange service DAAD. Within this project the Department of Geomatics (DGEOM), UFPR, Curitiba (Brazil) and the Geodetic Institute (GIK), University of Karlsruhe (TH) resp. Karlsruhe Institute of Technology, Karlsruhe (Germany) were cooperating.

In the beginning, studies concerning the appropriate location of the BCAL/UFPR on the Polytechnical Campus were carried out. The decision concerning the location of the calibration field was based on indicators like logistic aspects (e.g., power supply, security) and signal quality at the site (e.g., multipath effects). BCAL/UFPR was established on the roof top of the "Camil Gemael" astronomical observatory (Fig. 1) at the annex auditory alongside of LAGE (Spatial Geodesy and Hydrographic Laboratory).

Three pillars of BCAL/UFPR were built consisting of appropriate material and techniques in order to guarantee long life-times. Since one important aim of PROBRAL projects is to transfer technology between the two cooperating institutes, the applied knowledge concerning the establishment and monumentation was gained at the GIK. In the context of knowledge transfer, J. Freiberger Jr. plays an important role. He did carry out his PhD (FREIBERGER JR., 2007) jointly supervised by C.P. Krueger (DGEOM) and B. Heck (GIK). Therefore he stayed approx. 1.5 a in Germany and joined the GNSS working group of the GIK.

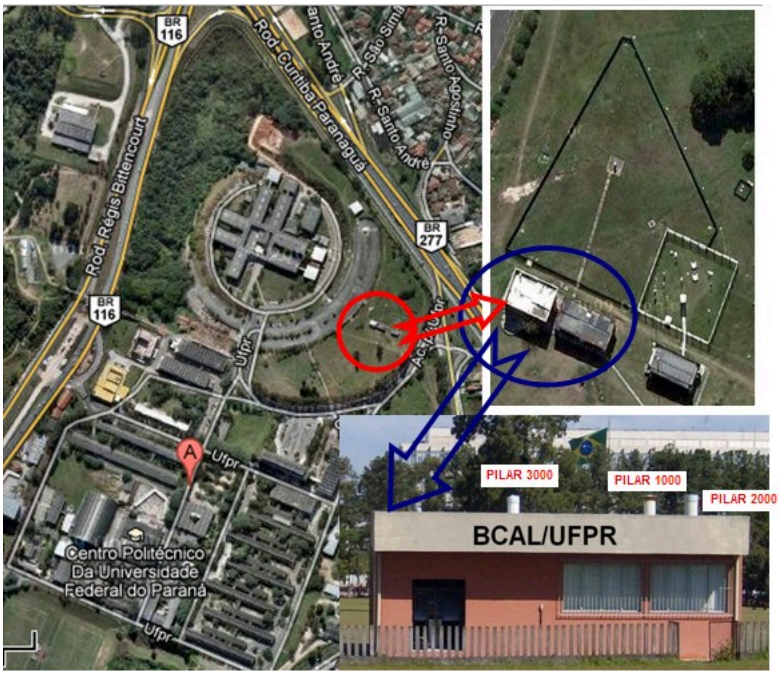

Figure 1: BCAL/UFPR; antenna calibration field (HUINCA, 2011) source: google.maps.

The BCAL/UFPR (Fig. 1) is equipped with three pillars (1000, 2000 and 3000). The construction (Fig. 2) is based on a core of steel and concrete with a 1.5 m height measured from the base of the block. The weight of each pillar is approximately 350 kg. A mantle of concrete with space in between, in order to guarantee thermal isolation and to minimize thermal expansion, surrounds the centre of the pillars. The pillars are equipped with a metal thread to enable the application of a geodetic tribrach following the rules of the responsible surveying and mapping authorities in Brazil – IBGE (Brazilian Institute of Geography and Statistics), see IBGE (2007). The marker used guarantees sub-millimetre accuracy. The circular form and size of the pillars was chosen to reduce pillar reflected multipath effects. A picture of pillar 1000 and a horizontal cross-section of this pillar (AA´) are presented in Fig. 2.

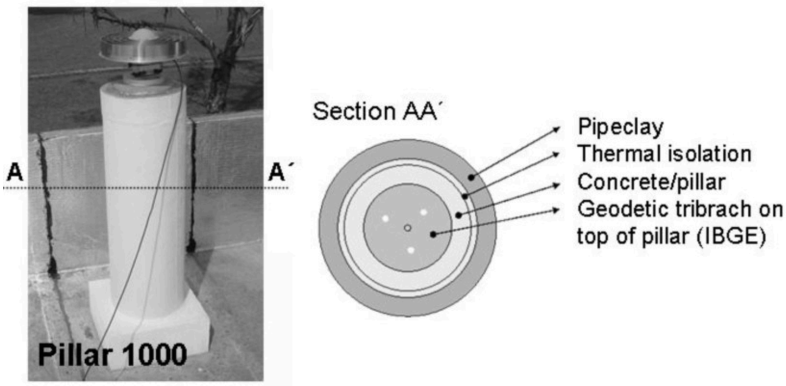

Figure 2: Pillar 1000 of the BCAL/UFPR and the cross-section AA' (KRUEGER ET AL., 2009).

It is very important to monitor the baseline calibration field with respect to vertical displacements (Sect. 3). In addition, multipath studies were carried out, due to the fact that, multipath effects can cause significant errors when GPS antenna calibration values are determined. These effects have to be taken into account, when choosing an appropriate calibration site location (Sect. 2). Section 4 and 5 are dedicated to selected first PCO-related results gained within PROBRAL.

2. Multipath analysis of BCAL/UFPR

The software WaSoft/Multipath 3.2 was used to detect and localize GPS carrier phase multipath (WANNINGER AND MAY, 2000). 24 hour GPS data are needed, with an interval not bigger than 60 seconds, in order to derive reliable daily results related to multipath impact. In order to analyse the multipath impact of potential calibration site candidates, GPS measurements were carried out using different dual-frequency GPS receivers. The data were collected in several sessions of 24 h with a data rate of 15 s.

The multipath analysis network was consisting of four stations. UFPR (old PARA) and the pillars 1000, 2000, and 3000 have been selected. The distances between the four sites are smaller than 100 m. The coordinates of the stations are known within the WGS84 reference frame with a precision in the range of a few centimetres. These circumstances meet all WaSoft/Multipath-related recommendations (WANNINGER AND MAY, 2000). Fig. 3 shows the results of the multipath analysis concerning the four stations. The carrier phase multipath patterns show low multipath impact resulting from signals with low elevation angles. The used symbols of Fig. 3 are relating to multipath impact

- blank: no observation data,
- dots: no multipath effects detected (standard deviation based on L3 < 5mm),
- small squares: minor multipath effects (standard deviation based on L3: 5 - 15mm),
- completely black: major multipath effects (standard deviation based on L3 > 15mm).

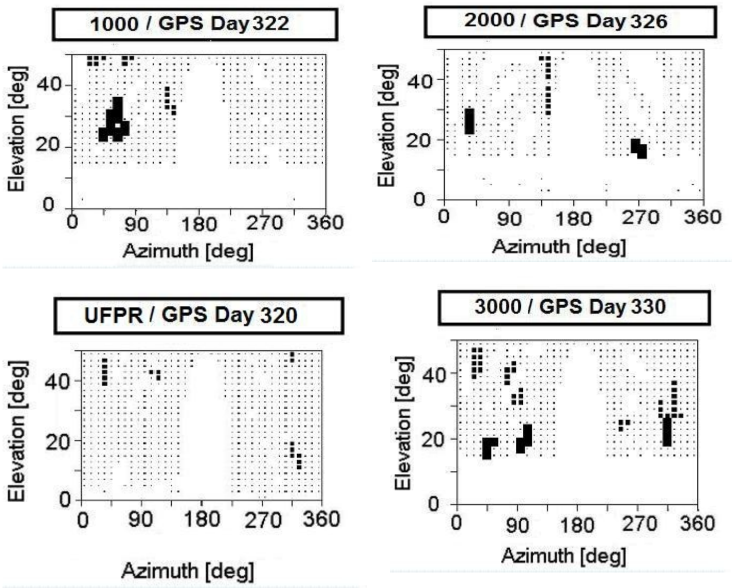

Figure 3: Representative results of multipath case study of four sites UFPR, pillars 1000, 2000, and 3000 (KRUEGER ET AL., 2009).

Pillar 3000 seems to be more affected by multipath effects than pillars 1000 and 2000. Nowadays, all pillars are less affected by multipath due to the fact that obstacles – detected within the above described case study – were eliminated. Based on this analysis, it could be ensured that BCAL/UFPR was built at an appropriate location.

3. Monitoring of BCAL/UFPR

High-precision geometrical levelling has been carried out to monitor BCAL/UFPR. The first campaign was realized before the construction of the pillars. Approx. 50 days after the construction another levelling line was measured. At least two times per year the levelling line is remeasured. The reference for the levelling consists of three reference points which are located near the GPS station UFPR, which is part of the IGS (International GNSS Service, DOW ET AL., 2009) as well. The distance from UFPR to the calibration pillars is less than 100 m. The site UFPR is also part of the Brazilian Continuous Monitoring GPS Network (RBMC) of the Brazilian Institute of Geography and Statistics (IBGE). Six control points (P1, …, P6, see Fig. 4) fixed to the laboratory were established and observed by means of levelling. Until now, the differences between the levelling runs were considerably small.

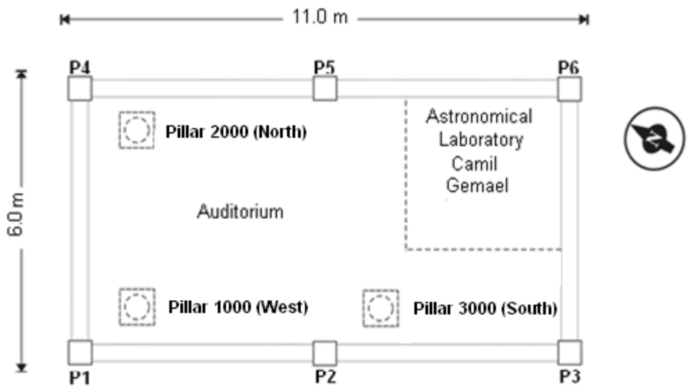

Figure 4: Location of the three pillars of the BCAL/UFPR and the six levelling control points (Krueger et al., 2009)

4. Antenna calibration values

The location of GPS antennas during a satellite signal reception is called antenna phase centre (FREIBERGER JR., 2007). Dealing with phase centres, one has to distinguish between the two terms: mechanical and electrical phase centre; whereas the electrical phase centre is identical to the direction-related signal reception point. This phase centre is in most cases neither located at the antenna's rotation axis nor necessarily coincident with the geometric centre of the antenna.

The PCO (Phase Centre Offset) is a 3D displacement vector between the average frequency-dependant electrically phase centre and the antenna reference point (ARP). PCV (Phase Centre Variations) are additional corrections with respect to the phase centre. They are often highly correlated to the angle of incidence of the signal. Therefore, the phase centre will vary with respect to the satellite signal direction. Ignoring the variations of the phase centre can lead to significant vertical errors, which can reach 10 cm (MENGE ET AL., 1998).

5. First results of BCAL/UFPR

At BCAL/UFPR the relative calibration field method was established, within this approach two antennas are used simultaneously. The reference antenna is usually a Dorne Margolin Choke Ring type antenna. The calibration values (PCV, PCO) of the second antenna are going to be determined with respect to the reference antenna relatively based on collected observations of GNSS (Global Navigation Satellite Systems). Choke Ring antennas are usually used as reference antennas, because these antennas have well-determined PCO and PCV values. The antenna, which is going to be calibrated, is rotated within the BCAL/UFPR approach using the so-called DRB device. DRB was developed by the Technical University of Dresden (Germany) to meet the needs of scientific experiments, especially in GNSS antenna calibration (FREVERT ET AL., 2003). This automatic device rotates the antenna to be calibrated scheduled. Within this case study the antennas were rotated within 60 seconds from north direction (measurement: T = 0 s) to south direction (measurement: T = 15 s). 15 seconds later the antenna points to west direction (measurement: T = 30 s) and finally at T = 45 s the antenna points to east direction and is than rotated back to the north direction. This cycle is repeated each minute for approx. 24 h.

The first calibration experiments were carried out using TRM22020.00+GP antennas. Based on the above described multipath case study, pillar 1000 (pillar 2000) was chosen as location for the reference antenna (antenna to be calibrated). The collected data were post-processed using the software WaSoft/Kalib (WANNIGNER, 2002), which was developed to determine GNSS antenna parameters for relative calibration consisting of PCO and PCV. This paper will only focus on PCO values.

A two-frequency geodetic equipment (Leica GPS1200 receiver, Leica Choke Ring antenna (LEIAT504 NONE), see Fig. 5, left pillar) was used as reference antenna. The antenna to be calibrated (Trimble TRM22020.00+GP) is shown in Fig. 5 (right) as well as the DRB device. The measurements were carried out in three sessions of 24 hours, with a data recording interval of 15 seconds. The estimated PCO values (north component, east component, up component) and the corresponding standard deviations for L1 and L2 of the antenna TRM22020.00+GP (SN 12347) can be found in Tab. 1.

Table 1: L1 and L2 related PCO values (north, east and up components) [mm] and corresponding standard deviations (std, [mm]) of TRM22020.00+GP (SN: 12347) (HUINCA ET AL. 2012).

1st experiment, DOY2008: 245					**2nd experiment, DOY2008: 247**					**3rd experiment, DOY2008: 248**				
component	L1	std	L2	std	component	L1	std	L2	std	component	L1	std	L2	std
north	0.1	0.0	-0.3	0.1	north	0.2	0.0	-0.5	0.1	north	0.3	0.0	-0.3	0.1
east	-2.1	0.0	2.7	0.1	east	-2.0	0.0	2.5	0.1	east	-2.0	0.0	2.6	0.1
up	51.9	0.1	60.8	0.2	up	51.9	0.0	60.6	0.2	up	51.8	0.0	60.4	0.2

Figure 5: Relative field calibration at the BCAL/UFPR, left: reference antenna, right: DRB device and calibration antenna (KRUEGER ET AL., 2009).

The same antenna shows slightly different PCO behavior for both L1 and L2. The largest variations are on L2 carrier, due to lower transmitted energy (FREIBERGER JR., 2007). For L1, the largest detected variation is 0.2 mm for the experiments 1-3 in the north component. For L2, the largest variation found is 0.2 mm for the experiments 1-2 in the north component. In the up component for L2, the largest variation found is 0.4 mm. Comparing the north, east and up components, for both carriers (L1 and L2), the largest variations show up for the L2 carrier. All results show good repeatability and meet the requirements of BCAL/UFPR, which were formulated in the beginning of the PROBRAL project.

6. Conclusions and future work

First results of relative field calibrations of GPS antennas at BCAL/UFPR (Baseline Calibration Station for GNSS Antennas at UFPR) were shown in order to proof that one main goal of the here described PROBRAL project could be fulfilled based on a close cooperation between the two participating institutions: Antenna calibration values can now be provided for Brazil and all countries of Latin America for the first time. Analysing the experiment's results, only small variations were found, which proof that the calibration method was applied correctly.

It is planned to do further calibration experiments in different seasons of the year in order to verify the behaviour of north, east and up PCO components of the calibrated antenna. In addition, the PCV are going to be analysed.

Experiments using absorber material in order to reduce pillar-reflected multipath are planned. Investigations on the influence of meteorology on phase multipath effects will be carried out, too.

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A proposal of geographical orientation for three-dimensional cartographic representations

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Abstract: In the paper we present the results of a study concerning geographic orientation for three-dimensional cartographic representation. Three possible solutions are proposed and evaluated. The first method indicates the cardinal points with letters on the edges of the model. The second method uses the wind rose as is used in 2D maps. The third method uses an auxiliary 2D map with a moving mark that shows the current position of the user. The methods were evaluated by a qualitative test of cartographic perception. Students of the study course Geodesy and Geoinformatics of the Karlsruhe University (TH) performed the test that was based on cognitive questions in order to understand the perception process when dealing with three-dimensional and interactive maps. Some results are presented and discussed in this paper.

1. Introduction

In the last two decades the geodetic community experienced the effect of new technologies that enable new options for cartographic representations, like three-dimensional environments and interactivity and can help to overcome human limitations in understanding maps. In addition, data collecting innovations, like laser scanning and digital photogrammetry, enable rapid three-dimensional data, which were previously difficult obtain. Current computer technology offers also software to generate and process three-dimensional models that enable detailed representations of the terrain and its objects. The discussion about representation principles for the production of interactive three-dimensional models for cartographic purposes is therefore open. Questions like symbology, cartographic projection, scale and geographic orientation are to be discussed within the scope of 3D Cartography. This paper discusses the perception of orientation in 3D cartographic representations. Three options are proposed and evaluated from students of the study course Geodesy and Geoinformatics of the Karlsruhe University (TH) as potential users. The methods, experiments and results of this experience are introduced in the following sections and later discussed.

2. 3D mapping and visualization

Human beings experience and interpret the natural world in a very intuitive way that was developed over evolution. This does not always valid when human beings are faced with 2D maps that result from the projection and simplification of the world in a bi-dimensional space. Therefore, some representation principles are followed in Cartography when a map is designed in order to guarantee an appropriate communication between the map producer and the user.

According to TERRIBILINI (1999) the quality of cartographic products can be improved knowing how information is processed by the human brain and to generate maps that look more similar to the real world. That does not mean that the map manufacturer should aim at a full realistic representation but that the map should be produced as the world is perceived. It is reasonable to expect that a 3D map should be understood more easily than a flat map, because the space (world) is three-dimensional. Human perception can also be enhanced adding interactive features to the 3D map. According to TERRIBILINI (1999), in a 3D interactive map the user is able to improve the information flow choosing the best viewpoint to interpret it.

Nowadays, available computer technology offers new options for map production. Maps can be produced quickly, cheaply and the user can interact with it, changing and transforming the appearance. Therefore, emphasis should be given to this new map production options that change the map from a static to a dynamic document (CARTWRIGHT AND PETERSON, 2007). It becomes necessary to study 3D map design in detail in order to understand deeply how they work, the cognition process within the 3D interactive environment. The question of geographical orientation is always present and should be taken into account within this problematic.

3. Perception test

A three-dimensional digital model was first produced for the tests. The study area lies in Macaé, within the state of Rio De Janeiro (Brazil). This is a rural, mountainous, and slightly populated region. The Digital Terrain Model was represented in TIN format (Triangular Irregular Net) and a horizontal reference surface was added.

The next step was the development of options for 3D geographical orientation. The first option follows the approach proposed by HAEBERLING (2002) and uses letters on the sides of the model to show the cardinal directions: N = North, S = South, E = East, W = West, NE = Northeast, SE = Southeast, SO = Southwest and NO = Northwest. Because the letters are bi-dimensional they may become unreadable in the virtual environment if they are static, depending on the viewing angle. Thus, the letters are rotated according to the user´s position. Figure 1 illustrates this method.

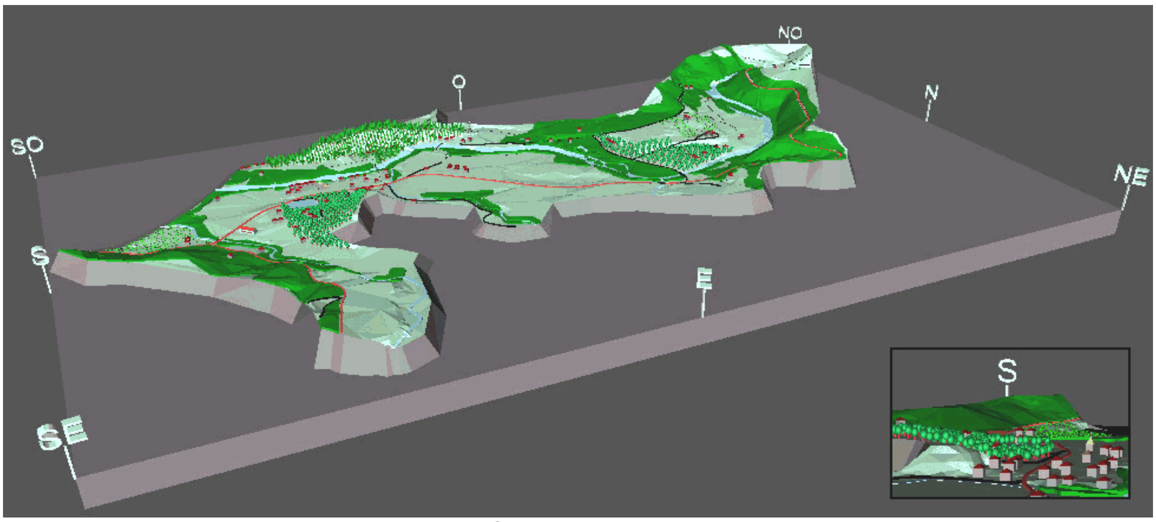


Figure 1: Cardinal directions as letters.

The second method resembles the orientation tool of the traditional 2D maps inserting wind rose in in the upper left corner of the model, as shown in Figure 2.

Finally, the third method uses an additional auxiliary image, where the user can see a bi-dimensional map of the region where his position is marked. The mark moves as the user changes his position in the 3D model. Figure 3 illustrates this method. Within this figure, the flat map is on the right side and the asterisk mark is zoomed.

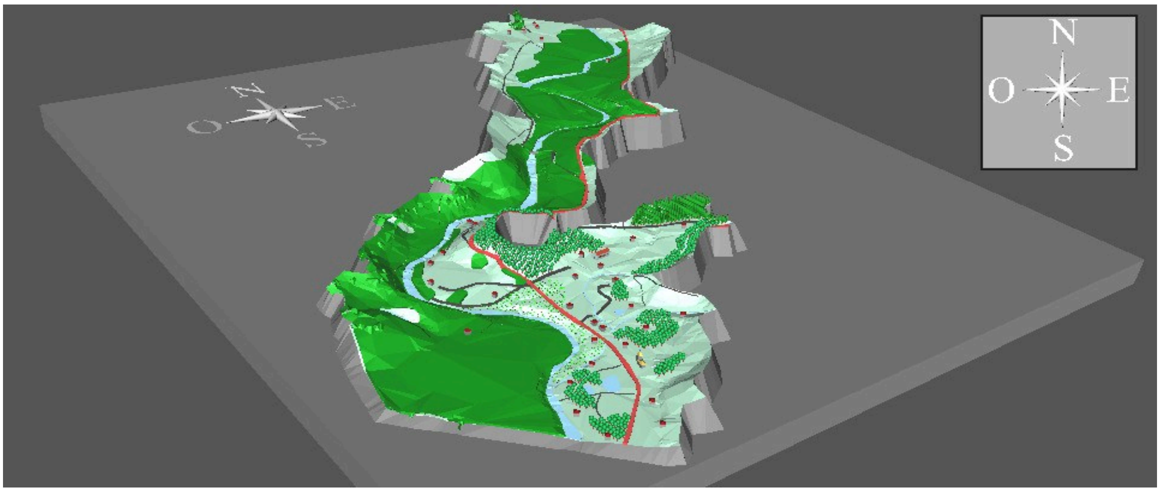
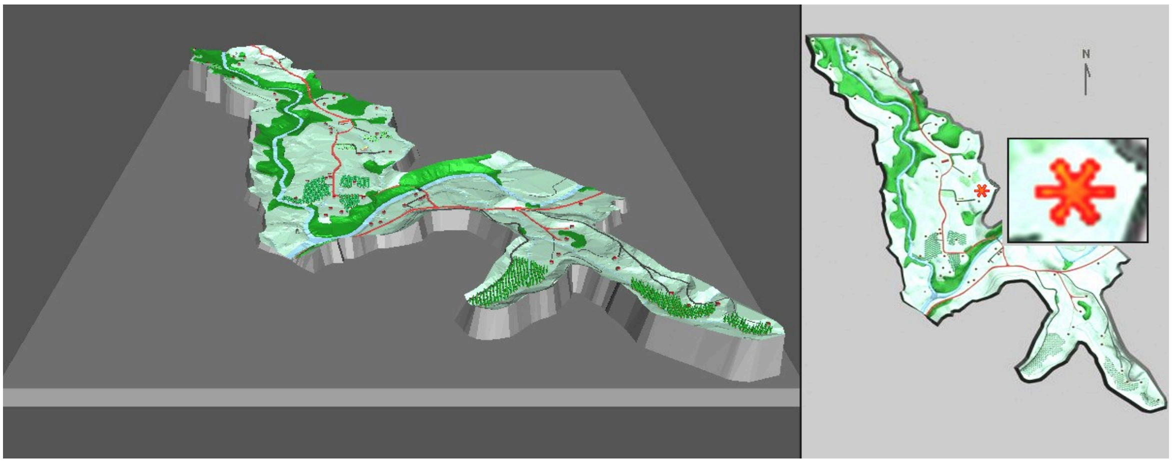


Figure 2: Wind rose (compass).

The 3D cartographic representations were evaluated between January and February 2008 by students of the Karlsruhe University (TH) using a visual perception test. The cartographic perception test was based on cognitive questions. Within the test, the test persons navigate within the 3D model and make use of the above mentioned methods of geographical orientation to answer specific questions. In the following section the results of the test are presented and discussed.

Figure 3: Dynamic 2D map with moving mark.



4. Results

The test was performed by nine persons with knowledge about cartography and was divided in tasks. The first task of the test aims at the identification of the preferred geographical orientation method. The test persons also had to explain why the method is considered better.

Five of the nine test persons said that the model that uses the letters on the edges to indicate the geographical reference is the easiest to use, because it is always possible to see a letter of the cardinal points of any point of view on the model. One test person found the method of the wind rose easier, since this symbol is already known and commonly used for the orientation in maps. According to him, this method is easier because it is already familiar. One test person chose the first and second method, due to the reasons quoted above. Two others opted for the third method. One of them based his choice on the availability of a plain map with the north on the top and the moving mark, which makes it easier to use the 3D model. The second one justified the use of the 2D map mainly because he is an expert in the field of Cartography, which, according to him, makes it easy to use the third method using his previous knowledge. He also pointed out that this may not be valid for other persons without enough knowledge in Cartography.

Based on the results obtained in the first task it was not possible to conclude which is the best method, but a trend towards the first method was noted. The use of letters to indicate the directions is a simple solution that is easy to use, especially by persons without deep knowledge in Cartography. However, a final conclusion cannot be drawn but the gained results point out the need for further research in this topic.

In the second task, the users were asked if they would recommend the method that they chose in the first task to be used by the general public. If a test person chooses another method in this task, he is also asked to justify his choice.

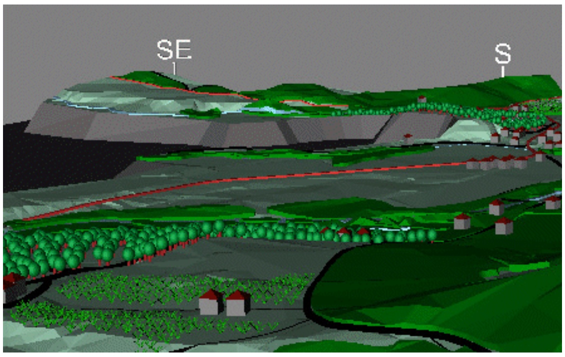
Two persons recommended the use of letters, because this method enables a better understanding for people without deep knowledge on Cartography and it is easy to visualize the letters when walking on the 3D model. Three other users opted for the method that uses the auxiliary 2D map. According to them, the experience of 2D map reading can be easily adapted to this new situation. They also said that this method seems to be difficult for users with less knowledge in Cartography.

Four other test persons suggested to introduce changes to improve the solutions. Two suggested to combine the first and the third method, keeping the auxiliary map and introducing the letters in the 3D model. One test person suggested to add a Cartesian axis system as reference in the third virtual model. Finally, one test person proposed the use of the first or the second method, increasing an auxiliary compass to show direction variations and to improve the third method by adding the view direction to the auxiliary 2D map.

Again, a conclusive affirmation could not be drawn in this test and further research on this topic is still necessary. However, the suggestions given by the test persons show some improvements that should be evaluated.

The last research topic aimed at complementing the previous two research aspects taking the critics and suggestions on the previous experiments into account. In addition, the test persons were asked to suggest another option for future experiments or some improvement that should be considered. The test persons did not recommend the first method for an overview of the model, but they considered it most suitable when the position of the user is close to the surface of the terrain in the model, because it is always possible to see one or more cardinal points (Figure 5a). This method was also recommended for people who are no specialists in Cartography. The second method, based on the use of a wind rose was not recommended, because the wind rose is not only visible when the scale is augmented (zoom). This solution was considered appropriate only when the person needs to visualize the whole model, otherwise the reference is lost, as shown in Figure 5b.

The third method was considered by some students as the most complete, because the auxiliary map helps to orientate and the moving mark enhances this idea. However, it was pointed out that more mental energy is needed to interact simultaneously with the virtual model and the auxiliary map. This method could become more complex rather than practical.



(a) Letters are visible and help to orientate.

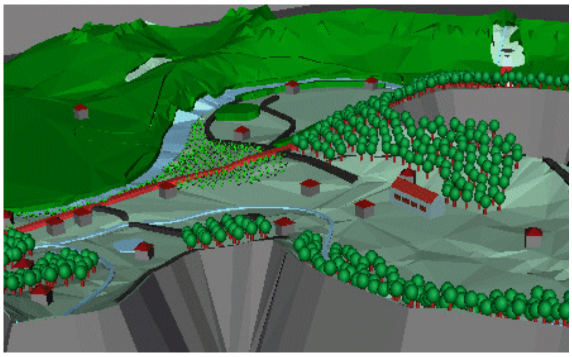

(b) The wind rose is not visible and the orientation is lost.

Figure 5: Advantages and problems in close views.

5. Conclusion

This research has just begun and therefore the results cannot be considered conclusive. Based on the responses and suggestions given by the test persons there is need for further research in order to find the most suitable solution for the orientation problem in 3D mapping, especially when users have less experience in Cartography.

The results show that the relative position of the user has to be taken into account, in order to enable the visualization of the reference points or symbols even when zooming the model. It was also noted that the inclusion of new layers or maps may lead to confusion because of the additional mental work that the user has to carry out in order to understand two representations at the same time.

In addition to the geographical orientation, symbology, map projection, and scale are important elements within 3D cartographic representation and also deserve further studies. It is necessary to know how the user reacts to these four elements to propose design rules for the 3D representations for mapping purposes. In this context, it is recommended that further efforts should be dedicated to these topics, which are of paramount importance for the development of 3D cartographic representation.

Acknowledgement

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ANN interpolation of contour lines data to obtain digital terrain models

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Abstract: The objective of this study was to propose a method for interpolation and generation of Digital Terrain Models (DTM) from contour lines, using artificial neural networks (ANN). Contour lines (20 m equidistance) used in this investigation vary in altitude from 700 to 1100 m and correspond to the land relief of the Tibagi region (PR, Brazil). The proposed method uses the ANN technique to perform interpolations of data resulting from interpolations based on northing (N), easting (E), and altitude (H) coordinates. To train the ANN contour lines samples of coordinates N, E and H were used as input variables for initial processing. Regarding to the results, it is posed that utilizing the ANN technique in order to obtain a DTM was as successful as the traditional method of Inverse Square Distance (ISD). Furthermore, it interpolates altimetry data acquired from contour lines with a decreased amount of samples.

1. Introduction

Terrain representation is a preponderant issue in territorial space studies. Computer terrain representation began in the 1950s, when the so-called numerical models, the Digital Terrain Models (DTM), were developed. The representation of the DTM is done by generating a digital model, which can be defined through analytical equations or a network of points, known as grid (FELGUEIRAS 2001). The phases in DTM building are sampling, modelling, visualizing, manipulating and, generating by-products finally. The modelling stage is based on a regular or an irregular distribution of data observations. Irregular distributions can be interpolated, while regular grids can be generated or irregularly utilized based on a Triangulated Interpolation Network (TIN) (FELGUEIRAS 2001). One method of regular grid interpolation is the Inverse Square Distance (ISD) classified as a local method based on a moving average approach (PETTINATI 1983). Another important interpolation technique is based on Artificial Neural Networks (ANN) which is a branch of Artificial Intelligence.

1.1 Artificial Intelligence and Artificial Neural Networks

Artificial Intelligence (AI) is defined as a set of programming techniques that seek to solve problems using algorithms and mathematical techniques in a computerized system, which simulates human cognitive abilities (HAYKIN,1999). An AI system must be capable of storing knowledge and applying stored knowledge to solve problems and acquire new knowledge through experience. Thus, this system has three components: representation, reasoning and learning. These systems were designed and have been widely used to solve complex problems in which algorithms and traditional techniques are often inadequate or inappropriate (HAYKIN 1999).

SIMPSON (1990), HILTON (1989), and LIPPMAN (1987) mention that ANN is the AI research branch, within the concept of connectionism, which aims to investigate the possibility of simulating intelligent behaviors using models based on the human brain. It is composed of processing units operating in parallel, inspired by the biological system of neurons. An ANN consists of a number of processing units and elements called neurons, units, cells or nodes. Each neuron is connected to another by means of links, each of them associated with numerical weights. According to REZENDE (2003) an ANN is a mathematical model that resembles biological neural structures and possesses computational capacity acquired through learning and generalization. Learning is not achieved through the modification of neurons, but through modifications of the weights of interconnections. Learning in a network is equivalent to conducting systematic changes to these weights in order to bring the level of network response to an acceptable level. Therefore, the set of connection weights can be seen as a dynamic system, since they adapt themselves to encode desired knowledge for the system to learn. The generalization of an ANN is linked to the ability to providing coherent answers to data that were not previously presented in the training stage (PIZOLL 2002). On this basis, an ANN consists of an AI approach to problem solving founded on a known and accepted model of intelligence: the human brain (NIEVOLA 1998).

1.2 Architecture of Artificial Neural Networks

An ANN is composed of multiple neurons distributed in layers. The first one is the input layer and it has the function of storing input data in the network. Within the hidden layers the network processing occurs. The last layer is defined as output layer. This layer receives already processed values by the network. The quantity of neurons per layer and the quantity of layers in a network is named after ANN architecture (ITO et al., 2000). The neurons located in the hidden layers play an important role during training because they act as feature detectors. As the learning process progresses, hidden neurons gradually begin to "discover" the pronounced features that describe a non-linear transformation of data entry into a new space, the hidden space or characteristics space. In this new space, the variables of interest can be more easily detected and separated from each other than in the original input space (HAYKIN, 2001). GERMAN AND GAHEGAN (1996) report that the number of nodes (neurons) of the hidden layer is defined taking into account the network operation, i.e., neurons in the middle layer perform the space separation of the variables. Some authors cite the Hilton rule (1989) to define the number of neurons in the hidden layers that a network should have, suggesting that the number of neurons in the second hidden layer should not exceed one third of the first layer value. See FITZGERALD AND LEES (1996) for details concerning the Hilton rule.

1.3 Collection of Training Samples

Within the concept of the ANN, the collection of training samples is defined by a set of representative elements of the studied object. This collection can be done manually or automatically. Within the manual training sample collection, the user selects a specific element, whereas within the automatic training sample collection, computer language code is developed to collect training samples of a file containing all data.

1.4 ANN Training: supervised and unsupervised

The learning of an ANN is accomplished through iterative processes of adjustments applied to the weights. This processing part is called training. Learning occurs only when the ANN reaches a general solution for a given problem. According to LEES (1996), the most important property of an ANN is the ability of learning.

According to RIBEIRO AND CENTENO (2002), training a network means to adjust its weights matrix (w) so that the output vector (y) coincides with a certain desired value for each input vector (x). Training a network can be done by two methods: supervised or unsupervised, while the former requires of input and output pairs to the training, the latter requires only the input vector. In supervised training, both input and output vectors are supplied to the network. Hence, it is possible to apply the input vector and the output of the network is calculated. The obtained output is compared to a desired output vector (which was initially presented to the network) and an error is calculated from this difference. Weights assigned to each entry are used according to the algorithm, so that this error is minimized. This process is repeated for the set of training samples until the error reaches a desired and previously stipulated threshold (stop criterion or tolerance). In unsupervised training, the output vectors are not presented to the network. Thus, training cannot compare estimated outputs to the desired output in order to determine the answer closest to the ideal. Without training, it is not possible to determine what value will be generated in the output network for an input vector. The training process extracts the statistical properties of the set of training samples and groups similar vectors into classes. The output is obtained by applying a vector from a particular vector class in the network input which will then produce a specific output.

ANN training was inspired by the Hebb law (HEBB, 1949) which states: “the strength of a synaptic connection between two neurons increases if both are excited simultaneously”.

Either in supervised or unsupervised training, there are several training algorithms applied to ANN models. The training algorithm used in this study was the propagation of error, also called simply backpropagation.

1.5 Backpropagation networks

A feedforward multilayered network as shown in Figure 1, consists of a set of perceptron units formed by the input layer, one or more hidden layers and an output layer of computational nodes (HAYKIN, 2001).

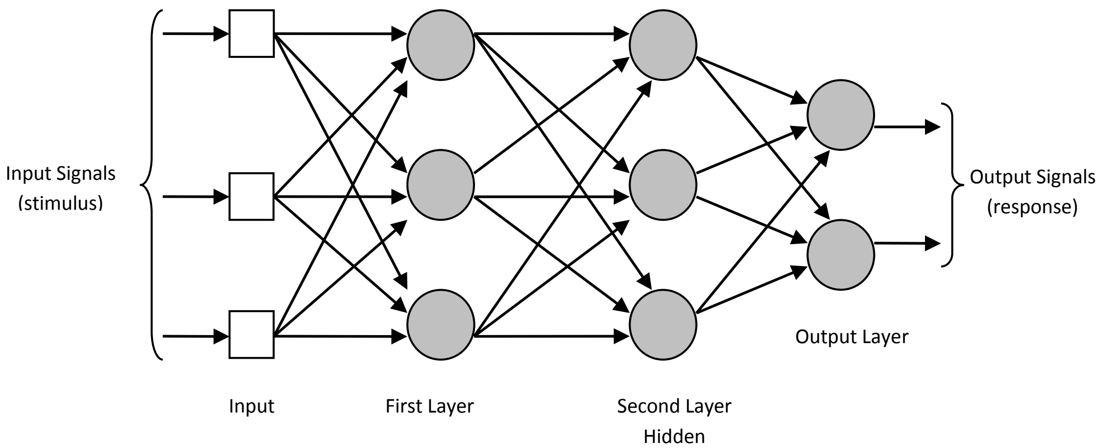

Figure 1: Example of a multilayered Artificial Neural Network (after HAYKIN, 2001).

The backpropagation training algorithm is a method of supervised learning for a multilayered ANN. It is an algorithm capable of linking hidden layers, i.e. when two or more layers of weights are adjusted the hidden layer detects characteristics and responds to specific input pattern that it automatically detects. The connection weights are adjusted through backpropagation of error (HAYKIN, 2001).

Backpropagation consists of two steps through different layers of the network, respectively: forward propagation and backward propagation. In the first step, synaptic weights are invariant. In the second step, these weights are adjusted by a rule of error correction based on the difference between the output response of the network layer and the desired response. This produces an error signal that is propagated back through the network, in the opposite direction to the synaptic connections (HAYKIN, 2001). Equation 1 shows how the error signal of neuron k is calculated during the iteration (n), i.e., the presentation of the nth training example.

$$e_k(n) = d_k(n) - y_k(n), \qquad (1)$$

with $e_k(n)$: error signal,
$d_k(n)$: desired response or target output and
$y_k(n)$: output signal of neuron k.

According to PIZZOL (2002), error signals are transmitted to the previous layers from the output layer to all neurons of hidden layers that contribute directly to the output. However, each neuron in the hidden layers receives only a portion of the total error signal, which is strongly based on the relative contribution of that neuron to such output. This process is repeated, layer by layer, until each neuron receives an error signal that corresponds to their relative contribution to the total error. Based on the error signal received, the weights of the connections are updated by each unit; so that the network converges to a state that enables all training patterns to be identified and coded.

The error signal $ek(n)$ activates a control mechanism with the purpose to apply a sequence of corrective adjustments to the synaptic weights of neuron k. The corrective adjustments are designed to approximate step by step the output signal $yk(n)$ to the desired response $dk(n)$. This objective is achieved by minimizing a cost function or performance index $E(n)$, defined in terms of the error signal $ek(n)$ or the instantaneous value of the error energy for neuron k as shown in Equation 2 (HAYKIN, 2001, p. 188).

$$E(n) = \frac{1}{2} e_k^2(n) \qquad (2)$$

Correspondingly, $E(\overset{k}{n})$ is the instantaneous value of the error total energy, which is obtained by adding up the terms of Equation 2 from all the neurons of the output layer. They are the only "visible" neurons from which error signals can be directly calculated. Thus, it is possible to derive Equation 3.

$$E(n) = \sum_{K \in C} \frac{1}{2} e_k^2(n) \qquad (3)$$

with C: set including all the neurons from the network output layer

According to HINTON AND SEJNOWSKI (1987), during training, the backpropagation network tends to develop internal relationships between neurons in order to organize training data into classes of patterns. This trend can be extrapolated to the hypothesis that all neurons in the hidden layers in a backpropagation network are somehow associated with specific characteristics of the input pattern as a result of training.

The formal mathematical description of the backpropagation operation is performed by the Generalized Delta Rule (GDR), which is the learning algorithm of the network. This algorithm is a generalization of the Delta Rule algorithm as previously stated. In summary, we can conclude on backpropagation:

- For the adjustment of weights in this multilayered network the algorithm uses a minimization process through the process of gradient descent, which suggests changes in the weights by an amount of Δw_{kj} proportional to the gradient of the surface error. It also uses the activation threshold of the sigmoid function.
- Minimization through the gradient descent process and the activation function threshold, constitute the GDR used for feedforward ANN training.

The aim of the GDR is to determine a set of weights *w,* which minimizes the Root Mean Square (RMS) on a determined number of sample elements of training. Raising the minimum point is achieved through an iterative process that uses the training sample set (RIBEIRO AND CENTENO, 2002).

ANN is a dynamic system in which the new state is a function of previous state. The calculation of the new state is called the update as in Equation 4.

$$w_j^{new} = w_j^{previous} + \Delta w_{kj} \tag{4}$$

with C: set including all the neurons from the network output layer

Figure 2 shows, how training and backpropagation error are processed in ANN in a simplified manner. In addition, Figure 2 shows the operation of the ANN, it is described as follows: An input is provided to the network and the output is presented, the error vector is calculated by the network which is the difference between the obtained and the expected output (provided as a benchmark); an update of the output layer weights through the GDR is performed; desired values are extended to previous layers hence updating weights in other layers.

The aim of the Delta Rule is to determine a set of weights (K) that minimizes the mean square error in a determined amount of training samples. The attainment of a minimum point is achieved through a local iterative process utilizing a set of samples.

In unsupervised training, output vectors are not presented to the network. Thus, training is not able to compare estimated outputs with the desired output in order to determine the closest answer to an ideal one. There is no way to determine beforehand, which value will be generated in the network output to an input vector. The training process extracts statistical properties of the training samples set and groups similar vectors into classes. Output is obtained when applying a certain class of vector to the network input, which will produce a specific output vector.

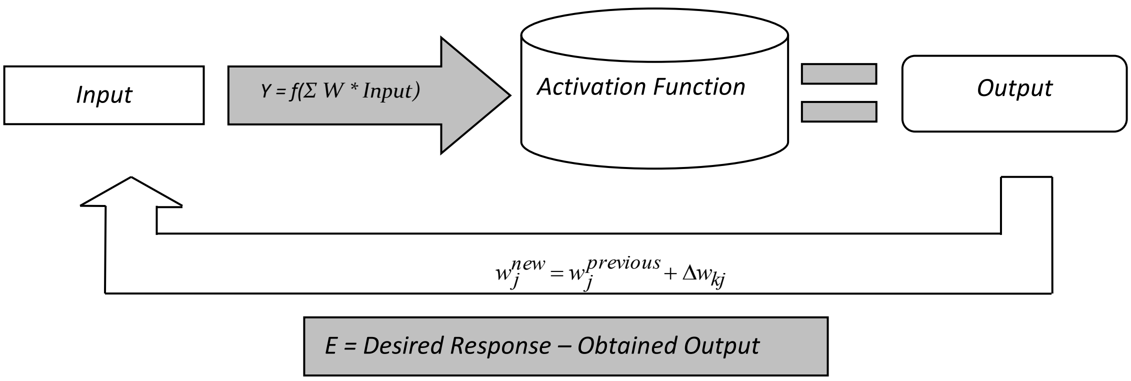

Figure 2: Diagram showing Neural Network training, adapted from Kóvacs (1996).

Other components to adjust ANN training are the variable learning rate, the momentum and the variation of the backpropagation training (Resilient Propagation: RPROP). The backpropagation algorithm provides an approximation to the space trajectory of weights calculated by the gradient method. The smaller the learning rate parameter (ŋ) the less will be the change, from an iteration to the subsequent, in the synaptic weights of the network. On the other hand, the higher the learning rate (ŋ) the greater the change in synaptic weights from one iteration to another. In this case the ANN can become unstable, in other words, oscillatory. A method of increasing the learning rate to avoid the danger of instability is to modify the Delta Rule, as shown in Equation 5 by including the term momentum α resulting in Equation 6 (HAYKIN, 1999). The momentum is a positive number called time constant. The momentum controls the feedback loop that is acting on $\Delta w_{kj}(n)$. For further details, see RUMELHARDT ET AL. (1986).

$$\Delta w_{kj}(n) = \eta\delta_k(n)y_j(n) \tag{5}$$

$$\Delta w_{kj}(n+1) = \alpha\Delta w_{kj}(\mathrm{n}) + \eta\delta_k(n+1)y_j(n+1) \tag{6}$$

Including a reference point in the backpropagation algorithm, will result in a stabilizing effect in directions experiencing signal oscillation. This term represents a small modification in the weight updates. Nevertheless it may have some beneficial effects on the learning behavior of the algorithm.

Yet due to the fact of network instability and that processing can occur slowly, the above mentioned variation of backpropagation training RPROP was developed by REIDMILLER AND BRAUN (1993). In training, during weight updates through the learning rate, a local minimum point might occur with the gradient descent presenting a slight magnitude and weights are not adjusted in the optimum value for the problem. In this case, a variation of the backpropagation algorithm can be used to minimize such problem and the expected network convergence is accelerated; this variation is called Backpropagation resilient. The purpose of resilient (elastic) training is to eliminate effects of magnitude loss in partial derivatives.

Just the signal of the derivative is used to determine the direction of the adjustment of weights, magnitude of derivatives has no effect on this adjustment, i.e., weight change is determined by adjusting separate values. The adjustment of each weight is increased by a factor every time that the performance of the derivative function, regarding the weights, has the same signal for two successive iterations. The adjustment value of the weight is reduced by a factor every time the derivative, regarding the weights, changes signal in the previous iteration. If the derivative equals to zero the gradient value remains the same. Every time weights are oscillating their change will be reduced. If the weight continues to change in the same direction for several iterations, their adjustment magnitude will then be increased (RIEDMILLER AND BRAUM, 1993). The adjustment of the weights is calculated using Equation 7.

$$DW = \Delta W * \mathrm{sign}(GW) \tag{7}$$

with DW: weight update,
sign: signal in purpose of the weight changes in the iterations,
ΔW: weight variation and
GW: gradient.

1.6 Generalization

After ANN training, it is expected that the designed network will be able to generalize further data. It is said that a network generalizes properly when the input-output mapping computed by the network, for the sample set not used in the network training, is correct (or nearly correct). The learning process can be seen as a "curve adjustment" problem. The network itself can be regarded as a nonlinear input-output mapping. This point of view allows considering the generalization of an ANN as an effect of non-linear interpolation on the input data (HAYKIN, 2001). The network performs mainly non-linear interpolation because multilayer networks constituted with continuous activation functions also produce continuous output functions.

An ANN, if well designed to generalize, will produce a correct input-output mapping even when the input is different from examples used to train the network. But if an ANN learns an excessive amount of input-output examples, this may lead to the memorization of training data. This phenomenon is known as over-adjustment or overtraining. When the network is over-adjusted it loses the ability to generalize between similar input-output patterns (HAYKIN, 2001).

2. Study area

The Tibagi region will be used as study area during this research. Figure 3 shows the Tibagi region in Parana where contour lines are located.

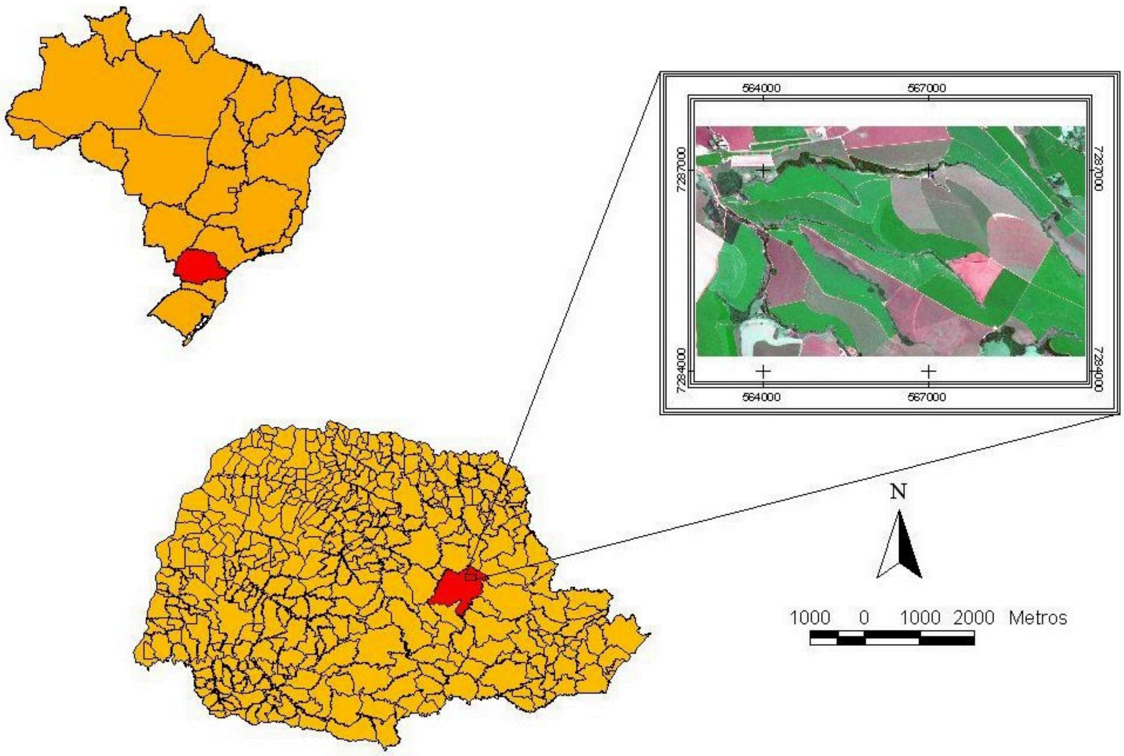

Figure 3: Tibagi region (PR, Brazil) – area under research.

3. Material and methods

To implement the program presented in this study, the following software were used: Matlab (Matrix Laboratory) 5.0, 6.5 and 7.0, Golden Software Surfer 8.0, Microsoft Office Excel 2003. Contour lines correspond to the Topographic Sheet SG -22-X-A-V-1 and MI - 2824-1 with equidistance of 20 m, which are the input data.

In order to be able make use of the ANN interpolation, a code was developed using Matlab. The methodology consists of three parts: the first part refers to sample collection in order to train the ANN; the second part is the ANN training with respective samples; while the third component part is the generalization of the interpolation (simulation) for all data. The flowchart shown in Figure 4 illustrates this process.

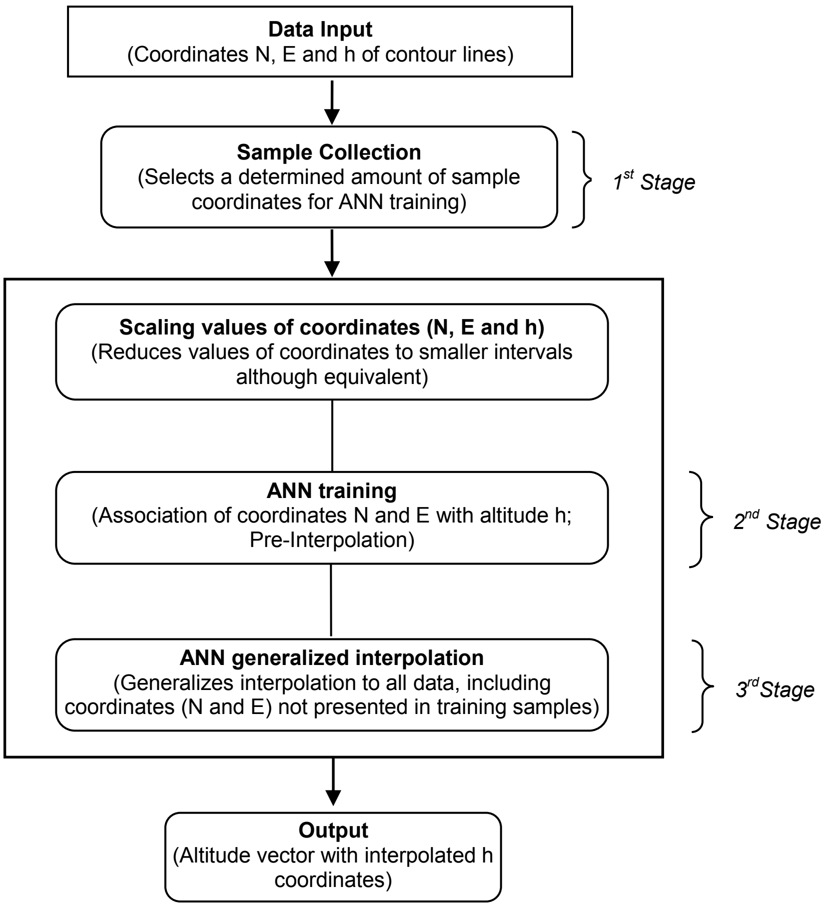

Figure 4: Flowchart: Code stages for processing contour line data in an ANN.

3.1 Collection of training samples

The user provides the amount of samples to be collected for training in a fixed or proportional mode. In the fixed mode the user sets the exact number of training samples desired, without considering the total amount of data. In the proportional mode, the user only defines the collection interval so that the more (less) data available the larger (fewer) the amount of samples. Therefore, the amount of samples to be collected is proportional to the amount of input data. Having made the collection of training samples, they are stored in a suitable vector to be used by the training code and for interpolation.

The code developed in this study comprised 16,384 coordinates (N, E and h) and the collection was done in the proportional mode. Four tests were performed. In first test, an interval of four coordinates was chosen and 4,096 samples were collected. The second test is based on intervals of six coordinates, thus obtained 2,370 samples. The third test (intervals of eight coordinates) obtained 2,048 samples, and within the last test intervals of sixteen coordinates were performed. This test obtained accordingly 1,024 training samples.

3.2 Training

The training consists of associating input vectors which are the planar coordinates N and E, and the height h, i.e., to each coordinate (N, E) a height (h) is associated according to the original data, so consequently this code "learns" that for a given plane coordinate pair a height value must be involved.

The training code separates coordinates N, E and h, scaling them to a range between 0 and 1, this is necessary due to high values that plane coordinates represent (N has an average of 500,000 m, E has an average of 7 million meters and h with an 850 m average; all measured in meters). Scaling is a mathematical process that implies scaling down a large value to a lower one, in a way that during this process equivalence of values is not lost and they may be reverted to their original form.

The second step of training is the ANN architecture configuration with the purpose of generating the desired output, i.e., performing the interpolation. The ANN architecture must have the input layer and the output layer, and may contain one or more intermediate layers (hidden). The amount of neurons per hidden layer is decisive for a relevant final result because neurons are one of the core internal elements that configure the ANN and they depend on the complexity of the problem. The amount of hidden layers and neurons per layer interferes with time and with ANN capacity to "learn". "Learning time" is then training time, so one must consider the training time cost with regards to the final quality of the interpolation. Other external factors that affect ANN processing time are: number of training samples and processing capability of the machine.

In the code developed in this study, according to the results, the training carried out presented variations in the values of the ANN architecture parameters, so the study is experimental. Concerning the inputs no variance was observed because input vectors are fixed (N and E) and (h), as well as the single output vector. What has changed is the amount of training samples, as already above mentioned on the topic about sample collection, hidden layers and number of neurons in these layers.

The number of layers used in the majority of trainings was composed of an input layer, two hidden layers and an output layer. The interval of the number of neurons in the input layer ranged 6-180, while the number of neurons in the hidden layer varied between 20 and 60. According to the Hilton rule, the number of neurons in the hidden layer should not exceed one third of the input layer value. The output layer was composed of a neuron, due to the fact that there is only one output (h) in the code. During ANN training, a hidden layer was added. Regarding to the processes the network architecture is composed by an input layer, three hidden layers and an output layer. In the second hidden layer output results using 20-40 neurons were tested.

The functions for neuron processing were, initially, the step activation function (Purelin in Matlab), and then the Sigmoid function (Logsig in Matlab) that started to be applied in all layers. Relative to the mean square error target to be achieved there was a significant variance. In the first tests, the value of 0.8 was set as the greater target and in the latest tests the lower target used was 0.00008.

3.3 Generalization/Interpolation

After ANN training, it is expected that the designed network will be able to generalize further data, i.e., for each coordinate pair (N, E) not presented in the samples a height (h) proportional to the (N, E) values of the original data is assigned. The ANN "learns" to calculate the estimated height based on training samples collected from the original data containing N and E coordinates and altitude h. Interpolation thus returns a single output vector, which corresponds to the height vector h interpolated by the ANN.

Within the interpolation of the developed code, two vectors with different plane coordinates were used. The first one was the original contour vector from which the training samples were collected. The second vector was a grid position (N, E) generated using the program Surfer 8.0, which was used for the purpose of interpolation by replacing the first vector mentioned with the original coordinates of the contour lines. The intention of the grid generation is to visualize the altitude data output of the network to be represented in the form of wireframe in the Surfer software.

4. Experiments

The program developed within this research is comprised in three stages of testing. Previously to the steps themselves, a DTM was generated by Surfer 8.0 with the ISD interpolator which served as visual support to assess interpolations performed by the ANN.

4.1 Step 1

For the first tests the software Matlab 5.0 was used, with 4,096 training samples from a total of 16,384 data. The ANN architecture consisted of four layers, the first being the input layer, the first hidden layer containing 150-180 neurons, the second hidden layer containing 50-60 neurons and finally the output layer containing just one neuron. The tolerance of mean square error was set to 0.8 and as activation function the Purelin one was used. In the rate of learning a value of 0.3 was inserted and set a total of 50,000 interactions. However, these tests did not yield an expected result because the target mean square error was never reached. Table 1 shows the architecture of the first tests conducted.

Table 1: Step 1 tests conducted to define the optimized ANN architecture.

Tests	MatLab Version	N° of Samples	Neurons per layer	Transfer function	Learning rate	Mean square error (0.8)
1	5.0	4,096	180; 60; 1	Purelin	0.3	7.5
2	5.0	4,096	150; 50; 1	Purelin	0.3	6.4

Table 2: Improved tests conducted to define the optimized ANN architecture.

Tests	MatLab version	N° of samples	Neurons per layer	Transfer function	Learning rate	Momentum	Mean square error (0.08)
1	6.5	4,096	120; 40; 1	Logsig	0.8	0.2	0.79
2	6.5	4,096	90; 30; 1	Logsig	0.8	0.2	0.53
3	6.5	4,096	60; 20; 1	Logsig	0.8	0.2	0.079

Table 3: Tests conducted within step 3 to define the optimized ANN architecture.

Tests	MatLab Version	N° of Samples	Neurons per Layer	Transfer Function	Learning Rate	Momentum	Mean Square Error (0.003)
1	7.0	4,096	80; 25, 1	Logsig	0.8	0.2	0.02
2	7.0	4,096	80; 30; 1	Logsig	0.5	0.5	0.00018
3	7.0	2,370	60; 20; 1	Logsig	0.5	0.6	0.05
4	7.0	1,024	36; 12; 1	Logsig	0.6	0.2	0.0008
5	7.0	2,048	27; 9; 1	Logsig	0.6	0.4	0.00029

4.2 Step 2

The following tests were performed using the software Matlab 6.5. The number of neurons per layers was reduced and the Purelin function was replaced by the Logsig one. And yet, that the target error was achieved, the mean square error (target) was also reduced to 0.08, notwithstanding the results generated by the interpolation were still visually unsatisfactory, in comparison to the base-interpolator ISD. Other parameters that were altered to fit the ANN better, were the learning rate and the inclusion of the time term. The initial value supplied to the program Matlab was 0.3 as learning rate, illustrated in Table 1. The value of the learning was increased to 0.8 and the term Momentum was inserted with a value of 0.2. Table 2 shows how the ANN architecture was optimized in order to obtain an acceptable mean square error.

4.3 Step 3

Tests of step three were the ones that presented the greatest change related to ANN parameters. The Matlab software version 7.0 was used. The number of neurons per layer and the number of hidden layers were altered in some tests, the neurons increased from 2 to 80 and hidden layers from 2 to 3, yielding different results as shown in Table 3. The learning rate was varied between 0.5 and 0.8. The momentum values varied from 0.2 to 0.6. Also, the number of samples (1,024-4,096) was modified. The mean square error was reduced (range: 0.002-0.005).

5. Results and discussion

Analysing the interpolation results is noteworthy that the number of training samples is crucial for generating accurate results. The method proposed in this investigation only aimed for collecting training samples proportionally to the input data. Although this training samples were randomly collected, the exact location corresponding to a collection point in the area is unknown, therefore, "nuances" of the land relief cannot be represented. Thus, the points collected cannot be the best places that significantly represent all the altimetry characteristics of the region. So, to achieve acceptable results, 4,096 samples were used, from a total of 16,384 field data, because this was the sample with the largest number of coordinates used in ANN processing.

Initially, the activation function used was the Purelin function step (Matlab), but as the target mean square error could not be achieved. Therefore, it was replaced by the sigmoid logistic activation function (Logsig, Matlab) through which the target mean square error could be achieved. The final output presented by the network was still not visually satisfactory. Therefore, other parameters of the ANN architecture were modified.

Firstly, the mean square error had to be reduced with respect to the visual analysis of the results. This parameter determines the amount of time the ANN has to "learn". If the ANN reaches the root mean square target too fast, it may indicate that the ANN had too little time for training ("learning") and consequently the results generated may not be the desired ones.

The layers initially used consisted of one input layer, two hidden layers, and one output layer containing respectively a total of 180, 90, and 1 neuron(s). Based on the visual analysis of the results, already interpolated and obtained by the ANN, the quantity of neurons of the hidden layers was gradually reduced, acknowledging that the number of neurons is another decisive driver for the ANN learning time. Subsequently, the term Momentum was inserted to best adjust the variation of the neurons' weights in the layers, and as much as other parameters, both the term Momentum and the learning rate were presenting their values altered according to the visual analysis of results.

Finally, tests were conducted inserting one additional hidden layer, and failing to fulfil the Hilton rule. The layers consisted respectively of 2, 80, and 30 neurons and therefore the ANN demanded a larger number of iterations for training and processing. This number varied between 30,000 and 45,000 iterations while for previous tests about 18,000 iterations were needed. The visual analysis of this result showed a significant improvement in various parts of the DTM. Based on this result, all parameters of the ANN were improved again in order to enable more training time. The number of layers was set to four: one input layer, two hidden layers, and one output layer. The number of neurons per layer was reduced once again. The learning rate had its value increased while the term Momentum had its value reduced (see Table 3).

The visual analysis of results, after the above mentioned changes, presented a very good result. Comparing the DTM generated by Surfer 8.0 ISD interpolator with original data (Figure 5) and DTM generated in the software Surfer with data obtained from the ANN output (Figure 6), the similitude can be noticed.

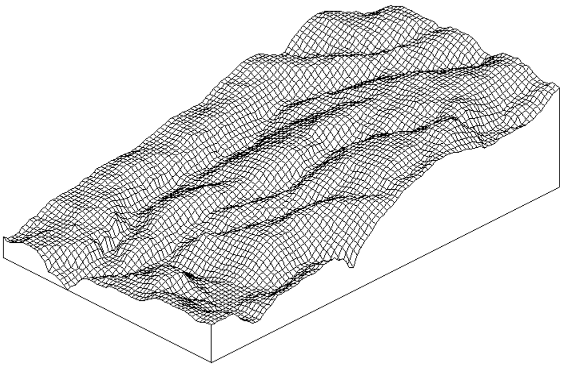

Figure 5: DTM generated from ISD interpolator of Surfer 8.0 software comparison with original data.

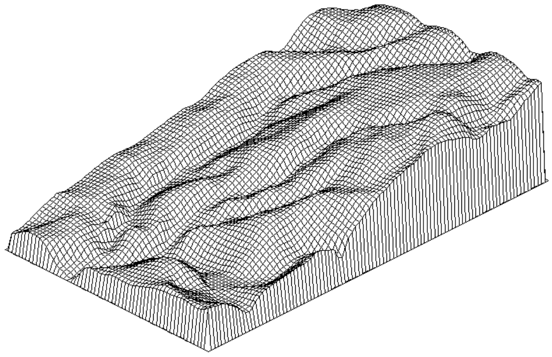

Figure 6: DTM generated with the software Surfer based on ANN derived result.

6. Conclusions

With the code developed within this research, it is concluded that it is possible to obtain a DTM through ANN interpolation of contour lines data, in the study area in Paraná State, municipality of Tibagi in south of Brazil.

During the code development and the implementation of experiments, it was found that the best interpolation results were generated with 2,048 and 4,096 training samples. This amount of samples is compatible to specific parameters of the ANN architecture. For 2,048 training samples the architecture was defined as containing two hidden layers, with the first layer containing 27 neurons and the second containing 9 neurons; the value of the target mean square error set for 2,048 training samples was 0.0003, with the term Momentum 0.4, and a learning rate of 0.6. For 4,096 training samples the defined architecture contained two hidden layers, first layer containing 36 neurons and second containing 12 neurons, the value of the target mean square error set for 4,096 training samples was chosen to 0.00015, with the term Momentum as 0.3 and a learning rate of 0.5.

An interesting feature of the ANN architecture realised within this study is that the number of neurons per layer is inversely proportional to the target value of mean square error. The larger the number of neurons per layer, according to Hilton’s rule, the lower the target value of the mean square error should be. This is due to: More neurons per layer make the ANN tend to train faster, while the lower the values of the root mean square target the longer the training time of the ANN.

Another characteristic observed within this study is in relation to overtraining or over-adjustment. When the same code was repeatedly implemented several times or made many alterations in the

ANN parameters was done, the code showed certain difficulty in reaching the mean square error target. So, the command "Clear All" was used in Matlab 7.0, the command clears the program memory discarding all previous learning, thus increasing approximately in 70% the probability of the code to achieve the mean square error target.

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Noise reduction for range imaging devices

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Abstract: Within this paper, options for reducing noise in range images obtained with the PMD[vision]®CamCube 2.0 are discussed. This range imaging device allows capturing the range by utilizing the time-of-flight principle. One of the advantages of such cameras is that it provides range information of a large number of points, its pixels, at the same time. The data quality is strongly affected by the integration time. The obtained images, depending on the integration time, may be strongly affected by noise. In the paper, two options for noise reduction are discussed: spatial and temporal filtering. Experiments with low-pass and median filters are performed to reduce noise in the spatial domain. Further, a temporal mean value is computed by the average of a series of images taken from the same point of view.

1. Introduction

Technologies aimed to obtaining spatial information of objects without directly contacting the objects are very frequently used in Geodesy, Architecture, Engineering, and Surveying. The most well-known one is the stereo photogrammetry. Recently, new instruments have been developed, such as laser scanner or ranging cameras (e.g., PMD[vision]®CamCube 2.0) that use special sensors based on the CMOS technology. Ranging cameras are able to generate two kinds of images simultaneous: one is an intensity image and the other is an image where each pixel stores the distance between the sensor and the visible objects. The sensor used in CamCube 2.0 is a CMOS CHIP, specially developed by PMD Technologies.

Because ranging cameras are active sensors, they use an illumination source to measure the distance. The resulting data can be strongly affected by noise, lack of illumination or over-saturation of the sensor. Therefore, it is necessary to determine the optimal setting for a survey, considering the characteristics of the objects, the distance, and the external illumination. The presence of noise can also be reduced in a pre-processing step.

By the end of 2008 within the framework of PROBRAL, it became possible to develop a joint research between the Federal University of Paraná and the Karlsruhe Institute of Technology with a range camera. It was the first contact of the Brazilian side with such equipment. The initial work proved again the synergy between both institutions, proving that there are more common aims that can be achieved by joint research. This paper describes the first experiments aimed at studying errors of range images and techniques to reduce them. Therefore, two aspects are considered: spatial and temporal filtering as well as multipath effects.

2. Range cameras

Range cameras capture data by utilizing the time of flight principle. The advantage of these cameras is that they use the complete surface of a CMOS as measuring element and are able to register a large set of points at the same time. The camera uses an electromagnetic source to project light on the scene. The PMD sensor computes the distance to objects by measuring the phase shift (φ) of the reflected signal to the phase of the emitted signal, which depends on the modulation frequency (f_m) and allows computing the range:

$$dt = \varphi / (2\ p\ f_m) \quad (1)$$

$$R = (c\ \varphi) / (4\ \pi\ f_m) \quad (2)$$

3. Error sources

Systematic errors follow a pattern that can be modelled and corrected, while random errors cannot be predicted. Some systematic errors are expected in the measurements using a range camera device and can be predicted like, for example, the inhomogeneous scene illumination. Four systematic errors of a PMD camera are described by RAPP (2007):

- Errors due to the inharmonic correlation function,
- Noise caused by the integration time,
- Spatial shift of the pixels, and
- Errors caused for insufficient exposition.

The first error (correlation function) can be caused by the movement of the camera or the object. When incoming signals do not follow the expected sinus pattern, the estimated distance can be lower than the real one. This error, for instance, can be modelled during the calibration step.

The variation of the integration time can lead to noise in the images. A very low integration time causes under exposition and therefore noise caused by the background illumination is noticed. On the other hand, if the integration time is too large the surface reflects too much energy, saturating the sensor and producing a random noise, too. The best option to reduce the noise is to choose the optimal integration time for each distance and surface, which may be difficult in some scenes.

Pixel displacement caused by the optical system of the camera is also expected. When a flat surface is measured, the points appear not coplanar on the recorded data. The distortion can be modelled if the interior orientation parameters of the sensor are known.

The illumination conditions cause errors that are not systematic, but can be reduced by appropriate setting of the camera. As RAPP (2007) describes, it is possible to experimentally determine the best illumination conditions for a survey, reducing the illumination problems. The integration time influences the amount of electromagnetic radiation that falls on the surface and returns to the sensor. Therefore, the illumination conditions can be previously chosen to avoid too low illumination or sensor saturation that causes errors.

4. Methodology

When noise is present in a dataset, it becomes necessary to reduce it by applying image processing tools. This should be done before the object recognition step, in order to better describe the visible objects using the range data. KHONGSAB (2009) shows a solution for this problem that can be described as follows:

- Reduce saturated pixels by choosing the appropriated integration time.
- Apply a median filter to reduce noise in the 2D range matrix.

- Reduce the pixels affected by low exposure, which may occur especially if they lie far from the sensor. In case of reduced integration time, the pixels do not receive enough electromagnetic energy. This effect can be minimized within pre-processing, by setting limits on the values of extended reflected signals.
- Reduce the mixed pixels and those caused by the multipath effect.
- Transform the dataset to an orthogonal system.

The presented research is using the ranging camera to survey small objects from a short distance; therefore, the experiments are focussing on a distance between sensor and surfaces of about 2-3 m. This range lies within the usable range of the camera and is enough to obtain a detailed description of the objects. For the experiments a PMD[vision]®CamCube 2.0 was utilized to capture data of a flat surface (wall).

4.1 Integration time

Experiments varying the integration time for different ranges were performed and the results are described in CENTENO AND JUTZI (2010). Figure 1 shows the range variation using the standard deviation of range measurements for a flat surface as a function of the integration time for three different ranges: 108, 215, and 310 cm.

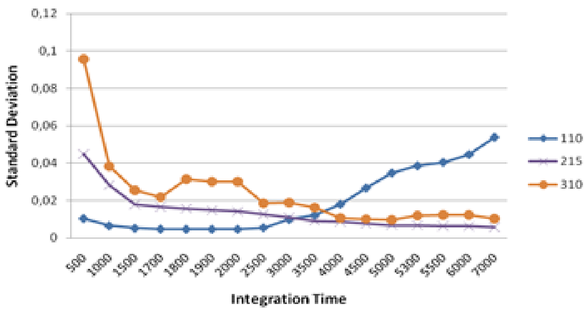

Figure 1: Standard deviation (cm) of the range for different integration times and distances.

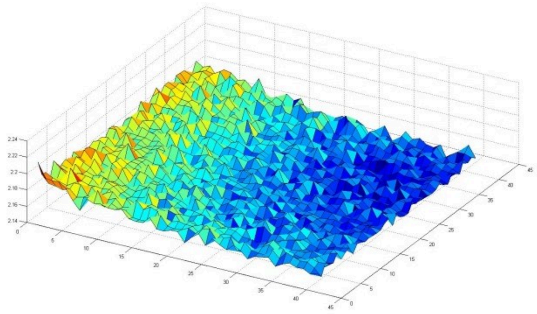

Figure 2: Original dataset with integration time of 5000µs at the centre of the image (45x45 windows).

Figure 1 shows that for short ranges the standard deviation is low for lower integration times and grows as the integration time is increased due to saturation effects. On the other hand, if the integration time is too large, then the noise is higher for short ranges (saturation), decreasing as the range grows. For a distance near 200 cm a suitable solution can be achieved using integration time above 4000 µs.

4.2 Noise reduction

As explained by KHONGSAB (2009), spatial filtering is a solution to reduce noise. In order to evaluate the effect of different spatial filters, experiments were performed using data of a flat surface, a white wall, using images taken from different distances. Two options were considered, low-pass filter and median filter.

A third option was also evaluated. If a series of images is available, then it becomes possible to compute the mean of each pixel along time. If the noise is random, then it is expected that the temporal mean is not affected by noise. A set of five images was used to prove this hypothesis. Of course, this option serves only when dealing with static scenes.

A detailed analysis of the effect of the filters and the temporal mean was performed using a small 45x45 window at the centre of the image. The standard deviation for regions of varying size was computed. Figure 2 shows the central region as a 3D plot in the original image captured with an integration time of 5000 µs. Figure 3 displays the resulting surface after spatial filtering, while Figure 4 displays the result of the temporal mean computation for each pixel.

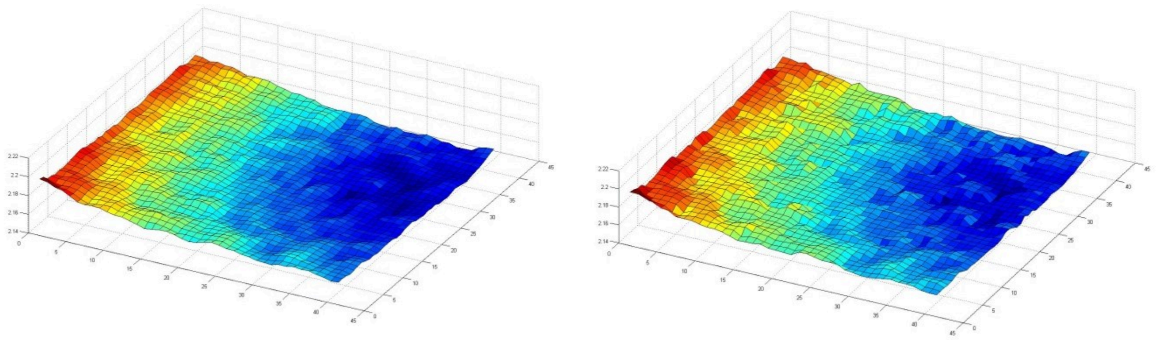

Figure 3: Low-pass (left) and median filter (right) with integration time of 5000 µs at the centre of the image.

Table 1 summarizes the standard deviation of each resulting image for regions of different size: 10x10, 20x20, 30x30, and 40x40 pixels. The same data can be seen on Figure 4. The three methods were able to reduce the standard deviation, the texture, on the surface. Nevertheless, the effect varies. The spatial filters produced more homogeny surfaces than the temporal mean. The reduction of the standard deviation of the temporal mean is always lower than the others for all window sizes (Figure 5). The difference between the methods is lower for larger windows, which was expected because as the window size increases, the borders of the image, with different illumination conditions, are included and introduce more noise.

Table 1: Standard deviations of images.

Standard deviation (mm)				
Window size	Original image	Median filter	Low-pass filter	Temporal mean
10 x 10	5,2	3,0	2,6	4,0
20 x 20	6,8	5,1	5,0	5,7
30 x 30	9,0	7,6	7,6	8,1
40 x 40	10,7	9,6	9,6	10,1

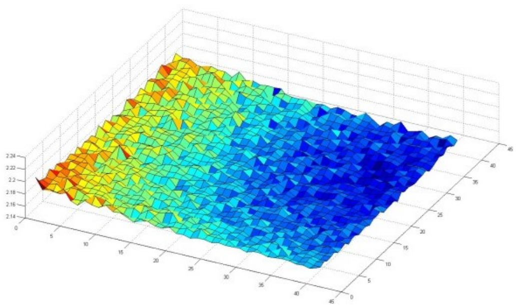

Figure 4: Temporal mean of five images with integration time of 5000 µs at the centre of the image.

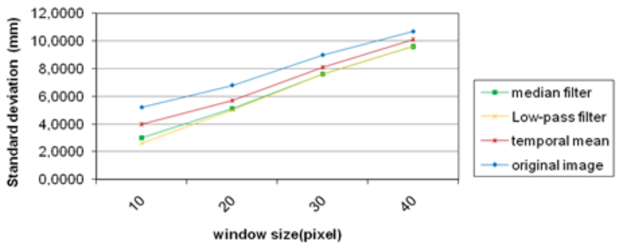

Figure 5: Comparison of the standard deviation for different window sizes.

5. Conclusions

This initial study and its results show some limitations of ranging imaging sensors that may reduce its application potential if not managed correctly. First, it was seen that the accuracy of the dataset depends on the integration time and range. For ranges close to 2 m the best results can be achieved using an integration time above 5000 µs. The problem will rise if the measured objects lie at different ranges. For instance, if part of an object lies about 1 m far from the sensor, then the integration time that is better for 2 m will cause saturation of the sensor and noise. This noise can be reduced in the pre-processing step, applying spatial or temporal filtering.

In order to reduce the noisy appearance of the captured data, the best option is the use of spatial filters. The low-pass filter and the median filter produce almost the same effect. The only reason to prefer one of them would be the processing effort needed. The temporal mean was not as effective as expected. The low performance can be explained by the small number of images used to compute the mean. Nevertheless, increasing the number of images reduces the potential use of such approaches, because it limits the use of ranging cameras to static scenes.

The result of this cooperation also shows the potential to develop joint research, although the institutions lie far from each other. The exchange of ideas and data, coupled with the current communication facilities, enable the development of research that contributes to both universities. For instance, data captured during a PROBRAL visit in Karlsruhe are being used to develop a Master thesis in Curitiba. This work is part of a basis for future cooperation.

Acknowledgements

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Shoreline Positioning Tendency

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Monitoring and management of coastal shorelines is very important but still remains a difficult task (LI ET AL., 2001). The shoreline variability is crucial for daily operations undertaken by coastal scientists, engineers, and public managers (BOAK AND TURNER, 2005). Here, information concerning the position of the shoreline in the past and in the present is needed in order to predict future shoreline characteristics.

The uncontrolled settlement as well as the natural dynamics of coastal areas can affect and cause coastal erosion which is defined as the loss of land, the removal of beach, or dune sediments by wave action, tidal currents, wave currents, or drainage. These processes are the reason for variable shoreline positions (PILKEY AND THIELER, 1992; SOUZA, 2009).

At first, it is necessary to provide a functional definition of the shoreline, which is not an easy task. Afterwards, a sufficiently robust technique is needed (BOAK AND TURNER, 2005). This technique should be able to detect and extract the chosen shoreline feature within the available data base. As an example, the shoreline indicators used within this case study are presented:

- seaward stable dune vegetation line,
- landward edge of shore protection structure, and
- erosion scarp.

In addition to the coastal shoreline extraction, a shoreline change mapping system has to be established. This system unifies the position information from various data sources. A database that contains a shoreline movement must refer to the same reference frame, with a defined degree of accuracy.

The historical information used for a short-term analysis is always dependent on uncertainties associated with the data collection strategy. Even experienced scientists have problems to identify the correct position of the shoreline. Therefore, the outcome of inherent subjectivity is that the spatial error in determining historic shoreline positions may exceed the predicted rate of shoreline change (CROWELL ET AL., 1997; DOUGLAS ET AL., 1998).

The quality of the historic shoreline data varies with respect to the region under research. The main difficulty in Brazil, is to obtain historical information about surveys and mapping. In order to overcome this remedy, the Spatial Geodesy Laboratory (LAGE) at Federal University of Paraná (UFPR) collects precise and accurate data of the Paraná state coast using GPS since 1996. The data consist of digital cartographic documents and reports related to the specific survey.

With the proposal to study shoreline dynamics at Paraná coast it became necessary to find cartographic information. Based on an intensive research, material from analogue photogrammetry was found. These data, related to the years 1954, 1963, 1980, 1991, and 1997, were used for shoreline extraction in a 6 km section in the area of Matinhos beach.

Combining these photogrammetric data with GPS data of observations campaigns of the years 2001, 2002, 2005, and 2008 (as control), the here described study aims for the comparison and assessment between three different models of shoreline bidimensional positioning tendency

- robust parameter estimation,
- neural network, and
- linear regression.

Tests focussing on the changing of the weight matrix for the case of linear regression and robust estimation were done. Different promising tests based on neural network were carried out. Important setting parameters are

- architecture (Elman and feedforward backpropagation network),
- number of neurons in hidden layers, and
- training algorithm.

With the information acquired and organized it was possible to test promising shoreline tendency models. The observed data for the year 2008 were removed from the model and used for a comparison with the predicted data for same year.

The gained results highlight the importance of the tendency model choice for predicting the shoreline positions and the applicability in this specific case study. Details of the here described work can be found in GONÇALVES (2010).

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Interkulturelle Kompetenz

Intercultural Competence

Competência Intercultural

Brazilian impressions gained during the ProBrAl project at the Geodetic Institute of the University of Karlsruhe (Germany)

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Abstract: The PROBRAL – Cooperation Program Brazil-Germany – is an institutional program that enables doctoral students to accomplish their theoretical and practical activities in a German university. The Geodetic Institute Karlsruhe (GIK) of the Karlsruhe University (TH) hosted since 2004 several doctoral students, especially from the Federal University of Paraná, Curitiba, Brazil. This paper highlights some technical contents as well as the sights of three doctoral students that lived this period in Germany. Beyond technical aspects, opportunities to improve linguistics skills and cultural instructions were deeply relevant. This report is composed by an introduction, research lines, communication in scientific papers and events, acknowledgments and references.

1. Introduction

Germany stands as an actual and modern educational center in the world. Brazilian scholarships have the opportunity to live in Germany for certain time in order to acquire scientific instructions that will help them to complete the doctoral researches in their original country. The gain is not only in the technical field but also social and cultural.

Before moving to Germany, students[1] have to poor their ability of being able to understand and speak the German language. Therefore, some classes (4 levels) on Goethe-Institut Curitiba have to be visited. In addition, there is the opportunity to keep studying on an intensive course at "The Center of Language of the Karlsruhe University". Inside the university foreigner students can communicate in English and also take disciplines given in English or German.

The first formal presentation and discussion about the research where done during the program on the Mitarbeiterseminar framework, where students and researchers are informed about different projects of the institute. This was a good opportunity to show what was made, plan the schedule of the research project, show the viability and directions for the development of the thesis and also get some feedback of the researches.

Germany offers great facilities to travel inside the country and vicinities. Every city appears to be well connected with a good and fast transportation access by railroad or freeways. Go to other cities in the north of the country for eventual technical visits for example as already happened where we needed to go to an Institute in Hamburg and another company in Hannover and that was easy to go by fast train (ICE) buying tickets in the moment of the boarding and with a cheapest price buying in advance.

Concerning transportation it is good to know, if you plan to always use the train for example, you can pay some amount to get a discount card in every ticket with 25% or 50% valid for one year. So it is important to plan the viability of this kind of promotion. Travelling by group on weekends also has some advantages, taking regional trains. All details of promotional tickets can be easily access in any machine terminals of the main stations or by the internet. Another way to travel around Germany is getting a ride (German: Mitfahrgelegenheit), it is an alternative choice where people put onto a web site the viability to give a ride and normally cost less than take a train.

The Geodetic Institute and the partner institute (Institute for Remote Sensing and Photogrammetry) has the tradition to make a Christmas party in the end of the year and one headlight point is that they have a choir group to sing traditional songs rearranged by people that work in the institute. Students have the opportunity to take part of this choir during the stay in Karlsruhe. Once per week, two months before Christmas, they could meet to practice for the main presentation in the party (figure 1).

Figure 1: Christmas choir (2009).

The daily life in campus is enjoyable. There is a library that works 24 hours per day during all year. The food court (German: Mensa) offers many options of menus, is very practical and has good prices for students.

The weather during winter semester is a little bit different from Brazil that are not used to see snow for example, but it is quite easy to get used, all the places are prepared to cold temperatures. Figure 2 shows some members of PROBRAL during one relaxing visit and recreation to find a geocache near Karlsruhe (Kloster Maulbronn) in the winter.

In the winter of 2008, the International Office (Akademische Auslandsamt - AAA) of the Karlsruhe University organized an excursion to Speyer, South of Germany, where doctoral or post doctoral students were invited (figure 3). They learned about the Speyer's history and visited the city, its Cathedral and the Technik Museum.

Figure 2: From left to right Andreas Knöpfler, Dr. Michael Mayer, Rodrigo Mikosz, and Dr[a]. Cláudia Krueger

Figure 3: Excursion to the city of Speyer (Germany) organized by the International Office of Karlsruhe University, February 2008.

Several technical visits to scientific laboratories in Germany were proposed[2]. For example, the Fundamental Station Wettzell with its space techniques such as SLR/LLR, VLBI, GNSS and PRARE and with its facilities for local measurements such as a gravity meter, seismometer, water vapor radiometer and its time and frequency system. The contact with GNSS antenna calibration systems as well as with their developers in Germany was critical to steep oneself in theory and practice, also to perform further measurements in Brazil.

The next section gives emphases on participation in events and scientific production during the period in GIK.

2. Research lines

The authors of this paper have experienced different research lines during their time at GIK. A brief outline of each research line is presented.

Contributor: Rodrigo Mikosz Golcalves
Research: Study of the consequences for models applied to shoreline position prediction
Period: October 2008 to September 2009.
Abstract: The main subject of the Ph.D. thesis was related with the consequences using different models to shoreline position prediction. The shoreline variability is crucial for daily operations undertaken by coastal scientists, engineers, and managers who require information on the position of the shoreline in the past, present and possibly where it will move in the future. This topic is very interesting and innovative area of geodetic research applied for coastal environments.

Contributor: Jaime Freiberger Junior
Research: Investigations of relative GNSS antenna calibration
Abstract: The relative GNSS antenna calibration method was investigated in the Geodetic Institute Karlsruhe (GIK) to be introduced in Brazil. Several geodetic measurements were carried out with different antenna models. Phase center corrections (PCO and PCV) were estimated using specific programs. Multipath effect was investigated considering different antenna heights, adapters and pillars. Studies concerning the signal to noise ratio (SNR) were also carried out to evaluate the quality of GPS data. In Brazil, two pillars were built according to geodetic guidelines on the roof top of the astronomical observatory of the Federal University of Paraná to compose the first GNSS antenna calibration base in this country.

Contributor: Mauricio Ihlenfeldt Sejas
Research: Ionospheric modeling using local GPS networks
Period: August 2007 to July 2008.
Abstract: The goal of this study was to propose a local ionosphere model that uses a set of double-frequency GPS receivers for generating ionospheric corrections. These corrections allow single frequency receivers, located at the neighborhood of the network to correct their raw observations from the ionospheric delay. The proposed model was tested in single point positioning, where only code observations were used for data processing. Experiments were carried out using data collected in regions with different ionospheric conditions: in mid latitudes and equatorial regions. A set of IGS and RBMC stations were chosen for experiments and the data were obtained from a period of low solar activity. The results show that the model could remove a significant part of the ionospheric refraction for these experiments.

3. Participation in events

Participations in events were very productive to the development of the work during the doctor research at GIK. Living in Germany provided us the opportunity to participate of some important conferences in Europe like:

- ICS - 10rd International Coastal Symposium, April 13-8, 2009 - Lisboa, Portugal ([1]).
- 33rd International Symposium on Remote Sensing of Environment (ISRSE) May 4-8, Stresa, Italy, 2009 ([1]).
- Geodätische Woche 2009, September, 22-24. 2009, Messe, Karlsruhe ([1]).
- Geodätische Woche 2004, Stuttgart, 12.-15.10.2004 ([2]).
- Geodätische Woche 2005, Düsseldorf, 04.-06.10.2005 ([2]).

These conferences helped to improve technical's contents of the thesis. Also new ideas were formulated and contacts were made with several research institutes in Europe. In contrast of Brazil one advantage to live in Europe is the minor distance between important cities. These facts contribute significantly for the accomplishment of the researches.

4. Conclusion

Getting contact with different cultures bring important benefits that make people mature not only in technical aspects but also in science, social and cultural aspects. Commonly, Brazilians that took part in this program miss Germany.

Acknowledgements

The authors acknowledge the financial support of CAPES/DAAD, throughout the PROBRAL Program. We would also like to thank the Geodetic Institute of University Karlsruhe (TH), especially the working group of Professor Bernhard Heck's chair for "Physical and Satellite Geodesy".

Brazilian experiences – An insight into German perceptions

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In remembrance of JAIR SILVEIRA DA SILVA JR. †

Kooperation – Cooperação

“PROBRAL: Precise positioning and height determination by means of GPS: Modelling of errors and transformation into physical heights” is the name of a joint venture between the Department of Geomatics (DGEOM) of the Federal University of Paraná (UFPR), Curitiba (Brazil) and the Geodetic Institute (GIK) of the Karlsruhe University (TH), Karlsruhe (Germany) resp. Karlsruhe Institute of Technology (KIT), which was founded by a merger of Forschungszentrum Karlsruhe and Karlsruhe University (TH) in October 2009.

This research project started in 2006 and is funded by the Brazilian Academic Exchange Service CAPES and the German Academic Exchange Service DAAD. The aim of the PROBRAL project is the validation and improvement of the quality of GNSS-based point positioning. The main focus is on the height component.

In order to fulfil this goal the close and more than ten years lasting cooperation between the DGEOM and the GIK was intensified. In the forefront of this project, several Brazilian and German students exercised exchange options and attended the university of the cooperation partner. Beside this fruitful and fascinating exchange, some researchers visited the cooperating institutes in order to give courses or to coordinate future plans. Within the PROBRAL project an exchange of institute members is established on a regular basis for the first time.

Bemerkung der Autoren – Nota dos autores

This paper is focused on the gathered experiences of the authors during their trip to Brazil started in September 2006. The experiences described within this paper are mainly non-technical. The progress in the field of satellite-based precise point positioning using GPS (Global Positioning System) gained in the framework of this international project will be summarised and discussed elsewhere.

DAAD-Philosophie – A filosofia do DAAD

The DAAD supports and promotes all areas relating to science, research, language, teaching and very much more (DAAD 2007). The five main goals of the DAAD are shortly summarised in the following:

- Promotion of young foreign elites as a means of gaining future leaders in education, science, research and culture, in business and industry, in politics and in the media as partners and friends of Germany.

- Promotion of young German elites in order to qualify them as open-minded future leading figures in education, science and research, in culture, in business and industry, in politics, and in the media in the spirit of international and intercultural experience.
- Promotion of the internationality and appeal of Germany's universities to ensure that Germany remains a leading address for young academics and researchers from all around the world.
- Promotion of German studies, the German language, literature and area studies at selected universities around the world in order to strengthen German as a major international cultural language and lingua franca and to advance interest in, knowledge of and understanding for Germany.
- Promotion of academic and scientific advancement in developing countries and in the transformation countries of Central and Eastern Europe as a means of supporting the economic and democratic reform process there.

Forschung – Pesquisa

The two main research goals of our visit at the DGEOM were

- progress of establishing the First Baseline Calibration Station for GNSS Antennas (1a. BCALBR) on the Polytechnic Campus and
- informing of our Brazilian cooperation partners about the recent GNSS-related research activities of the GIK.

Therefore, e.g., four oral presentations KNÖPFLER (2006), MAYER (2006A), MAYER (2006B) and WILD-PFEIFFER (2006) were given. In addition, we helped two students of the GIK to organise and carry out various GPS measurements performed in the framework of their study works on the roof top of the Astronomical Laboratory Camil Gemael near the Laboratory of Space Geodesy (LAGE - Laboratório de Geodésia Espacial), see KRUEGER (2007) and SCHÄFER (2007) for scientific details and Figure 1 for an impression of the roof top of the Astronomical Laboratory Camil Gemael.

Figure 1: J. Freiberger Jr, M. Mayer, and A. Knöpfler (from left to right) on the roof top of the Astronomical Laboratory Camil Gemael.

Figure 2: Using „The Magic Red Carpet“ to reach another time zone.

This work was carried out in the field of satellite geodesy in order to transfer a receiver antenna calibration method developed and tested at the GIK (FREIBERGER JR. 2007, KNÖPFLER ET AL. 2007) to Curitiba and adjust this method – consisting of hard- and software components – to Brazilian conditions.

Motivation – Motivação

Apart from the scientific exchange and the experiences on excursions there are still a lot of important DAAD goals, especially, the exchange on the human and cultural side, see KNÖPFLER

AND MAYER (2007). Some experiences gained by the authors of this paper during their trip to Brazil will be presented in the following.

Umgang mit Zeit – Lidando com o tempo

The arrival with the plane "The Magic Red Carpet" in a country that has an exceptional flora and fauna was quite exciting. First of all we recognised that the clocks – apart from the actual clock changeovers – run somehow different (Figure 2). Everything is more calm and serene.

Freundlichkeit, Hilfsbereitschaft – Amabilidade, eficiência

During the entire stay the continuous friendliness and helpfulness of the Brazilians made our journey even more pleasant. A typical gesture of friendship is putting the thumb up, what means "Tudo bem!" or "You got it!". The German exchange researchers and exchange students adopted this gesture quickly. The picture shown in Figure 3 shows the German exchange student Pascal Knoch using this gesture while cleaning the roof top of the Astronomical Laboratory Camil Gemael near the Laboratory of Space Geodesy. Despite workload or stress, the Brazilians helped us always spontaneously. Especially, the members of the Department of Geomatics have to be mentioned, but also totally unknown people supported us with advice and action in some awkward situations. For instance: On a sunny Sunday morning we decided to visit the famous district Santa Felicidade in order to get an impression of the diversity of traditional Brazilian food and an insight into folcloric art. After entering an Italian style restaurant and sitting down at a table the waiter asked us something which we did not understand at all. A woman realised that and came by and translated the words for us.

Figure 3: Pascal Knoch showing the "Tudo bem!" – sign.

Figure 4: Having lunch together.

Engagement, Gastfreundschaft – Dedicação, hospitalidade

Various regional delicacies were presented to us, e.g. at lunchtime: During our stay in Curitiba we all visited a churrascaria for the first time. We heard about this kind of restaurant before, but it is very impressive to realise all the things which are happening in a churrascaria at the same time. In the first churrascaria we visited, we were just sitting on our chairs with open jaws, nearly unable to start eating. We looked at all the grilled meat served on a spit (Figure 5). Waiters were going from table to table, offering different spits. Furthermore there is always luxurious buffet with salad, vegetables, bread, pasta dishes etc., this is very comfortable for non-Brazilians, because you don't have to order your meal; you just pick the things you would like to eat. Normally, churrascerias are themed “All you can eat”, you pay a fixed price and you can eat as much as you like. The visit is always unique, maybe because there is large society.

But soon we got very familiar with churrascarias and enjoyed each meal very much. One churrascaria, which we would like to recommend, is called “Boi Dourado”, what means “Golden Ox” (Figure 7).

Another delicacy was presented by our college Jaime Freiberger Jr.: He offered us fresh sugar cane, cultivated by his father. None of us had eaten this kind of sweet fruit before. Due to the fact that sugar canes have strong fibres and are therefore very stringily, they are sweet and very delicious. On the left hand a picture of Jaime Freiberger Jr. preparing sugar cane is shown (Figure 6).

Sprache, Kultur – Língua, cultura

We had to experience the difference between the languages in a hard way: During a stay in a pub in the evening, “cha frango” has been ordered. A great astonishment and lack of comprehension was the result. After we recognised, that “tea of chicken” was ordered instead of “tea of strawberries”, the situation became less unpleasant. In such and other everyday situations it is advisable that the Kauderwelsch book of SCHRAGE (2001) is nearby. A highlight during our stay in Curitiba was the “leaf pipe man” on the weekly arts and crafts market. The man making music on the guitar and a leaf is a real unicum (Figure 8).

Figure 5: Churrascaria.

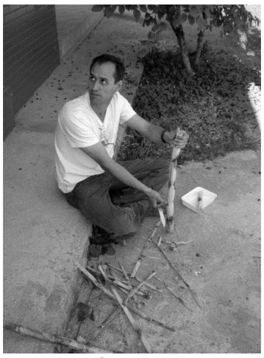

Figure 6: Sugar cane.

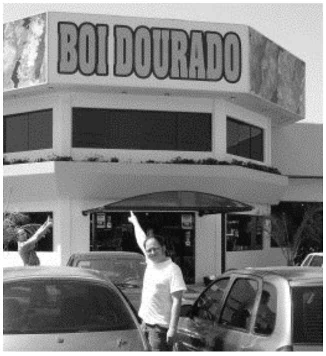

Figure 7: Boi Dourado.

Figure 8: Leaf pipe man.

Beobachtungen – Observações

In this section we would like to mention two topics which impressed us very much: The public transportation system and the ideal integration of nature into the cityscape.

Curitiba has – in our opinion – a simple but nevertheless very practical transportation system. The public transportation system consists entirely of buses. There are several types of buses, each with a different function. Especially the transfer from and to the city centre by bus is very comfortable and cheap as well. The key elements of the bus system of Curitiba are the so-called tube stations (Figure 9). Tubes are approx. 10 m long cylinders, which are used for waiting purposes as well as getting on/off sections. The passengers pay a fee when entering a tube for the first time of a bus ride and can use as many bus lines as they want, as long as they stay inside a tube.

Figure 9: Public transportation system, tubes.

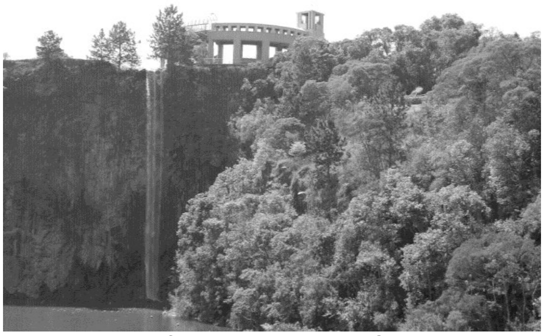
Figure 10: Beautiful parks surrounding Curitiba.

Curitiba is surrounded by various beautiful parks (Figure 10). Some of these parks are dedicated to the European immigrants. In combination with the park located near the city centre and several recreation areas these parks make Curitiba to a very eco-conscious and liveable city. In addition, the public is granted free access to most of these parks.

Welch ein Zufall – Que coincidência

In our hotel “Deville Express”, we met some other German people in a small elevator. When we were moving downwards in order to find a place to eat, a guy joined us and asked in Brazilian language “up or down”. We didn’t understand a single word and started a discussion in German. The guy realised that we are Germans and therefore new pickups were made. The hotel “Deville Express” cooperates with the University of Paraná and different groups of researchers are accommodated there. During this small talk started in the elevator and continued in the lobby of the hotel, we discovered that the guy was part of a group of biologists of the Research Institute of the Museum of Natural History situated also in Karlsruhe. They worked on the faunistic classification of secondary forest habitats by investigations on flora and fauna of test areas. As there was a big interest to get to know a complete different science, they invited our group to come along with them for several days to see their work and to get another impression of Brazil.

Expedition zu den Bananenplantagen – Expedição às plantações de banana

The trip to the test areas was done by a Volkswagen T2, a model which was built in Europe until 1979 but in Brazil until 2005 (Figure 11). There this car is still very common in daily use due to its very simple and easy to repair technology. On this trip, special properties of Brazilian motorways were shown, e.g. pedestrians crossing the lanes or – very dangerous in our opinion – motorway turning lanes to the left side.

The main aim of this trip was to build up special traps for spiders and insects. Therefore, suitable areas have been explored by the biologists in previous trips. These areas have all been situated in banana plantations. These traps consist of a plastic cup with a special fluid which are inserted in soil and covered by a plastic cap. After a period of one up to two weeks, the traps are taken out and the caught insects and spiders are counted and sorted. The number and kind of animals is a specific dimension for this area, which can be used for classification. Another method is to cut plants in the area of one square metre with a machete and to sieve them by using a special filter. By drying this mulch in special nets, the insects and spiders fall into boxes under the nets. With this method other kinds of animals can be found and counted for classification purposes, as well.

Figure 11: Journey impressions.

Figure 12: Banana farmers and German researchers.

Another way of catching spiders was practised in an earlier trip of these scientists. There the biologists entered the test areas at night and caught spiders and other insects which were sitting on the leaves and logs of the banana bushes. Among these spiders have been several exemplars of the sort "phoneutria nigriventer" which are very aggressive and very poisonous spiders ... research sometimes can be dangerous.

Beside the fauna of the test areas the flora was registered, too. The number of banana bushes has been counted and the different kinds of other bushes and trees were recorded. Also the size of the test area was calculated based on measuring tape observations. Furthermore, the absolute position of one point in the test area was determined by using a handheld GPS receiver.

In addition to the experience of a completely different science, the exploration of a completely unknown countryside and very friendly people was very impressive. During the trip many hospitable banana farmers have been visited, which offered fresh bananas, papayas or banana cakes (Figure 12). These fruits tasted completely different compared to the ones bought in German supermarkets. Another very impressive event was the observation of beautiful humming birds in the banana plantations. These fascinating animals could be heard before they can be seen, their noise sounds like the deep hum of a bumblebee.

Acknowledgement

We would like to thank DAAD (German Academic Exchange Service) for the financial support in the framework of the project PROBRAL "Precise positioning and height determination by means of GPS: Modelling of errors and transformation into physical heights". DAAD did give us – besides research – the possibility to receive an impression of an interesting, beauteous and friendly culture.

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Exchange semester in Brazil – A retrospective view

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Resumo: Esta retrospectiva conta a minha experiência vivida em Curitiba, e o que eu penso agora sobre o intercâmbio, quase cinco anos mais tarde. Minhas impressões descritas aqui resumem parte dos sete meses em que eu morei e estudei em Curitiba. Destaco minha motivação e exemplos de problemas com o idioma, aspectos do trabalho científico que desenvolvi e os levantamentos de campo, visitas a congressos e viagens.

Abstract: This retrospective article is about my experiences gained in Curitiba, Brazil and what I think about my exchange semester now, almost five years later. The impressions described here give a rough overview of all episodes of seven months living and studying in Curitiba. My motivations are described. The aspects language problem, scientific work, field measurement, visiting congresses, and travelling are exemplified.

1. Motivation – How benefiting from PROBRAL, without being part of PROBRAL

Studying in Brazil, this idea was born at an annual students' slide-show evening in Karlsruhe. Inspired by the presentations of students who talked about their experiences in surveying and studying abroad, the decision of studying in Curitiba was already made in my first semester. I was fascinated by the idea of learning new things, getting to know a foreign country with the people and their habits and customs. And I was encouraged by numerous exchange students from both sides. I knew, I had to learn Portuguese, so I took evening classes. When my time to go to Curitiba finally came, the UNIBRAL funding just ended and it seemed my dream came to an end, before it even started.

The DAAD Programs UNIBRAL (Integrierte Projekte der Hochschulzusammenarbeit Brasilien - Deutschland) and PROBRAL (Projektbezogener Wissenschaftleraustausch mit Brasilien) are the basis for many years of cooperation between the federal University of Paraná (UFPR) in Curitiba and the Karlsruhe University (TH). As a result of these programs, there were many exchanges of scientific and academic staff and students, see KNÖPFLER AND MAYER (2007). A contract between the two universities enabled the acceptance of lectures and grades from the exchange semester at the home university. Based on these arrangements, my exchange semester was possible, even without direct aid of the UNIBRAL and PROBRAL programme. But I benefited from PROBRAL, which allowed me to meet members of the UFPR in Karlsruhe to plan the semester in advance. My tutors could oversee my progress in my study work, while being on a PROBRAL stay in Curitiba.

2. Language

The language spoken in Brazil is Portuguese, but with a certain tune only the Brazilians have. I prepared myself before the exchange semester started taking two lecture courses of "Português do Brasil" at the Adult Education Centre (Volkshochschule) in Karlsruhe. But after I

Figure 1: The Centre of Languages and Cultures CELIN in the city centre of Curitiba.

arrived in Curitiba, I soon realized that the capability to speak and understand Portuguese was quite sobering. So the teacher of the following language course “Português para Estrangeiros – Nível Básico II” at the Language and Culture Centre (figure 1) of the UFPR played a very important role and helped in many ways. We, the participants, used the class room to question, discuss, and finally understand situations we struggled in the Curitiba city jungle. Friendships evolved in this classroom and the contacts still remain until today.

After all the efforts invested in learning a new language, it would be a shame, not using it. Whenever possible, I practice my Portuguese at the university and in private. Practicing, this was also the main reason, why I took two more courses back in Germany. All courses together resulted in a language certificate. But certificates are only on paper, more fun is to use the language and a very good opportunity for that is the Geodetic Colloquium held at the Karlsruhe University (TH). There are always some Brazilian Geodesists to talk with.

Some of the Brazilians, especially at the Laboratório de Geodésia Espacial (LAGE), speak German, which was a big relief at the beginning. After some months the usage of German by them was reduced more and more. I was even denied to speak English at one time, so my Portuguese was good enough then.

3. Scientific study work

A very important part of the stay abroad was the scientific study work, which consisted of practical parts, calculations, analysis and writing a study thesis. The Brazilian supervisor agreed on the research area before my stay and the topic was fine-tuned together with all German and Brazilian supervisors in Curitiba. My topic was embedded in the PROBRAL project *Precise positioning and height determination by means of GPS: Modeling of errors and transformation into physical heights,* see FREIBERGER JR. (2007), KRUEGER ET AL. (2007) and KRUEGER ET AL. (2009). The task was the evaluation of multipath effects of the new-build measurement pillars (figure 2) of the so-called 1^{a}BCALBR, the First Baseline Calibration Station for GNSS Antennas in Brazil, see SCHÄFER (2007).

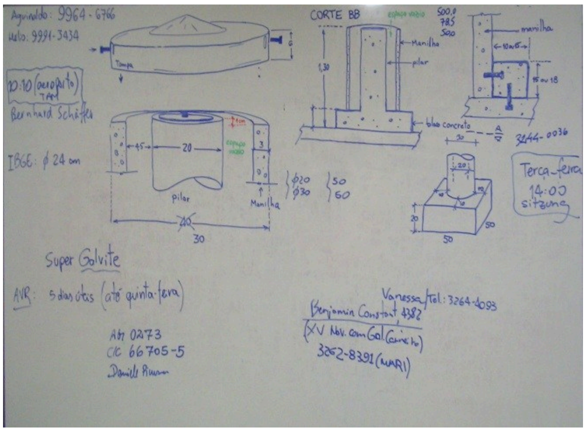

Figure 2: Whiteboard at LAGE with detailed plans for the pillars of the antenna calibration station.

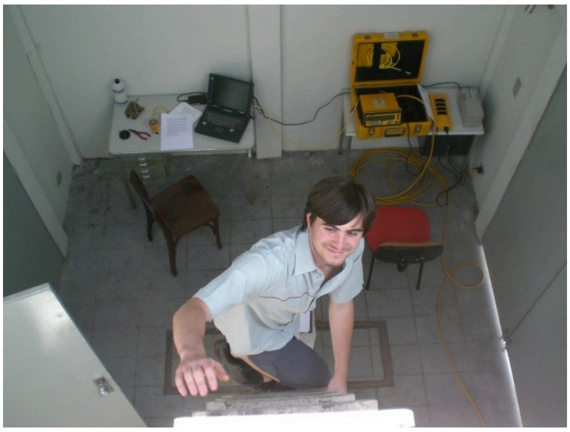

Figure 3: Climbing up to the measurement pillars.

In order to carry out the required measurements, all kind of soft had to be trained: asking for permissions to borrow or use equipment from other institutes and institutions, improvising a continuous power supply, handling with all kinds of constraints, and arranging temporal simultaneous GNSS sessions (figure 3). One data set was from a local surveyor (Digital Mapas), who had his own temporal constraints; however we managed the simultaneous sessions without ever meeting in person.

The data processing and analysis were performed at the LAGE (http://www.lage.ufpr.br), were I spend most of the time when I was at the UFPR campus. I enjoyed the atmosphere there and I also adapted the special lunch schedule. The location of the LAGE is perfect, not only for GNSS measurements, the proximity to the coffee bar on the campus and to the Churrascaria on the other side of the freeway are additional conveniences.

4. Field measurements at Rio Negro

The participation at a field campaign at Rio Negro was a remarkable highlight of my exchange semester. I am very glad and thankful, that I could join the team. Rio Negro is a small town at the border of the states Paraná and Santa Catarina, where the UFPR owns a fazenda within a mostly forested area. The objective of the measurement campaign was to estimate geodetic coordinates of the marked estate border. This was performed with a special GPS antenna mounting, which allowed setting up the antenna high above the dense foliage of the forest, see figure 4 and FREIBERGER JR. ET AL. (2006).

Figure 4: GPS measurement with extreme antenna height

The campaign in Rio Negro gave also interesting insight into the rich flora of Brazil. The forest at the fazenda was surprisingly dense and some paths to the marked points had to be created with ample usage of the machete. The paths became impassable due to the rain and the tripods sunk into the mud. At this point I agreed to the statement: “GPS cannot be used by rain.”

5. COBRAC

I also used the opportunity to visit a congress in Brazil, the „Congresso Brasileiro de Cadastro Técnico Multifinalitário“ in Florianópolis. For me this was the first time on an event like this and I struggled through the sessions, trying to understand some of the presentations given in Portuguese. So I concentrated on the social aspect of such events, which resulted in contacts and friendship.

6. Traveling

Staying seven months in Brazil, there was enough time to travel around in Brazil and some parts of South America. One of the trips carried me to the campus of the UFRRJ near Rio de Janeiro, where I visited some friends, which I just met at the COBRAC congress. Continuing North, I came as far as Salvador da Bahia. Other journeys included countless hours in buses to Buenos Aires, Asunción and Foz do Iguaçu. The famous waterfalls of Foz do Iguaçu are a must-have-seen and there are so close to Curitiba, only some hours by bus. For the visitors on a tight schedule (i.e. PROBRAL visitors from

Germany), I was glad to organize the mandatory train ride to Paranaguá with the optional weekend add-on to the honey island.

Acknowledgement

The exchange semester was a very pleasant experience for me, special thanks is due to the DVW e.V. for the financial aid. But it was all only possible, because the PROBRAL program was such a success. Therefore, I want to thank all persons who helped and supported me.

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Publikationen

Scientific Output

Publicações

PROBRAL Publications
Papers, Oral Presentations, Poster Presentations

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Within this contribution, a listing of the scientific papers, the oral presentations, as well as the poster presentations created during the PROBRAL cooperation between departments of the Federal University of Paraná (UFPR), Curitiba (Brazil) and the University Karlsruhe (TH), Karlsruhe (Germany) is given in order to document the great success of the cooperation. The enormous numbers of presentations given during a stay abroad are not taken into account.

The symbol is referring to publications where no German (co-)authors were involved. In addition, the symbol is used to highlight publications where no Brazilian (co-)authors were involved.

References without specification of pages (p.) indicate oral resp. poster presentations on conferences and workshops. References according to meetings (e.g., proceeding papers) indicate also an oral resp. poster presentation. These references are attributed to the year of publication. The related presentations are not taken into account within this listing in order to keep it short.

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Seminário: Natural disasters – Catastrophe management and prevention. Santiago do Chile, Chile.

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