

NEW ADVANCED GNSS and 3D SPATIAL TECHNIQUES

APPLICATIONS to CIVIL AND ENVIRONMENTAL ENGINEERING, GEOPHYSICS, ARCHEOLOGY and CULTURAL HERITAGE

in memory of Professor Giorgio Manzoni

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Abstracts



con il patrocinio del Comune di Trieste

Title	High Precision GNSS – prospects for science and applications
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Abstract	During last and coming years we are witnessing the immense qualitative progress in the GNSS domain. Two new technologies are under development offering considerable improvement of the accuracy of orbits: the on-board accelerometers and the inter satellite links. Because some non-gravitational forces can not be modeled with the desired precision, the direct measurements on the board of the satellite of those forces may improve the solutions for orbits, positions and timing. The range and range-rate measurements between satellites open the way to the elimination of the errors caused by the ionosphere and station uncertainties. The improvements in the board equipment like clocks and signal generators will provide enhanced radio signals while in the user segment the receivers of the new generation will be able to digest up to 50 signals received. Combined with the MEMS type inertial devices the user platforms will be able to provide the high accuracy positioning and timing even in the very hard conditions, including the high dynamic motion or covered environment. The question of the usefulness of the High Precision PNT is discussed for the scientific research. The following issues are taken into consideration: 1. More accurate, robust, and global ground site coordinate determination; 2. Real-time determination of neutral atmosphere water vapor content for input to weather prediction models; 3. Very accurate airborne gravimetry ; 4. Millimeter accuracy low-altitude satellite orbit determination using GNSS observables ; 5. Length-of-day and earth wobble monitoring at finer detail. In space the high precision PNT will be used for the fundamental physics research. Some relativistic effects could be identified and measured. One of them is the Earth gravity field torsion, that could be considered as a gravitational wave generated by the rotating Earth.

Title	Accuracy and Availability of the Real Time GNSS Geodetic Networks
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Abstract	In recent years, all over the world there has been a period of intensive development of GNSS measurement techniques and their extension for the purpose of their applications in the field of surveying and navigation. A team of academic researchers from the Gdańsk University of Technology, Gdynia Maritime University and the Polish Naval Academy have been working since 2009 on the methodology of using active GNSS geodetic networks for geodetic inventory of railways and on adapting this measurement technique for designing geometric layouts of railway and tram lines. Over the years, the team tested a variety of configurations of receivers and

	settings of active GNSS networks with the objective to upgrade the accuracy of defining position coordinates and the availability of accurate determinations. The applied optimization methods helped to increase the accuracy and availability of appointed positions in real-time measurement from 3 cm (drms) in 2009 to 6 mm (drms) in 2016, thus opening the possibility of simultaneous study of deformation of the rails. Availability of the precise position (2D, drms error < 1cm) increased from 56% to 88 %. The article presents a summary of several years of studies on the application of mobile satellite measurements in the field of designing and operation of railways. The problem of an accuracy and availability of satellite measurements has been discussed. It has been proved that the optimum solution, i.e., maximum accuracy of coordinates and availability from GNSS measurements during inventory of railroads - was obtained using GPS/GLONASS/BEUIDOU satellite geodetic network and INS system.
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Title	Geospatial Technology in Air Traffic Management - Validation of Real Time Airspace Status Information Exchange Process
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Abstract	Objectives and business models of airspace requirements are different for civil and military airspace users. Whereas civil aviation develops a trajectory with the most cost-efficient routing, military have mission objectives including the most mission effective routing and usage of the airspace. The Advanced Flexible Use of Airspace (AFUA) allows to achieve both mission effectiveness and flight efficiency, promoting a performance-oriented civil-military cooperation and providing more flexibility based on dynamic Airspace Management (ASM) procedures. Advanced ASM prototypes were developed within the Flexible Airspace Management project - funded under the Single European Sky Air Traffic Management Research (SESAR) Framework Programme - in order to support enhanced local and regional airspace planning processes. A live trial, focused on the automation of the pre-tactical and tactical civil-military airspace management coordination, was conducted in order to validate the Real Time Airspace Status (RTSA) information exchange process. RTSA information were encoded in AIXM 5.1 (Aeronautical Information Exchange Model), a GML-based (Geographical Mark-up Language) data exchange format, and shared among ASM, Air Traffic Control (ATC) and Air Traffic Flow and Capacity Management (ATFCM) systems, as well as civil/military Aircraft Operators Flight/Mission Planning tools, through the Eurocontrol NM B2B Web Services. The involvement of the Aircraft Operators in an early stage of the airspace information sharing process allowed Airlines Flight Operation Centres to promptly adapt the flight plans of a set of eligible flights in order to take advantage of an airspace extra capacity due to the early release of a restricted area previously booked for military operations, leading to enhanced of ASM/ATFCM collaborative decision making (CDM) process and an increase of 17% of the overall effectiveness of airspace usage. A post-operations analysis was conducted, highlighting positive environmental effects for civil aviation operations, in terms of Direct Operating Costs (-1,36%) and emissions (-1,79%).

Title	Space, time and maps
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Abstract	Concepts of space and time were always important for man, at various levels, for everyday life, for philosophy, science and religion. Astronomy, Philosophy, Mathematics, Physics, Geography and Cartography were most involved topics. Actually, shape and history of Universe, and specially of Earth, are related to the way of their representation: so, ideas about space and time have largely coped with surveying and mapping, from Geodesy to Geomatics. Greek people moves in the Mediterranean sea (Argonauts, Ulysses) and therefore acquires geographical data, which represents in maps, according to celestial and terrestrial measurements. Nevertheless, numbers, weights and measurements became much more important since Middle age, with the contributions of Indian, Persian and Arabic peoples Aristoteles says that a state of rest is the most favourable and the Earth does not move; on the contrary, in modern times, both Galilei and Newton are interested to the motion of bodies. In this context, majority supports geocentric configuration, but Aristarchus of Samos and Archimedes propos an innovative heliocentric configuration, like Copernicus in the Renaissance. As for time, Greeks see it as cyclical and absolute; on the contrary in modern times, time is linear and absolute (Newton). Quite opposite is Augustine of Hippo view: time is related to physical perception. Newton assumes that space is absolute in nature, some sort of void container of objects and facts, based on Euclidean geometry. Quite opposite is Leibnitz's view: space blows up from relationship between objects. Travels from Renaissance to XVIII century, stimulate production of maps, and related instruments: finding correct geographical coordinates is essential at high sea. Fixing latitude is comparatively easy, the problem of longitude requires a good timepiece. A map results from a plane design of Earth surface, keeping into account Cartesian reference system, as well as Euclidean geometry and Galilean physics. According to Kant's philosophical legitimation of Euclidean geometry and Newtonian physics, space and time are inner conditions of human which allow our perceptions: these will later be ordered by logical categories. The efforts to demonstrate the fifth postulate of Euclid (Saccheri, Legendre) resulted in the birth of non-Euclidean geometries. Hyperbolic geometry is due to Gauss, Bolyai and Lobačevskij; later, Riemann found spherical and elliptical geometry. Einstein, with his Theory of relativity, put geometry inside physics: space and time are not separated, but they are a complex structure, able to account for limit of light speed and for effects of gravity with the curvature of space-time. Cassirer incorporated the Reimann's geometry and the relativity theory (as well as going over, quantum physics, strings theory,...) into neo-kantian critical philosophy. After Wittgenstein, philosophy appeared for some people as aimed mainly to linguistic analysis: however, science and technology developments has given to philosophy new place, some concepts like space and time may become the object of a new philosophical thought. Geomatics, e.g. space geodesy, image analysis and GIS, deals with the concepts of space and time: for example, space-time integration, mapping starting from different cultural viewpoints about space and time, different scenario investigation, etc.

Title	GNSS data analysis at Politecnico di Milano for crustal deformation studies
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Abstract	Crustal deformation analysis in seismogenic areas is one of the most important applications of GNSS. In the last twenty years, the GNSS technology has opened new perspectives in this field allowing the estimation of the crustal deformation at different scales both in time and in space. It is now possible to estimate the tectonic deformation at regional level coupling it with studies at the fault scale. On the other hand, the entire seismic cycle can be studied thoroughly. Co-seismic and post-seismic deformations can be properly estimated. Furthermore, recent studies aim at analysing the inter-seismic phase giving important insights in the dynamic of the crust of seismic prone areas. These studies are based on the analysis of data from both permanent and non-permanent GNSS networks. The increasing quality of the GNSS receivers and the use of improved methodologies for data analysis have led to significant results which are relevant in geophysical modeling studies. In this work, some investigations carried out at DICA-Politecnico di Milano are presented and revised.

Title	The actual perspectives of GNSS multi-constellation services and receivers for kinematic applications
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Abstract	10 years ago, on 28 December 2005, was launched the Europe's very first navigation satellite, GIOVE-A, thus starting the deployment of Galileo, the EU's own global satellite navigation system. The deployment phase of Galileo suffered of many difficulties and delays but recently the Programme has been accelerated and, in the last months, the pace of deploying Europe's own satellite navigation system continued to increase with the launch of the latest pair of Galileo satellites, in December 2015, doubling the number of satellites in space within nine months. It is expected that the system will be fully operational by 2020, with actual implementation costs in the range of 5.23 billion of euros and 7 billion foreseen till 2020 for EGNOS e Galileo Projects. The excellent performances of Galileo satellites, as measured on the ground, "allows Europe to join the club of the worldwide providers of satellite navigation services". Galileo will be integrated by EGNOS (European Geostationary Navigation Overlay service). Consisting of three geostationary satellites and a network of ground stations, EGNOS achieves its aim by transmitting a signal containing information on the reliability and accuracy of the positioning signals sent out by GPS. It allows users, in Europe and beyond, to determine their position to within 1.5 metres. Since the first signals became available to users, demonstrations have shown the usefulness of EGNOS services in every type of kinematic application, in the aerial, maritime and terrestrial domain. As part of 'GIANT' (GNSS Introduction in the Aviation sector), tests have proved the benefits of EGNOS when landing at airports with fewer aids or when helicopters make emergency landings. The integrity data provided by EGNOS is particularly suited for applications driven by stringent safety constraints during critical navigation phases such as landing aircraft, maneuvering ships in narrow channels, and tracking the precise locations of trains. Actually many applications are based on EGNOS, and the Open Service (OS), available since October 2009, is widely used in the agricultural world, where it has proved valuable for reducing the use of fertilisers, thus helping to protect the environment. The accuracy of the Open Service has also proved useful to guide blind people in the city via mobile phones – like car drivers using GPS.

	Towards the certification of the Safety of Life service, many tests have been performed in the aviation, maritime and rail sectors. Mapping of fixed assets, controlling mining machinery and other professional uses are potential applications that could benefit from the EGNOS Commercial Data. Demonstrations showing the potential of EGNOS have been performed in many other sectors and many applications are just waiting to be thought of, such as for rail, road and maritime users. The European Commission (EC) estimates that 6-7% of European GDP (Gross Domestic Product) – around 800 billion by value – is already dependent on satellite navigation. Any GNSS device available on the market is able to receive GPS, GLONASS and EGNOS signals and globally 40 % of GNSS receivers are ready to receive Galileo signals. Multi-constellation services & receivers are used by millions of people in the world, being part of their daily life, towards a future where geolocalisation of persons and things will become essential for safety and well-being.
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Title	PRECISE POINT POSITIONING FOR HIGH PRECISION GEODETIC APPLICATIONS
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Abstract	The precise point positioning (PPP) represents a positioning method that uses GNSS phase and code observations from single receiver only and determines high precision coordinates of geodetic points in a global coordinate system. However, in order to determine high accurate and precise coordinates, three issues must be addressed. Firstly, a proper set of unknowns in mathematical model must be set. The coordinates of geodetic point are of primal interest, but troposphere parameters, receiver clock errors, differential code biases and phase ambiguities must also be estimated. Additionally, the GNSS biases must be eliminated or mitigated to a millimetre level and since phase observations are also processed, cycle slips must be determined and possibly corrected. Finally, for the highest accuracy and precision of estimated parameters, highly accurate IGS products must be used. The paper represents an analytical approach to the PPP method where the (un)biasedness of the unknowns in the Gauss-Markov model is discussed. The deficiency of the Gauss-Markov model is described and consequently the estimable parameters are defined. For a case study, we present the PPP on a set of permanent stations from permanent network SIGNAL on a territory of Slovenia for reference frame determination and maintenance.

Title	Stability of the reference frame for structural monitoring
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Abstract	GNSS technology is a useful tool, for precise positioning applications, such as the monitoring of structures. This technique permits an all-weather continuous remote control as well as a quite low cost, both for instrumentations and for monumentation aspects. The traditional approach to GNSS monitoring is based on a relative positioning between one (or more) monitoring stations (MS) and a reference station (RS), assumed as stable; if the distance between RS and MS is short, also L1 receivers can be used and nevertheless high accuracy results are obtained. For data processing, several software packages are now available, both by GNSS manufacturers and by scientific institutions. Recent free and open source software packages, such as RTKLIB and GoGPS, are particularly interesting because they allow a much higher level of customization of the data processing and post processing phases and, for short distances, they offer performances comparable with those of more consolidated ones, such as Bernese, Gamit, Gipsy. The continuous monitoring based on a daily position estimation produces a time series that can be useful both for structure stability studies and for “early warning” systems. Assuming the RS as ‘stable’ the time series of relative positioning provide the ‘movements’ of the MS (in the same coordinate reference system of the RS). The hypothesis of stability of the RS, however, have to be checked particularly when we are looking for small movements and therefore a high accuracy is required. To check the stability of the RS we need for a RS equipped by a dual frequency geodetic receiver. The stability of the RS can be evaluated or using GNSS Permanent Station belonging to a national or international network or considering the Precise Point Positioning approach that permit to reach very high accurate solutions without the need to consider others permanent stations. With this approach we can trace and consider any possible movements of the MS and perform very high accurate solution of the RS. In this paper, several aspects related to the monitoring problem using GNSS have been investigated using a GNSS receiver located on the top of the Garisenda tower (Bologna, Italy). The Garisenda tower is one of the most important features of Bologna’s cultural heritage, but it is notoriously affected by problems of stability and has already been monitored using also other different techniques. The acquired data, have been processed starting from four GNSS reference stations located in different parts of Bologna, but each one at a maximum distance of 2km from the tower. Assuming each reference station as stable, a single base data processing has been performed and four time series have been obtained. After a phase of outliers detection and removal, mean velocities for each time series have been estimated using a least squares approach. A comparison of the mean velocities shows significant differences, probably due to some instabilities of the reference stations. Therefore, each reference station has been processed and a model for each reference station has been defined using Precise Point Positioning approach; the solutions have been aligned to the ETRF2000 using local parameters transformations, generated by a regional network of 16 stations that covers the Italian peninsula and the bordering Countries. The models obtained have been considered for a new data processing and new mean velocities of the Garisenda station have been estimated. The new time series have a higher level of accuracy than the previous series. Despite that improvement in the level of agreement between the four solutions, some differences are still present. This work reports a proposal concerning more complex analysis, with the aim to improve solutions and results interpretation.

Title	GNSS related activities of the ICTP Telecommunication/ICT for Development Laboratory
Author(s)	Sandro Maria Radicella and Bruno Nava
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Abstract	The Telecommunicationbs/ICT for Development Laboratory (T/ICT4D) of ther Abdus Salam ICTP, previously called Aeronomy and Radiopropagation Laboratory started its operations in 1990. Since the beginning his main activity was related to ionospheric physics and applications. Later on, in 1995, the work of the laboratory extended to wireless communications for internet access. At present, the T/ICT4D covers activities that enter in the trend that combines uses of GNSS and ICT. In this presentation, after a brief historical outline of the laboratory, its involvement in topics related to ionospheric effects on GNSS since the year 1998 will be described.

Title	Studies of Tectonic Movements in Saudi Arabia
Author(s)	Dr. F. Kartal, Dr. M. Al Rajhi, Prof. Dr. T. Uzel, Prof. Dr. K. Eren
Affiliation	Istanbul Kultur University
Abstract	The precise positioning at the Global Navigation Satellite System (GNSS) stations yields better view in the understanding of the crustal deformation that requires global-scale measurements. There have been numerous studies examining the data process of continuous GNSS observations in the field of earth monitoring. More recently, GNSS stations established for Continuously Operating Reference Station (CORS) networks have been beneficial resources in the tectonic plate-monitoring studies in lieu of campaign-type observations. However, this requires that the CORS should be established on stable structures acting like foundations and requires investigation of the long-term repeatability time series. This study aims to introduce lately established national CORS network in Saudi Arabia, named CORS-KSA, covering almost the entire Saudi Arabia, and to explain the process of the long-term data obtained from the network on the characteristics of the tectonic plate movement within the area. The results of the CORS-KSA data process present a great potential of using CORS not only in real-time kinematic applications of conventional geodesy studies but also in detecting and monitoring the crustal deformations. It is a well-known fact that the Earth is made of many plates. The Arabian plate moves towards the Eurasian plate squeezing Anatolian plate and earthquakes have been the great natural hazard that threatens the Middle East region socially and economically. Hence, it is crucial to have knowledge on the characteristics and dynamics of the tectonic fault lines to mitigate this hazard. This mission is partly accomplished by the outcomes of the CORS networks. This is demonstrated by looking at the results of GNSS data process obtained from an 11 year measurement period in Saudi Arabia and presented in this paper.

Title	Single-frequency receivers as master permanent stations in GNSS networks: precision and accuracy of the positioning in mixed networks
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Abstract	Continuous Operating Reference Stations (CORSs) are widely used for many purposes, such as precise positioning, mapping and monitoring. These architectures are formed by a control centre and some permanent stations, that are composed by geodetic antennas and dual frequency receivers. The cost of this infrastructure is high, due to the instruments used; moreover the inter-station distances between CORSs is often too high if a single frequency receiver is considered as rover. This work focus the attention on the usefulness of single frequency permanent stations in order to thicken the existing CORSs, for monitoring purposes. In this context, some innovative GNSS networks were developed and tested, analyzing the performance of rover's positioning in terms of quality, accuracy and reliability in real-time. Some tests have been carried out considering different types of receivers (geodetic and mass market) and antennas (patch and geodetic). The tests have been conducted considering several positioning approaches (static, stop and go and real time) in order to make the analysis more complete. Interesting results were obtained: the followed approach will be useful for many types of applications (landslides monitoring, traffic control), especially where the inter-station distances of GNSS permanent station are greater than 30 km.

Title	Internet platform for improving the EGNOS ionospheric corrections
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Abstract	The problem of insufficient accuracy of the EGNOS corrections for the Eastern Poland, located at the edge of the EGNOS range, is well known. The EEI PECS project (EGNOS EUPOS Integration) assumes improving the EGNOS corrections by using the GPS observations from Polish ASG-EUPOS stations. One of very important parts of the EGNOS correction is ionospheric delay of incoming GNSS signal. New ionospheric corrections are computed using selected stations located at the eastern and central part of Poland. The new corrections substituting the original ones for selected grid nodes are transmitted by the SiSNet to the receivers. The use of regional parameters for ionospheric model increased the accuracy and stability of the navigation position determined during the experiments carried out at Biala Podlaska airport.

Title	"Recovery of the spatial state of the ionosphere using regular definitions of the TEC identifier at the network of continuously operating GNSS stations of Ukraine"
Author(s)	Liubov Yankiv-Vitkovska , luba_y@ukr.net
Affiliation	Institute of Geodesy, National University Lviv Polytechnic, Ukraine
Abstract	For continuously operating reference GNSS stations, the results of the determined ionization identifier TEC (Total Electron Content) that describes the number of ions in the atmosphere on the line between the ground station and the moving satellite accumulate. On the one hand, this data reflects the state of the ionosphere during the observation; on the other hand, it is a substantial tool for accuracy improvement and reliable determination of coordinates of the observation place. Thus, it was decided to solve a problem of restoring the spatial position of the ionospheric state or its ionization field according to the regular definitions of the TEC identifier, i.e. STEC (Slant TEC). The description below we showed one of the possible solutions that is based on the application of the regularized approximation of functions with numerous variables.

Title	TREGA Project: Towards a SBAS-EGNOS in Sub-Saharan Africa
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Abstract	TREGA (TRaining on EGNOS-GNSS in Africa) is a joint project between the European Commission (EC) and the Abdus Salam International Centre of Theoretical Physics (ICTP) that aims to support the implementation of SBAS/EGNOS in Sub-Saharan Africa providing training and research activities. SBAS is considered to be the future of navigation in civil aviation in replacement of the existing ground-based navigation technologies. It is well known that GNSS technology is especially vulnerable to some factors. Among them, ionosphere is a major source of error particularly in low-latitude regions. TREGA conducted, as part of its training through research, a in-deep study using a state-of-the art SBAS testing/simulation platform. The study focused on the effect of the West Africa low-latitude ionosphere in the GNSS/SBAS performance. Results were computed using experimental GNSS data from the Sub-Saharan African region during solstice and equinox months of the year 2013, characterised by high solar activity. The work revealed a significant correspondence between the SBAS performance variation and the development of ionospheric irregularities in the region. This effect is clearly present after sunset hours where irregularities activity increases and it changes in a day-to-day and seasonal basis. A particular was given to those geomagnetically disturbed days with inhibition of ionospheric irregularities.

Title	Interoperability of the GNSS's for positioning and timing applications
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Abstract	The capability of commercial receivers to track multiple GNSSs poses the problem of mutual alignments of reference frames and time scales. System biases should possibly be computed in advance and made known to the user, so that the only unknowns for code point positioning are the receiver coordinates and the receiver clock offset relative to a unique time scale. We have examined data from five GNSS constellations GPS, GLONASS, Galileo, QZSS, BeiDou, for two years, up to 20 European GNSS stations and six different GNSS receivers, with the goals to a) estimate systematic offsets of the time scales kept by each GNSS relative to GPS, and verify if the navigation data enable all the satellites of the same GNSS to synchronize to a common time scale, and b) investigate possible receiver dependent system biases. We report that System time biases relative to GPS typically of the order of 360 – 380 ns for GLONASS in 2014 have been reduced to some 10 ns in 2015. For Galileo the time biases were variable in 2014 but have reduced to some tens of ns, relative to the GPS time scale. For QZSS we evaluate a QZNSS to GPS System Time Bias modeled to sufficient accuracy with a linear drift. For BeiDou the timing of the data must be offset by a fixed amount of 14 sec exactly. When this is done then the System Time Bias of all examined BeiDou satellites in GEO (Geostationary Orbit), IGEO (Inclined Geosynchronous Earth Orbit) or MEO (Medium Earth Orbit) orbit is quite repeatable for the different satellites, but varies from day to day, in the range of 100 ns relative to GPS. For PPP the time bias is added to the phase ambiguity and cannot be decoupled with undifferenced measurements. Receiver dependent biases are also an issue which affects the interoperability of the different GNSSs. We present examples of receiver dependent biases for a number of commercial receivers. We conclude by proposing some specific calibration items relating to the receiver type and the GNSS constellation which could be broadcast to a user to facilitate the combined and simultaneous use of several GNSSs with various receiver types.

Title	GNSS Radio Occultation: an augmentation tool to improve Geodetic Surveying
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Abstract	The coordinates of a static Global Navigation Satellite System (GNSS) station placed on the ground are estimated together with the delay suffered by the incoming satellite signals through the atmosphere. The tropospheric delay (TD) is shaped as the product of the zenith total delay (ZTD) times a mapping function (MF) depending on the sine of elevation angles. In processing chain, ZTD is just estimated together with the coordinates; while the MF is modeled apart, in an independent way, by using atmospheric profiles retrieved with balloon observations (RAOB) as done for the Niell MF (1996) or provided by climate or Numerical

	Weather Prediction (NWP) models as in the Vienna MFs. The several space missions devoted to GNSS-RO (e.g. COSMIC-FORMOSAT, METOP, CHAMP, GRACE and others) are providing a huge amount of data which makes worthwhile to be attempted the reconstruction of a new mapping function based on such kind of data. Thus we have built the so called “Matera” MF (MTMF) based just on GNSS-RO observations. The new MTMF will be applied to a network of EUREF GNSS stations in the Mediterranean area. Formal errors and repeatability of ZTD and coordinates in terms of baselines estimated with the MTMF have been compared with those achieved applying the Niell mapping function. In validation activities we have implemented the MTMF in the Bernese software to carry out our comparisons. In the pres
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Title	25 years of GNSS Researches & Applications at the Department of Engineering and Architecture and at GeoNetLab, Centre of Excellence for the Research in TeleGeomatics and Spatial Informations, University of Trieste, Italy
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Affiliation	¹ GeoSNav Lab, University of Trieste (IT); ² GeoNetLab, University of Trieste and GeoNetLab consultants (IT); ³ University of Warmia and Mazury, Olsztyn (PL); ⁴ DIC, University of Pisa (IT); ⁵ Department of Engineering and Architecture, University of Trieste (IT); ⁶ IUAV, Venice (IT); ⁷ ENAV (IT); ⁸ Friuli Venezia Giulia Region (IT); ⁹ degree/PhD at GeoSNav, University of Trieste (IT); ¹⁰ Municipality of Trieste (IT); ¹¹ INSIEL (UD); ¹² DMG, University of Trieste (IT); ¹³ Province of Trieste, Italy.
Abstract	Starting from 1991, 25 years of researches and applications at the Department of Engineering and Architecture and at GeoNetLab, Centre of Excellence for the Research in TeleGeomatics and Spatial Informations, University of Trieste, Italy, are presented. Many research and surveying activities have been performed involving different national and international research groups and interdisciplinary fields: - GNSS networks for environmental monitoring (in cooperation with ISMES and F.V.G. Civil Protection); - application of integrated GNSS/gravity/laser scanner/seismic/GPR techniques on Alpine glaciers and Antartctica areas (in particular DomeC), PNRA, ENEA; - kinematic applications of GNSS (GPS+GLONASS) and SBAS/EGNOS for terrestrial, maritime and aerial applications. The most important funded Projects, in cooperation with national and international partners, have been: SISA Project (INTERREG IIIA Adriatic Cross Border, 2000-2006), MONITOR Project (6th EC Frame Programme – GJU), ArcheoMedSat Project (FIRB 2003), “Application of integrated GNSS/INS techniques for dynamic monitoring of cablecars” FRA Project (2013-2015), GNSS/INS integrated surveys for GNSS/GPRS/GSM modules validation.

Title	"Making GNSS receivers robust against environmental influences"
Author(s)	Guy Lemmens , , guy.lemmens@septentrio.com
Affiliation	Septentrio - Altus
Abstract	GNSS signals are vulnerable to radio-frequency interference. To address this threat, Septentrio has implemented unique interference mitigation techniques. These countermeasures include adaptive notch filtering, pulse blanking and GLONASS L2 band remapping. Working in concert, these and other analog and digital countermeasures form Septentrio's AIM+ (Advanced Interference Mitigation) technology. The effectiveness of AIM+ has been demonstrated in real field applications. AIM+, as part of a larger range of innovations, helps to safeguard positioning accuracy and availability in all possible circumstances.

Title	Readjustment of the fundamental leveling network in NH-EVRF2007 European Vertical Reference Frame
Author(s)	JAWORSKI Leszek, leszek@cbk.waw.pl , SWIATEK Anna, ana@cbk.waw.pl
Affiliation	Space Research Centre Polish Academy of Sciences, Warsaw, Poland
Abstract	The main purpose of the readjustment of the Polish fundamental leveling network was to define heights of the points in European Vertical Reference Frame EVRF2007. Previously vertical systems used in Poland were connected to tide gauge in Kronsztadt (Russia). In processing were included new leveling measurements and multifunctional points determined from GNSS observations and precise leveling. Additionally, the method of the connection to the reference frame was changed. New readjustment was connected to the EUVN reference points.

Title	FReDNet: evolution of a permanent GNSS receiver system
Author(s)	Zuliani David dzuliani@inogs.it Fabris Paolo pfabris@inogs.it Rossi Giuliana grossi@inogs.it
Affiliation	OGS
Abstract	Continuous GNSS networks provide unique information about the crustal displacements, of use for studies concerning plate motions, tectonic processes, and earthquake cycle understanding. OGS, since 2002, is responsible for the installation, maintenance, and development of FReDNet (Friuli Regional Deformation Network), the system for crustal deformation monitoring in the Friuli Venezia Giulia Region. The main objective of the network is the detection of the actual movement of tectonic plates in this collision area: such movements can give some guidance in terms of quantifying the seismic hazard. The infrastructure currently consists of 16 permanent stations located in the Friuli Venezia Giulia and Veneto regions, all equipped with GNSS

	receiver (Global Navigation Satellite Systems) capable of tracking satellite systems GPS, GLONASS and Galileo. The system includes a central server for collecting, processing and distribution of data and results. FReDNet, furthermore, provides a service for browsing high-precision real-time positioning in the most common differential correction RTK (Real Time Kinematic) modes. The current presentation will briefly describe the technical implementation of FReDNet in the last year with new stations, new features (high frequency sampling and monumentation) and upgraded services (GSAC and GNSMART).
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Title	Plate movement and karstic underground water flow on GNSS: lessons learned from fifty years of ultra broad band tilt observations in the Trieste Karst
Author(s)	Braitenberg, Carla, berg@units.it , Nagy, Ildiko', inagy@units.it
Affiliation	Dipartimento di Matematica e Geoscienze, Universita' di Trieste
Abstract	The development of precision and length of available time series of continuous GNSS observations reveals an increasing multitude of observed crustal deformation signals. The environmental induced signals are becoming more evident, as those due to thermoelastic deformation, due to subsurface water flows and loading tides and the tectonic signals as seismic fault movements. The time series covering fifty years of continuous underground geodetic observations from the Karst and seismic Friuli area (in NE Italy) offer a broad spectrum of earth signals that have been univocally identified and which will be increasingly observable by GNSS alongside improvements in precision. The geodetic time series were obtained with ultra broad band tilt meters of the Grotta Gigante and conventional tilt and strain meters in Friuli and Cansiglio plateau, all active to date. Especially the strong hydrologic deformation induced by underground water flows in the karstic channels and fractures has been already demonstrated to be seen also in GNSS (Devoti et al., 2015). The spectrum of crustal movements seen by the geodetic observations is though broader (e.g. Braitenberg and Nagy, 2014) and the other signals are still to be detected in the comparison of underground geodetic and space-geodetic techniques.

Title	The NeQuick ionosphere electron density model: an overview on GNSS applications
Author(s)	B. Nava, S.M. Radicella
Affiliation	The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy
Abstract	NeQuick 2 is the latest version of the NeQuick ionosphere electron density model developed at the Abdus Salam International Centre for Theoretical Physics - Trieste, Italy in collaboration with the University of Graz, Austria. It is a quick-run model particularly designed for trans-ionospheric propagation applications that has been conceived to reproduce the median behavior of the ionosphere. It allows calculating the electron concentration at any given location and thus the Total Electron Content (TEC) along any ground-to-satellite ray-path by means of numerical integration. In this paper an overview of the different model implementations and uses will be given, with particular focus on GNSS related applications. Attention will also be devoted to the assessment studies that have been performed with the model in order to investigate the effects of the ionosphere on satellite navigation systems.

	Finally, specific aspects concerning the assimilation of ionospheric data into NeQuick will be discussed and a test case will be described where a minimum variance least-squares estimation method has been implemented to incorporate ground and space-based (Radio Occultation) GNSS-derived TEC data into NeQuick 2 considered as a background model.
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Title	VADASE: The GNSS revolution
Author(s)	Giovanni Abate - giovanni.abate@lgs-geo.it Francesco Matteuzzi - francesco.matteuzzi@leica-geosystems.com Giuliano Gallerini - giuliano.gallerini@leica-geosystems.com
Affiliation	Leica Geosystems S.p.A.
Abstract	Running onboard the Leica reference stations and monitoring receivers, Leica Velocity and Displacement Autonomous Solution Engine (VADASE) provides an in-depth look into fast movements using unique processing algorithms. In real time, accurate high-rate velocity and displacement information of various activities and structures are provided to engineers and researchers for a complete, precise and reliable monitoring solution. Leica VADASE delivers actionable information independent of any GNSS RTK correction service in real time. Displacement events are recorded onboard a single stand-alone GNSS receiver, and the user can be notified by email. With this instant information, professionals receive a deeper understanding of how structural movements occur and can take necessary actions to mitigate damages and potentially save lives. When fast movements have to be detected and their effects suddenly evaluated, Leica VADASE can help researchers and engineers make the most informed decisions immediately. Leica VADASE adds additional value to traditional GNSS monitoring, providing accurate velocity information that is continually available in real time for precise and reliable analysis of fast movements. Unlike traditional GNSS monitoring systems that require additional hardware or infrastructure for differential processing (i.e., one or more reference stations or global correction services for precise point positioning), Leica VADASE provides autonomous processing capability with no extra equipment or services needed. Users can also apply the latest versions of Leica SpiderQC, Leica GeoMoS or any other customized software for advanced data visualization, analysis, threshold verification and notification. Slow displacements can be detected at millimeter level for a long time, based on several hours or daily high-precision GNSS data processing. When fast motions have to be detected and their effects to be suddenly evaluated, however, velocities have to be continually monitored and ideally the results have to be known in real time.

Title	ODOMETRY AND LOW-COST SENSOR FUSION IN TMM DATASET
Author(s)	Ambrogio Maria Manzino , Cinzia Taglioretti
Affiliation	Politecnico di Torino
Abstract	The case study describes a TMM survey realized in the urban centre of Turin: therefore the path is characterized by rectilinear segments spaced out by curves of up to 90 degrees,

	changes of velocity, some departures and stops and urban canyons. To achieve the necessary data and apply the motion models and the filtering techniques described above, the authors equipped a vehicle with various instruments: a low-cost Action-Cam able to record the trace of the vehicle even in the presence of obstructions, since it has a highly sensitive GPS, an inertial measurement unit (IMU), which is useful for obtaining the reference trajectory especially in the absence of GPS signals, and a DMI. Although the IMU has an integrated GNSS receiver, the authors preferred to use the less precise GPS data acquired by the Action-Cam, to test how far a motion model and a more or less refined filtering technique could bring benefits in the determination of the vehicle trajectory and the position of the perspective centres of the camera. The presence of a DMI permits the introduction of velocities in the analysis and also caters for the typical deficiencies of the models described above: e.g. failure to consider stops at traffic lights or zebra crossings, which are typically present in an urban road. The DMI has so permitted to “adjust” these models realized for a continuous trend of the vehicle also to a discontinuous trend. The data obtained by the instruments on board which were used in the TMM survey were included in a Matlab program. The results of analysis show that the UKF (Unscented Kalman Filter) technique provides good results in the determination of the vehicle trajectory, especially if the motion model considers five states (such as the two positions, the tangential velocity, the angular velocity and the direction angle). The authors also compared the results obtained with a motion model characterized by four, five and six states. A natural corollary to this work would be the introduction to the UKF of the photogrammetric information obtained by the same camera placed on board the vehicle. These data would permit us to establish how photogrammetric measurements can improve the quality of TMM solutions, especially in the absence of GPS signals in areas such as urban canyons.
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Title	Improving high-rate structures and ground monitoring through GNSS-MEMS accelerometer solutions integration
Author(s)	Elisa Benedetti ¹ , Athanasios Dermanis ² , Mattia Crespi ³
Affiliation	¹ Geodesy and Geomatics Division - Department of Civil, Constructional and Environmental Engineering, Sapienza University of Rome, Italy; ² Department of Geodesy and Surveying, School of Rural and Surveying Engineering, Faculty of Engineering, The Aristotle University of Thessaloniki, Greece; ³ Geodesy and Geomatics Division - Department of Civil, Constructional and Environmental Engineering, Sapienza University of Rome, Italy
Abstract	This research deals with the issue of monitoring applications as the combination of GNSS receivers and accelerometers in a unique solution for benefiting of the advantages offered by such different and complementary technologies. The challenge arising from this goal was actually twofold: on one hand a nonconventional variometric approach was chosen for GPS data processing and, on the other hand, low-cost MEMS-accelerometers (MEMS) were implemented on for providing acceleration data. The novelty of the variometric algorithm implemented in the VADASE software consists in allowing real-time displacement estimation in a global reference frame of stand-alone geodetic or low-cost GNSS receivers. The algorithm was successfully proposed in 2011 for GNSS seismology purposes and its use is here extended also to tasks, which can be helpful for structural

	monitoring purposes. On the other hand, despite their very low-cost, the MEMS adopted here are able to supply acceleration information with very high sensitivity and relatively low noise. They are produced for several applications, and currently they are becoming more and more attractive also for scientific purposes. The GPS-MEMS combination strategy proposed here is rather simple as the solution consists in applying rectangular window filters on kinematic parameters (velocity and/or displacement) retrieved with MEMS, between a typical threshold in low frequency range and the Nyquist frequency, and on GPS velocities and/or displacements (obtained with VADASE) between zero and the accelerometer low frequency threshold. Then, such kinematic parameters are combined through a cubic spline interpolation. Of major significance and originality is the preliminary resolution between GPS-MEMS differences in time and spatial reference frames, an issue not commonly addressed within the topic of GPS-MEMS data integration. A strategy based on Principal Component Analysis is proposed here for finding the transformation to move from the MEMS local reference frame (supposed to be with unknown orientation) to the GPS reference frame (WGS84) with only velocity data as input. Then, some suggestions and methodologies are presented to synchronize MEMS and GPS clocks. In order to check the effectiveness of the whole combination method, tests with low and fast dynamics were set up for GPS receiver (geodetic) and MEMS sensors: the high quality results achieved confirm the powerful opportunities behind GPS-MEMS data combination and its usefulness for improving GNSS receivers in high-rate capabilities with very low-cost solutions.
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Title	A simple integration of a mobile device in a Beacon environment
Author(s)	Palermo, Ciro , ciro.palermo@iuav.it Calderan, Mauro, mauro.calderan@iuav.it Migliorini, Marina, marina.migliorini@iuav.it
Affiliation	Università Iuav di Venezia
Abstract	Positioning capabilities are strategic for the Internet Of Things. Some interesting projects rely on small, integrated, wireless-enabled and low cost electronic devices, such as Kyneo (http://kyneo.eu). Kyneo (size 60 x 40 x 24 mm; weight 51 g – battery included) mounts a GNSS receiver (GPS, GLONASS, Galileo and SBAS) with integrated patch antenna, a 16 bit gyroscope, a 16 bit accelerometer, a 12 bit magnetometer and a 24 bit temperature and pressure sensor. It is capable of 10Hz positioning and timing solutions and 200Hz inertial motion solutions. Kyneo has two expansion ports for external sensors and transmits and receives data wirelessly. Some other projects rely on BLE (Bluetooth Low Energy) Beacon technology, such as Aruba Beacon (http://www.arubanetworks.com/assets/ds/DS_LocationServices.pdf) or Estimote Beacon (http://estimote.com) where a beacons wireless array makes a complete spatial reference system for BLE enabled user devices. Beacons are small in size (an Aruba Beacon sizes 47 x 47 x 16 mm) and the on-board battery can last up to five years. This paper proposes an enhancement of a Kyneo device in a Beacon environment. The Kyneo relies on the Beacon array data to obtain a more accurate, real-time positioning solution - even without GNSS coverage. A Kalman filter is used to accomplish this.

Title	GNSS/INS positioning for mobile mapping: analysis and performances in critical situations
Author(s)	Cina, Alberto , alberto.cina@polito.it Bendea, Iosif Horea, iosif.bendea@polito.it Dabove, Paolo, paolo.dabove@polito.it Manzino, Ambrogio Maria, ambrogio.manzino@polito.it Piras, Marco, marco.piras@polito.it Taglioretti, Cinzia, cinzia.taglioretti@polito.it
Affiliation	Politecnico di Torino - DIATI C.so Duca degli Abruzzi 24, 10129 Turin (Italy)
Abstract	Mobile Mapping positioning is a widespread technique that has been greatly developed in last decade. A mobile mapping system consists of a moving platform (typically a land vehicle), navigation sensors (typically GNSS and INS instruments) and mapping sensors, such as cameras, laser scanners or radar. Spatial information of objects or environment are extracted directly from the georeferenced mapping sensor data by integrating navigation data. In this context, this work analyzes the current accuracy obtainable from a navigation system for mobile mapping applications related to road detection or for updating large-scale cartography. The characteristics of the inertial system used are examined, and then tools and resources needed to check the accuracies achievable directly on site are tested. Compared with a reference trajectory and attitude, post-processing results show how, for the purposes described, GNSS outages up to 60 seconds are tolerable in hard-urban environments.

Title	OUTDOOR AND INDOOR NAVIGATION WITH MICROSOFT KINECT
Author(s)	Pagliari, Diana, diana.pagliari@polimi.it ; Pinto, Livio, livio.pinto@polimi.it
Affiliation	DICA - Politecnico di Milano
Abstract	Since its launch on the market, Microsoft Kinect sensor has represented a great revolution in the field of low cost navigation, especially for indoor robotic applications. In fact, this system allows to have a depth camera at a cost of about 200\$, integrating at the same time the data of a visual sensor too. The characteristics and the potentiality of the Kinect sensor have been widely studied for indoor applications. The second generation of the sensor has been announced to be capable of acquiring data even outdoors, under direct sunlight. The task of navigating passing from an indoor to an outdoor environment (and vice versa) is very demanding because the sensors useful in one case are typically unavailable in the other one. The Kinect could represent an interesting device allowing bridging the navigation solution between outdoor and indoor.

Title	SPARTACUS: positioning solutions for critical asset tracking and crisis management
Author(s)	*Vittuari, Luca, luca.vittuari@unibo.it **Zanzi, Matteo, matteo.zanzi@unibo.it **Ghetti, Antonio, antonio.ghetti2@unibo.it
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Abstract	Motivated by the opportunity to develop industry pull applications and services for the European EGNOS and GALILEO satellite systems, SPARTACUS will design, realize, test and

	validate in simulated and real world scenarios tracking/positioning solutions for critical asset tracking and crisis management. SPARTACUS innovation areas include hardware adaptations, algorithms for precision improvement, integration of the receivers with inertial platforms to provide dead reckoning functionalities. The presentation will introduce a two stages strategy approach based on lower and upper level algorithms, to enforce the reliability of an array of GNSS/INS tracking units.
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Title	Procrustean photogrammetry: From Exterior Orientation to Bundle Adjustment
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Abstract	Procrustes analysis is a well known least squares technique used to directly perform transformations among corresponding point coordinates belonging to a generic k-dimensional space. Applied at first in multifactorial analysis, shape analysis and geodesy, in the last decade it was also proposed to solve some classical photogrammetric problems. This work reviews the latest applications of the Procrustes analysis in Photogrammetry and Computer Vision. In this context, Garro et al. (2012) presented an anisotropic orthogonal Procrustes algorithm to solve the exterior orientation problem, achieving a good trade-off between accuracy and computational cost. A robust version of this algorithm, that tolerates a minority of arbitrarily large outliers, was implemented by Fusiello et al. (2013). A generalized extension of the anisotropic row-scaling Procrustes analysis is the basis of the analytical tool, developed by Fusiello and Crosilla (2015) to solve the classical photogrammetric bundle block adjustment. Moreover, Fusiello et al. (2015b) provided a Procrustean formulation of the Non-Perspective-n-Point camera pose problem, which generalizes exterior orientation to non-central cameras, i.e., generalized cameras where projection rays do not meet in a single point. The main advantage of using Procrustes analysis to solve these photogrammetric problems is that it leads to a least squares solution without any linearization of the original equations, and without any approximate value of the unknown parameters. Results obtained with Procrustean algorithms are comparable in terms of accuracy with those given by the state-of-the-art methods.

Title	Some documentations of Cultural Heritage in Poland by Spherical Photogrammetry
Author(s)	Fangi Gabriele , gabrielefangi@gmail.com
Affiliation	Università Politecnica delle Marche, Ancona, Italia
Abstract	Poland is a country with very rich CH, mainly in architecture. Churches, monasteries, castles, important buildings of noticeable workmanship are spread all over the country. I have made some experiences of metric documentation using a technique called Spherical

	Photogrammetry. Some projects are fully exploited; some are only at the orientation stage. Nevertheless, the philosophy is to document and build-up an archive: in case of need one can retrieve this documentation and use it to provide information, measurements, and so on. Spherical Photogrammetry is a new photogrammetric technique making use of the so-called spherical panoramas. They are obtained taking pictures from the same station point, partly overlapping, and covering up to 360°. Once downloaded in the computer they are projected on a virtual sphere having with the same center, then stitched together and projected in the cartographic plane with the so-called azimuth-zenith or longitude-latitude projection. The two orientation angles, horizontal direction and zenithal angle, can be measured, like in a theodolite. A software package has been prepared called Sphera. The 3D object extraction is assured, provided two or more oriented spherical panoramas, taken from different station points, by intersecting projective straight lines. The panorama orientation takes place in steps: 1) model formation by coplanarity, 2) absolute orientation, 3) block triangulation with independent models, 4) least constraints block bundle adjustments. For the absolute orientation the minimum requirements are three non-aligned control points or two control points and at least one geometrical condition. The block bundle adjustment is achieved in two steps, first with four unknown parameters per pano, assuming the panorama to be quasi-horizontal, and then six parameters. The four parameters are the three pano coordinates place the horizontal bearing. The six parameters are the three coordinates and the three orientation angles. The properties of the panoramas are many: FOV up to 360°, covering the entire visible space, the resolution is very large, much bigger than the one of any available commercial camera. Therefore the surveying time on place is short, enabling to produce large documentation projects in an easy and fast manner. Up-to-now no commercial software package is available, but I believe and hope that it will be available sooner or later. The main difficulty is in that any orientation and plotting is manual, making the procedure slow and difficult in the restitution phase. The stitching technique was set-up firstly in 18th century by the venetian vedutist painters, like Canaletto and his nephew Bernardo Bellotto. They used drawings instead of photographs obviously. The drawings were realized with the help of "camera obscura". The FOV of camera obscura was about 30° while the FOV of the paintings are 90°. Bellotto made many paintings of Warsaw. They have been useful for the reconstruction of Warsaw after II ww. Here some examples of documentation with SP, carried out in Poland, are presented. San Florian and market square, Kociny Palace in Cracow. Many other examples of orientation are cited: Carmelitan church , Isaka synagogue, saint Michel in Kasimirsk , transfigured Christ, saint Peter and Paul, the domenican church, all in Cracow, the municipality hall in Breslaw, saint Stanislaw in Poznan.
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Title	Evaluation of the accuracy of 3D point determination from stereo-pairsv
Author(s)	Marco Scaioni (1,2), marco.scaioni@polimi.it Xuan Zhang (2)
Affiliation	(1) Politecnico di Milano, Italy (2) Tongji University, Shanghai, P.R. China
Abstract	The stereo pair has also been the basic configuration for the photogrammetric reconstruction. In the past decades, this was motivated by the use of stereoscopic vision to derive 3D data for map production. In the modern digital photogrammetric, which has largely merged with Computer Vision, the use of stereo-pairs is still relevant, being the minimal configuration for 3D point determination. Moreover, the same concept of stereo pair has moved from the normal configuration to the use of convergent images as well.

	Although a great effort has been put on algorithms for image orientation, tie point extraction, and 3D surface reconstruction based on dense matching, a lack of research can be noticed on the evaluation of accuracy. This research is focused on the empirical evaluation of accuracy of 3D point determination, considering the effect of camera calibration, image relative rotation angles and baseline. Results of some tests on a calibrated test-field are presented and discussed. The aim of this work is to provide some hints for the application of stereo-pairs, covering a wide general case than the one dealt with in the theory of normal case, which is usually assumed as reference.
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Title	Fast field survey with a smartphone
Author(s)	Masiero, Andrea, masiero@dei.unipd.it Fissore, Francesca, francesca.fissore@unipd.it Pirotti, Francesco, francesco.pirotti@unipd.it Guarnieri, Alberto, alberto.guarnieri@unipd.it Vettore, Antonio, antonio.vettore@unipd.it
Affiliation	Interdepartmental Research Center of Geomatics (CIRGEO), University of Padova Viale dell'Università 16, Legnaro (PD) 35020, Italy
Abstract	Photogrammetry is one of the most used techniques for 3D reconstruction, monitoring and surveying. It is widely used in several applications and in different working conditions. The accuracy of photogrammetry reconstruction methods may change depending on the working conditions (e.g. the number of acquired images, lighting conditions, baselines between images), and it is strictly related to the success of the solution of the Structure from Motion problem (Agarwal, 2010). As shown in (Piermattei, 2015; Piermattei, 2016), photogrammetry has already proved to be able to provide quite accurate results in a quite wide range of conditions. Despite its widely spread use and the ever growing improvements to the reconstruction technique, photogrammetry still does not reach the same level of reliability of laser scanning surveying techniques (which can be considered the current state of the art, (Remondino, 2005)): more specifically, significant issues may occur in photogrammetric reconstructions when in presence of lighting problems or when the object of interest is not sufficiently textured. However, photogrammetry has several advantages with respect to laser scanning techniques: in particular, it relies on the use of much cheaper tools and surveying is usually much faster with respect to terrestrial laser scanning. This paper aims at showing the potential improvement that can be obtained by introducing information provided by the navigation system (Masiero, 2014) in the 3D reconstruction algorithm: the goal is that of improving the solution algorithm of the Structure from Motion problem making the solution more reliable and accurate. As a side effect, faster reconstruction is typically achieved as well. The technique is validated on different case studies, related both to human buildings and infrastructures and to natural scenes.

Title	Extreme miniaturization of remote sensing satellites: the experience of POPSAT and ATHENOXAT.
Author(s)	Giulio MANZONI , Yesie L.BRAMA, Meini ZHANG, Naushad RAHMAN. giulio.manzoni@micro-space.org
Affiliation	Microspace Rapid Pte Ltd (Singapore)
Abstract	Spacecraft miniaturization is a popular and growing trend since over a decade and the use of "Cubesat" designs has grown from University exercises to fully functional high performance commercial satellites. This contribution will review challenges and successes in the satellites miniaturization for the application on remote sensing and will report the results of the two satellites POPSAT-HIP1 (www.pop-sat.com) and ATHENOXAT-1 (www.athenoxat.com), developed, launched and operated by the authors to demonstrate micropropulsion attitude control, formation flight capability and day and night vision with medium-high resolution.

Title	Doing science with nano-satellites
Author(s)	Anna Gregorio, Mauro Messerotti , Alessandro Cuttin, Mario Fragiaco
Affiliation	University of Trieste & PicoSaTs
Abstract	Nano-satellites represent a new generation of satellite platform that is opening its own market niche expanding extremely quickly. These satellites are very small and light: thanks to their cubic shape they are also modular, as Lego bricks, and have raised the interest of space operators thanks to their jack-in-the-box concept. Particularly interesting is the Earth Observation and remote sensing market segment, that has large potential applications for safety issues (e.g. water and fire monitoring), or even more practical application for agriculture. The possibility of using a constellation or a network of nano-satellites as a new generation of telecommunication (e.g. for mobile applications) or navigation systems seems also very appealing for the next future. This type of space missions produce large amounts of data and by now these applications are accessible only by larger satellites with better performance of the data transmission system. PicoSaTs envisages a new generation of nano-satellite communication systems working at high frequencies (Ka band) providing very high data rates. Only by enabling the transmission of large amount of data, nano-satellites can become science and market-ready space missions.

Title	Shadow detection and removal in VHR RGB aerial images
Author(s)	Movia, Alessia, alemovi@gmail.com Beinat, Alberto , alberto.beinat@uniud.it Sandri, Thomas
Affiliation	University of Udine
Abstract	Digital aerial color images of the land at very high resolution are today very common and freely available. They provide valuable information for terrain analysis and land use classification. RGB images frequently contain shadows that can cover large parts of the scene, and that often cause misinterpretation, biased classification, and a general loss of information, particularly in the automatic approaches. The paper presents and compares some methods for shadow detection, with particular regard to those exploiting the sole RGB color components.

	Further, it analyses the results of alternative analytical solutions to automatically restore brightness in shadow pixels. Specific examples illustrate the experiments performed with the different considered techniques.
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Title	Laser scanning surveying and 3D modeling of the Aquileia Baptistery for structural analysis purposes
Author(s)	Domenico Visintini , domenico.visintini@uniud.it Anna Spangher, anna.spangher@gmail.com
Affiliation	University of Udine
Abstract	This paper presents a research, developed within a concluding PhD thesis in “Civil and Environmental Engineering and Architecture”, dealing with the terrestrial laser scanning (TLS) surveying and the following 3D modeling of an historical building, specifically devoted to be used with Finite Elements Methods (FEM) for structural analysis purposes. The case study is the Cromatian Baptistery of Aquileia (end of the IV century), octagonal shaped structure, resulting of various modifications, connected to the Patriarchal Basilica through the so-called “Church of Pagans” and an open porch. The surveying of the external façades has been achieved with our Riegl Z390i & Nikon D200 TLS system, while simultaneously the internal ones have been surveyed from the staff of the Department of Civil, Chemical, Environmental and Materials Engineering of the University of Bologna, by means of a Riegl VZ400 & Nikon D90 TLS system. This paper describes in particular the external surveying operations, as the topographic measurements on a ten-vertexes (one inside the baptistery) network and on 124 control points (for scans registration and photogrammetric orientations), and the acquisition of nine TLS scans and several images from the same (external) vertexes of the network. Scans registration on reflecting targets has required particular care in RiSCAN PRO elaborations: obviously, only thanks to the bypassing network and control points has been possible to join the external scans with the internal ones. Surface 3D modeling has concerned various difficulties also, in particular, to homogenize the point cloud resolution and to fulfil the geometrical congruence of the triangular surface, all steps accomplished by suitable tools of mesh editing software as MeshLab, CloudCompare and Geomagic. Last processing phase was the transformation of so obtained surface model in a solid model, in order to use it directly with Scan-and-Solve, a FEM software for structural analysis. Generally, high detailed 3D models from TLS (of photogrammetry) are strongly simplified instead, even not trivialized, for structural purposes. On the contrary, Scan-and-Solve, being a plug-in of Rhinoceros, allows to compute several object-model displacements, stresses and danger levels directly in a 3D modeling software environment, although with some simplifications from the structural point of view. So obtained results for Aquileia Baptistery are more than satisfactory compared to those coming from LISA FEA, software based on classical subdivision by ashlar 3D elements. Summarizing, this work investigate about the “Level of Detail” (LoD) that Geomatics seeks from its own mission, while Structural Analysis leans to simplify, trying to find a meeting point. In other words, the challenge is to reach a balanced “non-excessive” LoD model, faithfully representing the object, but also adaptable for Structural Analysis.

Title	Palazzo Italia at Expo 2015: 3D integrated and almost real time surveying technologies applied to the positioning of the external concrete panel
Author(s)	Vassena, Giorgio Paolo Maria , giorgio.vassena@unibs.it
Affiliation	Università of Brescia
Abstract	The paper deals with the experience of the 3D laser scanning and total station construction and monitoring of the Italian Pavilion and the International Exposition that took place in Milan (Italy), in 2015. All the construction phases have been controlled with 2-3 mm accuracy, thanks to a combination of 3D laser scanning and first order total stations. The construction geometries have been compared with the 3D BIM project and a “as built” analysis has been on a daily basis carried on. Thanks to a new software for point clouds automatic 3D registration, the scanning elaboration data processing time has been drastically reduced. This experience shows the high level of support, to the construction phases of high complex new architectural buildings, of the integration between laser scanning and 3D BIM managing of the construction projects.

Title	Project for a GNSS Widespread Territorial Park
Author(s)	Franco C. Grossi - Франко К. Гросси
Affiliation	Kazan State University of Architecture and Engineering Казанский государственный архитектурно-строительный университет
Abstract	Towards the end of the XVIII century, the so-called "Jardins de Plaisir" grew and multiplied. Frascati, Vauxhall, Tivoli's Jardins turcs, Montagnes Russes in Paris and the Prater in Vienna, combined "fun" with the local beauties and landscapes. Only in 1955 a real theme park was born, Disneyland in California, which can be accessed overcoming a barrier between the surrounding landscapes. Over time the industry has evolved and were born the so-called theme parks (amusement, scientific, aquatic, wildlife, nature, etc.), which are closer and closer to the concept of "resort", and are composed not only by an entertainment area (usually one or more of various types and theme parks), but also by shopping areas and outlets, cinemas, hotels, sports area and all it does entertainment. All these structures require, however, always the availability of a territory enclosed within well-defined boundaries, which is required, apart from delimiting property and safety, also and above all to be able to collect the tickets. This concept of "boundaries" can be overcome by using the present ICT technologies, which are able to guarantee all those services up to now provided in a closed park. Here then you can think regarding an open park, or "widespread", which will not need boundaries, as they will be technologies to provide this function in a virtual mode.

Title	KINEMATIC POSITIONING: FROM MOBILE MAPPING SYSTEMS TO UNMANNED AERIAL VEHICLE
Author(s)	Gabriella Caroti , Andrea Piemonte gabriella.caroti@unipi.it , andrea.piemonte@unipi.it
Affiliation	A.S.T.R.O. Laboratory – Civil and Industrial Engineering Department – Pisa University
Abstract	Since the nineties, with the advent of satellite positioning techniques, enabling to determine three-dimensional point coordinates in a global reference system with topographic accuracy, several applications dedicated to mapping of the territory by means of mobile geo-referenced sensors have continually been developed. This paper discusses the experiences gained in this field at the University of Pisa Topography seat over more than twenty years of experimental work. These activities often conducted in collaboration with the University of Trieste and in particular with Professor Giorgio Manzoni, have always been characterized by a multidisciplinary approach. Different types of sensors have been installed, at first in vehicles and currently on unmanned aerial systems: GPSs, GNSSs and INSS, carbon monoxide and particulate matter measuring systems, single- and multi-axis laser scanners, industrial and photography cameras. With these sensors, as well as drafting and testing maps of the territory in several areas (cartography, road cadastre, pollution monitoring, city modelling ...), it was possible to follow the development of instrumentation and methods of kinematic positioning.

Title	Applications of Digital Photogrammetry from UAVs integrated by terrestrial Laser Scanning to Disaster Management - Brcko flooding Case Study (Bosnia and Herzegovina)"
Author(s)	F. Cescutti ¹ , F. Coren ² , A. Pavan ² , R. Cefalo ³ , A. Calliari ¹
Affiliation	¹ Department of Engineering and Architecture, University of Trieste, Italy; ² Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS) Trieste, Italy; ³ GeoSNav Laboratory, University of Trieste, Italy.
Abstract	The use of professional UAV-based mapping solutions for environmental monitoring is growing worldwide. Digital images taken by UAVs (Unmanned Aerial Vehicles) integrated by GNSS and laser scanning surveys have a great potential in Disaster Management applications, in close range domain. Furthermore, they are competitive to other measurements systems in terms of economic aspects. In May 2014 heavy rainfalls, lasted several days, caused extensive flooding in Serbia, Bosnia and Herzegovina (BhI). A large number of landslides developed rapidly after several raining days. Immediately after, several groups of geologists and geophysicists got together and set up a project with the aim of investigating and characterizing these landslides in order to provide a useful tool to the local authorities. Society of Exploration Geophysicists (SEG) economically supported the project, under the management of Prof. Snezana Komatina, European University, Brcko District. Six different areas were investigated using reflection, refraction and resistivity data. A detailed high resolution DEM was acquired to outline the landslide topographic signature and provide accurate elevation data for seismic processing.

	Two of the six areas, were covered by a drone, acquiring digital images integrated, in the most sensitive area, by terrestrial laser scanning. A fusion between airborne and terrestrial dataset provided a high-density digital elevation model, characterized by high accuracy. The morphological signature of the landslides was outlined by direct data interpretation. In this paper, the results of the survey campaign, reporting a critic analysis of the adopted integrated methodologies, are presented.
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Title	Wavelet neural network application in function approximation
Author(s)	Pavlovčič Prešeren, Polona, polona.pavlovcic@fgg.uni-lj.si Stopar, Bojan, bojan.stopar@fgg.uni-lj.si Sterle Oskar, oskar.sterle@fgg.uni-lj.si
Affiliation	Assistant, PhD, University of Ljubljana, Slovenia Professor, PhD, University of Ljubljana, Slovenia Assistant, PhD, University of Ljubljana, Slovenia
Abstract	In recent years several successful applications of data processing based on a combination of methods from different fields of science have been introduced. After neural networks have been proven to be universal approximators, a new area of combining several topics of problem solving has been introduced. Wavelet neural networks (WNNs), where signal is decomposed and further decomposition coefficients are used in learning, belong to this group of methods. In current study we will show wavelet neural application could be successfully used in mathematical function determination, for both one-dimensional and multi-dimensional example. The first is tied to a trajectory determination and the latter to an elevation model determination from a discrete input-output data set. We will present solutions using several wavelet neural network structures by different mother wavelet functions. WNNs determine their own specific model for continuous function representation by learning and not by step-by step problem solving. WNN function determination is based on a single hidden-layer structure and uses pseudo-inversion as an alternative to back-propagation learning algorithm to avoid trapping into local minimum in the process of obtaining optimal weights. Results, we have acquired from different WNNs for both examples, lead to a superior performance of WNNs comparing to other interpolation methods especially near the endpoints and outside of data domain.

Title	Implementing an OGC Web Processing Service in a WebGIS Framework to analyze satellite data
Author(s)	Grazia Caradonna**, Antonio Novelli**, Eufemia Tarantino**, Benedetto Figorito*, Umberto Fratino**
Affiliation	**Politecnico di Bari, Via Orabona 4, 70125, Italy; +390805963417; *ARPA Puglia, C.so Trieste, 27, 70126, Italy
Abstract	In the last decades remote sensing has established itself as valuable instrument for monitoring environmental changes. Web application or “web apps” are growing in popularity as a means

	to overcome many of the challenges associated with monitoring. Infact, the interpretation of multi-temporal satellite imagery in a GIS or WebGIS framework allows to assess trend analysis accurately due to continuity of observations for monitoring the territory. The possibility to analyze satellite data on Web is a relevant research topic: often the dependency on Internet connection represents the largest limit of WebGIS application. In this paper, we are proposing the implementation of an Open Geospatial Consortium (OGC) Web Processing Service (WPS) in a WebGIS framework. The proposed method was tested using raster remote sensing and cartographic vector data. The WPS is able to execute operations and computations against gridded data sets by means of the Raster Processes. The possibility to clip vector/raster data was realized through the Process Chaining by “nesting” different inputs/outputs processes in order to get a chain of operations composing a unique more complex Process. The system was designed using open source Web-GIS tools (GeoServer, PostGIS and OpenLayers) to integrate the visualization of geospatial data present in various spatial databases related to different geographic locations. For this purpose, open multi-temporal and multi-scale satellite data aimed at retrieving indicators for land degradation phenomenon were processed.
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Title	Geography of WWI sites along the Italian front by means of GIS tools
Author(s)	Paolo Plini, paolo.plini@cnr.it Giuliano Fontinovo, fontinovo@iia.cnr.it Sabina Di Franco, difranco@iia.cnr.it Rosamaria Salvatori, salvatori@iia.cnr.it
Affiliation	National Research Council of Italy, Institute for Atmospheric Pollution Research
Abstract	The Institute for Atmospheric Pollution Research of the National Research Council of Italy, is carrying out on behalf of the Italian Presidency of the Council of Ministers a research for the identification, collection, georeferencing and dissemination of the places involved in World War I along the Italian front line. To achieve this result a Geographic Information System (GIS) is being used. At present the research, covering more than 50,000 km² in the Italian, Slovenian and Austrian territory lead to the identification of more than 5,700 places. Data have been collected and harmonised, in order to convert 'raw' information extracted from literature into a computer-readable tabular format. Resulting tables have been imported in a geodatabase where univocal geographic coordinates were assigned to historically relevant places. In addition the different terminological occurrences of place names and the equivalents in German and Slovenian are collected in order to ease the queries performed through the use of an online GIS. A wide use of historical and modern maps has been made, this implies a specific work in order to harmonise different coordinate reference systems and scales. Within the GIS several Web Map Service (WMS) raster layers are being used. The project has been designed using open sources tools that ensure the availability of a free source code that could be downloaded and updated by the community of users. The wide availability of plug-in enhances the capabilities of the core functions. On the GIS side QGIS is being used; it is the official project of the Open Source Geospatial Foundation with a continuously growing number of capabilities. Data are organised mainly in point layers even if a limited use of line and polygon layers are present into the system, mainly to represent changes of the front line during the war, drainage basins and the national, regional and municipal borders.

	As a second step after the development of the GIS, an online version has been developed as an interface for consulting information via web. The adopted open source online GIS is p.mapper in MapServer 3.0 environment. In particular the online GIS has been recently updated from version p.mapper 3.2 to p.mapper 4.3.2 due to the implementation of java-script and php routines and to substantial improvement of the graphical environment. The updated results of the research are regularly published at the address http://webgis.ia.cnr.it/GGGIS .
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Title	OPTIMIZATION OF A COGENERATIVE BIOMASS PLANT LOCATION USING OPEN SOURCE GIS TECHNIQUES. TECHNICAL, ECONOMICAL AND ENVIRONMENTAL VALIDATION METHODOLOGY
Author(s)	Agostino Tommasi ¹ , Raffaella Cefalo ¹ , Aldo Grazioli ² , Dario Pozzetto ² , Yaneth M. Alvarez Serrano ³ , Michel Zuliani ⁴
Affiliation	¹ GeoSNav Laboratory, University of Trieste, Italy; ² Department of Engineering and Architecture, University of Trieste, Italy; ³ Department of Electronical, Mechanical and Management, University of Udine, Italy; ⁴ Comunità Montana della Carnia, Italy
Abstract	The principal aim of this research activity is to identify, inside the administrative territory of the Carnia Mountain Community, Friuli Venezia Giulia Region, Italy, the optimal location of a new cogenerative biomass plant, starting from georeferenced parameters obtained through an integrated analysis based on open source GIS (Geographical Information System) and DBMS applications. The parameters used for this analysis are related to naturally available biomass estimation, public and private users distribution, already existing and planned thermal plants, wood industrial activities locations plus electrical and road infrastructures. All these georeferenced data have been homogenized and processed together in order to obtain the energetic demand and offer maps. Finally, the authors present a methodological approach to verify and validate the GIS based optimal solution, taking into account the thermal requirements of the residential, commercial and industrial settlements potentially connectable inside the cogeneration plant catchment area. It expects to realize the technical, economic and environmental feasibility related to the different proposed plant solutions (the generation plant of heat and electricity and district heating network), thus allowing to compare the proposed solution with the traditional plants powered by fossil fuels.

Title	Artificial Adaptive Systems to the monitoring of the extremely-slow landslide
Author(s)	Prof. Dominici D., Eng. Alicandro M., Eng. Massimi V.
Affiliation	University of L'Aquila – Department of Civil, Construction-Architectural and Environmental Engineering - Laboratory of Geomatics AFCEA - Via Gronchi 18 - L'Aquila - 67100 - Italy donatella.dominici@univaq.it
Abstract	At present time, our ability to analyze and compute exceeds considerably our ability to understand, measure, and characterize a problem or process. Thus, understanding and the

	ability to conceptualize become important (Mitchell, 1993). The field of Artificial Intelligence research, nowadays called more properly Artificial Sciences (AS), was founded as an academic discipline in 1956 and may support the process of data analysis. In fact, Artificial Sciences mean those sciences for which an understanding of natural and/or cultural process is achieved by the re-creation of those processes through automatic models. The Artificial Adaptive Systems (AAS) forms part of the vast world of Artificial Sciences and include Evolutive Systems and Learning Systems. This paper describes the possible application of some new mathematical algorithms, Twisting Theory (TWT) and Crowd Clustering Algorithm (CCA) developed at Semeion Research Center and based on Artificial Adaptive System (AAS), to the active and extremely-slow landslides considered as a natural phenomenon of diffusion. In particular, the main aim was to investigate the usefulness of these algorithms to a better understanding of the kinematic of extremely-slow landslides also when displacement measurements are affected by systematic errors. In order to verify this aim, the T64 extremely-slow landslide case study, was analyzed. This case had redundant information from total station and inclinometers with total station and inclinometer displacements similar in direction but greatly different in magnitude because the presence of systematic errors due to the instability of the reference system were recognized, but it was not possible to quantify and therefore to reduce their effects. The main aim in this context was to identify techniques of data analysis able to limit the influence of systematic errors in the definition of the kinematic behavior. The results obtained with the application of TWT and CCA show how the use of the Artificial Adaptive Systems on landslide measurements may get the information on the landslide kinematic behavior even when there is no agreement between displacements measured with the different techniques like inclinometers and total station. First of all, the algorithms were able to identify the areas moving at different rates and the cause-effect relations among the control points with only one year of observations (equivalent to displacements of only few millimeters). The validation of these results was made by comparing them with the well-known data field and a good agreement was found.
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Title	GNSS TEC anomalies as a precursor of the earthquake
Author(s)	Medzida Mulic , medzida_mulic@yahoo.com
Affiliation	University of Sarajevo-Faculty of Civil Engineering-Geodesy Department, Bosnia Herzegovina
Abstract	Earthquake occurrence is connected with plate tectonics and complex Earth dynamical processes. Some recent publications suggest that ionosphere anomalies occur over the earthquake preparation area, during the period of two weeks before, as well as a week or two after seismic shock. Remote sensing methods found that thermal radiation spike significantly nearly two weeks before the earthquake and also on the day of earthquake. Some scientists think that ionosphere anomaly, as well as the heat spikes and electrical changes in the atomsphere, before earthquakes are caused by radon gas escaping and heating the lower portions of the atmosphere. However, most geoscientists say that tere is no single indicator proved reliable one in the predicting earthquakes. Importance of the earthquake occurrence prediction is global and regional, as well as local one. For example, Bosnia and Herzegovina has a very complex geological and geodynamical

	structures, but also is the seismically active area. Numerous low or moderate magnitude seismic activities registered during 2015 in Bosnia and Herzegovina. In this paper, several quack events, magnitudes range from 3.1 to 4.3 by Richter, from period February-May 2015 were analyzed. Conditions in the ionosphere over the wide Sarajevo area investigated around the time of seismic events. Total electron content-TEC values were estimated from Sarajevo GNSS permanent station-SRJV using VShell program. Research detected that discrepancies are not sporadic and occasional, but to have a regular character that is associated with the earthquake. Analyzing day-to-day deviations from two weeks median of TEC values indicate that in 5 and 6 days (generally 3-7 days) before seismic shocks, TEC values were low, but also 3-7 days after event. From that we conclude that monitoring of the anomalies of GNSS TEC value may be used as precursors even for moderate magnitude of earthquake. The problem arises if geomagnetic storm happens, what additionally disturb ionosphere. Our results shows that described predicting pattern of the TEC behavior disappear under disturbed solar weather conditions.
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Title	Analysis of the GNSS Data Recorded at the Everest Pyramid Lab during the 2015 Nepal Earthquake
Author(s)	Giorgio Poretti (*) , Federico Morsut (*) and Franco Pettenati (**)
Affiliation	(*) Dipartimento di Matematica e Geoscienze - University of Trieste, Italy (**) OGS – Istituto di Oceanografia e Geofisica Sperimentale, Sgonico, Trieste, Italy
Abstract	The Himalayan GNSS network. The data recorded at the Pyramid permanent station were processed on a daily bases with precise ephemeris providing the Precise Point Positions (PPP) that indicate the northwards movement of the EvK2Cnr laboratory. The coordinates of the Pyramid Lab were also verified analyzing the correlations with three permanent stations of the IGS world-wide GNSS network. These stations are located in Lhasa (Tibet) and two in Lucknow (India). In order to detect an eventual permanent shift of the point during the earthquake the distances of the Pyramid Lab from the three IGS stations have been computed before and after the earthquake. Differential analyses of the data during the earthquakes. Particular attention was devoted to the recordings obtained during the days before, during and after the earthquakes and their processing with the PPP techniques and with differential method provided an interesting behavior. A special technique allowed to compute the kinematic site coordinates of the Pyramid point every 30" and to determine the distances from the original point. Integral analyses of the coordinates variations during the earthquake. In order to provide a better insight, a new function was defined that adds up the single changes for each component, from the beginning of the observations. An integral function adding up the data from the beginning of the observations interval provides the filtered sequence presented in Fig. 1. for the North component. It can be seen that the constant average movement of 5 mm/day assumes a sharp increase for 8 hours up to the moment of the 7.9 shock of the 25th of April at 5.55 UTM and then it decreases for about 16 hours. This behavior can be enhanced normalizing the input data. One can conclude that the seismic movements can be recorded and detected by a GNSS

	station that can point out not only the intensity of the tremors of the earthquake but also the amount of the shifts of the point at the permanent GNSS station location at every instant before and after the seismic event.
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Title	Recent developments towards the extension of EGNOS into Africa – The FP7 MISW project
Author(s)	B. Forte on behalf of the MISW Consortium B. Forte, F. Da Dalt, T. Paniciari, C. Mitchell – University of Bath (UK) N. Wilhelm, D Serant – Thales Alenia Space France A. Zin, L. Marradi, R. Muscinelli, R. Fiordiponti – Thales Alenia Space Italy V. Sreeja, M. Aquino – University of Nottingham (UK) F. Dovis – Politecnico di Torino (Italy) L. Alfonsi, L. Spogli, G. De Franceschi – Istituto Nazionale di Geofisica e Vulcanologia (Italy) I. Häggström, C.-F. Enell – EISCAT (Sweden) P. Chawdhry – European Joint Research Centre, Institute for Security and Protection of Citizens (Belgium) P. Høeg, H.-H. von Benzon – Danish Technological University - Space (Denmark) M. Pozoga – Space Research Centre (Poland) T. Kos – University of Zagreb (Croatia) E. Henley, D. Jackson – Met Office (UK)
Abstract	MISW (Mitigation of space weather threats to GNSS services) will tackle the research challenges associated with GNSS (Global Navigation Satellite System) and Space Weather to bring practical solutions right into the forefront of European Industry. Space Weather can affect many modern technologies that we take for granted. One of the most common technologies found across many systems today is navigation and timing provided by the Global Navigation Satellite System (GNSS). The main users of GNSS positioning are reliant on the inherent accuracy that the system can provide but this is not adequate for all applications. Aviation has its own augmentation solution called a Satellite Based Augmentation System (SBAS) and the European version is called EGNOS (European Geostationary Navigation Overlay Service). These systems gather additional information that allows some mitigation of Space Weather Events. However, they are not yet able to work in the most challenging regions and as a consequence Space Weather disturbances to the ionised upper atmosphere (ionosphere) will cause navigation errors that remain uncompensated. EGNOS extends from Scandinavia in the north and extends towards Africa to the south. These regions experience strong gradients in delay and break-up of the signals from scintillation, both of which are significant issues for the EGNOS system and represent a clear technological barrier to the expansion of EGNOS geographically. Overcoming these technological challenges within this project will allow the expansion of SBAS systems to previously un-instrumented regions at high and low latitudes. The objectives of this project are to develop innovative algorithms to mitigate against space weather vulnerabilities (i.e. ionisation gradients and scintillation) at both receiver and system level to enable EGNOS over Africa, and to devise recommendations on best practices for GNSS future services with reference to space weather. Recent developments following activities within MISW will be illustrated and described.

Title	Comparison between PPP and DD processing techniques using Bernese 5.2 – Computation of displacements and velocities of Marussi FVG and FredNet GNSS networks and visualization on GeoServer: first results
Author(s)	F. Morsut ¹ , R. Cefalo ² ; federico.morsut@gmail.com ; cefalo@dicar.units.it
Affiliation	¹ Department of Mathematics and Geosciences, University of Trieste, Italy ² GeoSNav Laboratory, Department of Engineering and Architecture, University of Trieste, Italy
Abstract	Precise Point Positioning (PPP) and Double Differences (DD) processing techniques were used on different set of geodetic GNSS data, relative to some vertexes belonging to Marussi FVG and FredNet, OgS, GNSS permanent networks, using Bernese 5.2 software. In particular, Marussi PORD vertex (Pordenone, Italy) and OgS FredNet AFAL were analyzed, dividing the relative recorded data sets in different time intervals: a daily subdivision relative to December 2014, a weekly subdivision relative to the first week of December from 2010 to 2014 and yearly for the data from 31th December 2003 to 31th December 2014. FredNet vertexes velocities were obtained to respect to the Euroasiatic Plate and Marussi; the coordinates of the network vertexes were computed in the ITRS2000 Reference System. Data analyses, storing, visualization and sharing were performed using GIS tools: QGIS for geographical data processing, GeoServer for geographical data sharing, PostGIS for the database linking and GeoExplorer for data visualization. Data analyses showed agreement with the official data reported in the monographs, confirmed a good convergence between PPP and DD solutions, using long period observations and the FredNet vertexes displacements and velocities referred to Euroasiatic Plate.

Title	Advances in the investigation and monitoring of rock cliffs and glaciers with Terrestrial Laser during the last decade. An overview.
Author(s)	Tamburini, Andrea, andrea.tamburini@imageosrl.com
Affiliation	IMAGEO Srl, via Valperga Caluso 35, 10125 Torino, Italy
Abstract	Thanks to the improvement of surveying equipment and data processing software, an increasing use of Terrestrial Laser Scanning for investigating and monitoring unstable slopes and glaciers has been made during the last decade. Both scanning speed and operational range have been significantly increased, reducing the surveying time and increasing the extension of the study areas. Thanks to the development of proper software packages, it's now possible to extract not only the attitude of rock mass discontinuity surfaces directly from the point cloud, but also to map the distribution of significant parameters influencing the behavior of the rock mass, e.g. discontinuity spacing, fracture density, URV, etc. Moreover, the possibility of draping high-resolution digital images over either a point cloud or a 3D mesh derived from it enhances the resolution of the 3D model and the capability of extracting geometrical information of the surveyed surface. Selected case studies and successful point cloud processing strategies will be presented.

POSTER SESSION

Monitoring of the Italian GNSS Geodetic Reference Frame

Maurizio Barbarella, Stefano Gandolfi, Luca Tavaschi

DICAM – ARCES – University of Bologna

Abstract

Since year 2009, the Italian Geographic Military Institute (IGM) has defined a geodetic GNSS network called “Rete Dinamica Nazionale” (RDN). The RDN is constituted by about 100 permanent stations with the aim of aligning the national frame to international standard. This network represents a regional densification of EUREF EPN and permits also a continuous monitoring. In 2011, the Italian official reference frame was redefined in ETRF2000 at the epoch 2008.0.

The data collection started at the end of 2007, and in November 2012 the IGM published the whole archive and maintains it up to date.

The data collected among 2008 and 2011 were calculated and analyzed by four different Independent Analysis Centers (AC): IGM, University of Padua, Polytechnic of Milan and University of Bologna. In particular, the AC of the University of Bologna performed the computation using three different software packages (Bernese, Gamit and Gipsy-Oasis II) obtaining results completely comparable, both in term of position and scattering, with each other and with those obtained by other ACs.

In this paper, an extended solution, in term of windows time span (2008-2015) and obtained by Gipsy software package in Precise Point Positioning (PPP), will be shown .

A discussion upon the results will be provided together with a description of the adopted methods and strategies both for data processing and for solution alignment to the ITRF2008. These involve an accurate pre-processing analysis archive, the PPP considered parameters, and the post-processing analysis of the obtained time series. All these procedures were implemented as much automatically as possible, due to the great amount of data to be processed.

Starting from the obtained GNSS time series, an evaluation of the estimate positions and related velocities of each site will be provided, both in ITRF2008 and in ETRF2000.

Monitoring and geodata analysis to support community

Tiziano Cosso (1), Bianca Federici (2), Ilaria Ferrando (2), Domenico Sguerso (2)

(1) Gter srl Innovazione in Geomatica, Gnss e Gis

Spin off of the University of Genoa – Italy

(2) Laboratory of Geodesy, Geomatics and GIS

DICCA - Department of Civil, Chemical and Environmental Engineering

Polytechnic School - Engineering

University of Genoa - Italy

Abstract

The complexity of current reality, combined with the availability of many data (even in Real Time) and the growing interest in civil protection and risks, requires an important contribution of Geomatic in support of the community. It can be summarized in the following points:

- acquire (through traditional and innovative survey techniques) metric and thematic information,
- combine different data sources (through geoDataBase Management Systems),
- take into account the data accuracy (through statistical analysis),
- analyse highly variable phenomena in space and time (through Geographic Information System), cooperating with experts in different disciplines,
- show and share (via web) geo information also for non-expert users, or implement a Decision Support Systems useful for territorial management.

The Laboratory of Geodesy, Geomatics and GIS of the University of Genoa and its spin-off “Gter srl Innovazione in Geomatica, Gnss e Gis” are working on this field, in particular on integration of survey techniques (traditional, GNSS, photogrammetric and laser scanner) and on spatial analysis procedures.

The main areas of research and innovation activities will be presented:

- in the field of GNSS, regarding the contribution to meteorology for an early warning system and the activity with low-cost GNSS instrumentation, for landslides monitoring or Real Time navigation support;
- about environmental modeling, a GIS application that might contribute in monitoring and predicting landslides triggered by rain.

The fil rouge of the activity is the low cost monitoring, using also existing infrastructures, implementing automatic and Real Time analysis techniques, for the safety of population.

This approach should encourage the application of extensive preliminary monitoring, allowing the decision-maker to pay more attention to the critical situations.

"EGNOS related Activities at GeoSNav Lab, University of Trieste"

Mauro Calderan¹, **Raffaella Cefalo**¹, Adam Ciecko², Stanislaw Oszczak², **Tatiana Sluga**¹, GeoSNav Lab, Department of Engineering and Architecture, University of Trieste, Italy; University of Warmia and Mazury, Olsztyn, Poland.

Starting from spring 2000, EGNOS-ESTB field tests in static and kinematic modes have been performed at GeoSNav Lab, Department of Engineering and Architecture, University of Trieste, using the ESTB signal from GEO satellite INMARSAT-3 AOR-E, PRN 120 (Cefalo et al., 2000, Cefalo, 2001; Cefalo and Gatti, 2001), by means of Novatel Millennium geodetic receivers implemented with WAAS GPS cards.

In Spring and Summer 2001 several kinematic tests were performed in order to analyze the EGNOS signal transmission capabilities through Geostationary Satellite PNR120.

Data were stored in Stand-alone mode and compared with the *a priori* known co-ordinates of the control point used for the experiment, or with the post-processed phase data relative to the same point. The results, at that time, demonstrated that EGNOS, even though enhancing the accuracies with respect to the Stand-alone positioning, couldn't yet completely meet the required standards, mainly due to used iono-model.

Several static and kinematic tests have been performed at the Sincrotrone site test area, using interferential and pseudo-range measurements and at Pompei archaeological site, in cooperation with Satellite Geodesy and Navigation Research Group, Warmia and Mazury University, Olsztyn, Poland.

Professor G. Manzoni himself recorded real time trajectories in Turkey, using a Trimble GeoXH receiver, in EGNOS mode, in Arslantepe and Elaiussa, in September 2008. These tests demonstrated the problems in the signal availability and accuracy requirements, experimented near the border of the covered area.

Recent experiments, demonstrating the high accuracy and signal availability on GNSS/GPRS/GSM devices, are then reported.

"EGNOS and GIS/WebGIS techniques applied to Air Space Management and Control"

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The first presented research activity is relative to the design of an EGNOS Pseudolite Navigation system (theory/function architecture/applications), particular relevant in critical situations: in many operative situations GEO satellites visibility is limited or absent and the availability of GPS sats for positioning calculation is poor: high Latitudes, mountain regions/terrestrial navigation, urban canyons, railway/Machinery movements inside industrial sites/aeronautical and maritime operations.

The second presented research Project is relative to GIS/WebGIS techniques applied to Air Space Management. One of the main concerns of Air Space Management is obstacle management: obstacle data are used to define flight procedures, to verify that minimum clearance is respected, as mandate by ICAO regulations.

The principal aim of the research activity is to study an infrastructure for aeronautical vertical obstacle data distribution, based on Geographic Web Services (GWS). Implemented functionalities:

- creation of an holding procedures based on GML coding; query to a Geospatial database to verify the presence of vertical obstacles inside the protection area. WFS e GML are Open Geospatial Consortium (OGC) standards. Web Feature Services exchange data in GML (Geographic Markup Language) format: they are used when the geospatial data are physical entities The Web GIS application has been implemented using C# and ASP.NET technology. For data visualization SVG format was used in order to: generate a SVG image starting from GML sent back by WFS, using a XSLT transformation; modify client side map visualization without a new interaction with the server; use Javascript code to query the map client side and visualize data associated with geometries.

Experiences of UAV Surveys applied to the Cultural Heritage and Environmental Risk Management

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In this paper the results of UAV surveys carried out in three areas of Apulian territory affected by serious environmental hazard are presented. Unmanned Aerial Vehicles (UAV) are emerging as a key engineering tool for future environmental survey tasks. UAVs are increasingly seen as an attractive low-cost alternative or supplement to aerial and terrestrial photogrammetry due to their low cost, flexibility, availability and readiness for duty. In addition, UAVs can be operated in hazardous or temporarily inaccessible locations, that makes them very suitable for the assessment and management of environmental risk conditions. Moreover, these techniques are of paramount interest for the documentation of cultural heritage sites and areas of natural importance, facing threats from natural deterioration and hazards. The first study area is an ancient Aragonese watchtower of the seventeenth century, located near the Abbey of San Vito in the countryside of Polignano a Mare (in the province of Bari, Southern Italy). The survey has been carried out with an “esacopter” equipped with a CANON EOS 550D and a GNSS satellite positioning system. Thanks to the GPS-Position-Hold technology a framework of 4 Ground Control Point (GCP) has been set on the study area and for internal use and further error checking 2 more points (check points) were collected using dual frequency Trimble GPS receivers. The image processing was carried out with Photogrammetric and Structure from Motion software (AgisoftPhotoScan) and, as a result, a cloud of 524.607 points with a 0.010096 m/pix resolution was calculated starting from 330 nadir and inclined images. The tower's model was extracted from the whole point cloud using ESRI ArcGIS 10.3 software. This kind of survey allowed highlighting some peculiarities of the tower, such as the presence of a trapdoor and of a chimney at the roof level that were not detectable with a terrestrial survey. In the 2nd study area several survey techniques and methodologies applied in a limestone quarry have been compared in order to describe the obtained accuracies, precisions, taken precautions, operative difficulties and costs. According to the Apulia regional mining and quarrying planning rules (Piano Regionale Attività Estrattive, PRAE) every year the quarries owners have to update the Quarry Cadastre Geographic Information System. To do this, some statistical schedules and topographic surveys are required for the PRAE Control and Management Office. Several surveys techniques have been applied using low cost instruments (Total Station and GNSS receiver) and LiDAR and UAV photogrammetric surveys. For each method different algorithms have been used in order to build the Digital Terrain Models (DTM) which eventually have been compared. This analysis showed that the obtained DTM are almost perfectly comparable. Finally, the UAV survey has been carried out along about 1 km of coast in the Salento peninsula, near the towns of San Foca, Torre dell'Orso and Sant'Andrea (Lecce, Southern Italy). This area is affected by serious environmental risks due to the presence of dangerous rocky cliffs named “falesie”. The UAV platform was equipped with a photogrammetric measurement system that allowed us to obtain a mobile mapping of the fractured fronts of dangerous rocky cliffs. UAV-images data have been processed using dedicated software (AgisoftPhotoscan). The total error obtained was of centimeter-order that is a very satisfactory result. The environmental information has been arranged in an ArcGIS platform in order to assess the risk levels. The possibility to repeat the survey at time intervals more or less close together depending on the measured levels of risk and to compare the output allows following the trend of the dangerous phenomena. In conclusion, for inaccessible locations of dangerous rocky bodies the UAV survey coupled with GIS methodology proved to be a key engineering tool for the management of environmental risks.

Title	Monitoring of highway structure 3D deformation caused by landslides
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Abstract	Deformation and damages caused by landslide on the new highway corridor Vc in Bosnia and Herzegovina, near town Kakanj, observed recently. Geodetic control networks for the monitoring of stability and deformations established. First measurement carried out in May 2015 (zero epoch) and since then six series of measurements completed. This paper describes the geodetic works for the monitoring of the stability and operational safety of highway structures as well as the surrounding terrain. The object is covered with micro-triangulation, precise leveling and GNSS network. Network consists of six control points and 54 points on the object of observation. The own software solution for hybrid adjustment of geodetic networks developed, in order to take advantage of combining GNSS and classical terrestrial measurements. However, in the hybrid adjustment, a vector of measurements combines horizontal directions, distances, vertical angles, height differences and coordinate differences. Hence, to solve problem of determining the common variance factor successfully, the estimates of variance of the components applied. Based on the common vector of the hybrid measurements processing, shifts of the all control points were estimated and analyzed.

Title	Use of NeQuick 2 model for real-time ionospheric correction in single frequency GNSS positioning: an assessment study
Author(s)	A. Kashcheyev, B. Nava, Y. O. Migoya Orue', S.M. Radicella
Affiliation	The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy
Abstract	The delay introduced by the ionosphere on radio signals propagating through it is one of the main sources of positioning errors in single-frequency GNSS receivers. To overcome the ionospheric effects in order to improve positioning accuracy, these receivers that dominate the market have to account for the ionospheric delay using an appropriate model. In this work we assess the capabilities of NeQuick 2 model to eliminate ionospheric range errors in single-frequency GNSS positioning, envisaging the possibility for real-time applications. NeQuick 2 is the latest version of the NeQuick ionosphere electron density model developed in the International Centre for Theoretical Physics (ICTP), Italy with the collaboration of the Institute for Geophysics, Astrophysics and Meteorology of the University of Graz, Austria. It is a climatological model that uses monthly average values of solar activity expressed by the 12-month running mean sunspot number R_{12} as a driver. To switch from ionospheric climatology to weather, the daily solar radio flux $F_{10.7}$ is used as an input parameter. In this work solar flux of the day before is used with the aim to apply NeQuick 2 model corrections in real-time. As a reference for the performance assessment we select the following procedure to correct ionospheric errors. Global Ionospheric Maps (GIMs) generated by the International GNSS Service (IGS) are used to calculate range delay assuming the ionosphere as a thin shell with a height of 450 km. For the evaluation of NeQuick 2 model performance a comparison is done with the GPS ionospheric correction algorithm (ICA). To assess the efficiency of the proposed algorithm globally, the verification has been done using data sets from GNSS stations distributed around the world. Data sets for various ionospheric conditions corresponding to different solar and geomagnetic activity levels and different

	seasons have been used. The results of the statistical analysis of positioning error distribution are presented in terms of average and standard deviation. In this work only the height error is considered, as it is the most significant one.
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"Challenges and solutions of estimating low-latitude ionisation gradients in the case of EGNOS"

F. Da Dalt, T. Paniciari, C. Mitchell, **B. Forte** – University of Bath (UK); N. Wilhelm, D Serant – Thales Alenia Space France; A. Zin, L. Marradi – Thales Alenia Space Italy

The "Mitigation of Space Weather threats to GNSS services" (MISW) is a project funded by the European Commission within the Seventh Framework Programme. One of the aims of the MISW project is to facilitate the implementation of an augmentation system over the African continent, in particular, by extending/adapting the European Geostationary Navigation Overlay Service (EGNOS). Currently, EGNOS is implemented and operational over Europe. It consists of geostationary satellites together with a network of ground-based monitoring stations and it provides integrity messages in order to increase the accuracy of the single-frequency user positioning. At service level, EGNOS generates ionospheric delay corrections calculated from monitoring stations observations and combined through a mapping algorithm.

The future expansion of EGNOS over the African continent presents challenges. The application of mapping algorithms used by EGNOS at mid-latitude is not sufficient to characterise ionospheric gradients originating at lower latitudes where the Equatorial Anomaly is present. Furthermore, the distribution of ground-based monitoring stations in Africa is far from ideal. As they tend to be concentrated in specific areas, extended sectors are affected by very low data availability. These aspects introduce big uncertainties in the mapping algorithms that could translate to incorrect and unreliable ionospheric corrections.

The objectives of this work are to use Computerised Ionospheric Tomography (CIT) to describe the limitations of estimating low-latitude ionisation structures in a heterogeneous data availability environment and to provide possible solutions. The methodology consists in the application of the Multi-Instrument Data Analysis System (MIDAS) over the African sector. The presented approach includes different simulation sets of ionisation gradients for testing the performances of CIT in various scenarios of data availability. This study, in turn, is necessary in order to understand the algorithms needed to calculate accurate ionospheric delays at low latitudes given the network of monitoring stations.

Impact of Ionospheric scintillation on the performance of a network of EGNOS-like monitoring stations"

B. Forte, T. Pinto Jayawardena, T. Paniciari, F. Da Dalt C. Mitchell – University of Bath (UK); N. Wilhelm, D Serant – Thales Alenia Space France; A. Zin, L. Marradi – Thales Alenia Space Italy; L. Alfonsi, L. Spogli, G. De Franceschi – Istituto Nazionale di Geofisica e Vulcanologia (Italy)

The "Mitigation of Space Weather threats to GNSS services" (MISW) is a project funded by the European Commission within the Seventh Framework Programme. One of the aims of the MISW project is to facilitate the implementation of an augmentation system over the African continent, in particular, by extending/adapting the European Geostationary Navigation Overlay Service (EGNOS).

One of the main limitations to augmentation systems at low latitudes is the presence of ionospheric scintillation, which can disrupt the normal operation of ground-based monitoring stations as well as of single-frequency users. The disruption is caused by enhanced errors in the calculation of the additional ionospheric delay correction as well as by losses of lock in either the monitoring stations and/or the user receiver.

The objective of this study was to statistically characterise the impact of ionospheric scintillation on a network of ground-based receivers installed and operated at low-latitudes in Africa in order to quantify the limitations to EGNOS at both system and user levels. Observations of scintillation-related parameters were studied from the point of view of the impact of scintillation on the calculation of VTEC at grid points with the assumption of a 2°× 2° grid at 350 km of altitudes.

This information is necessary to create countermeasures to the presence of scintillation both at system level as well as at user level (i.e. single-frequency receiver).

Title	Accelerometric measurements to assess horse welfare
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Abstract	The ability to quickly identify the animal's possible state of lameness, and thus prevent further serious injury, is important. To this aim, horse gait symmetry is currently analyzed using symmetry scoring scales when trotting. In fact, both walk and trot, unlike canter and gallop, are symmetric gaits and therefore useful to assess horse gait symmetry. In this paper, the possibility of a precocious lameness diagnosis through accelerometric measurements is analysed. The experiment consisted of placing 3 accelerometers on withers, and on the horse's two front limbs. The measurements were executed for about one minute with a frequency of 100 Hz during trot. Each accelerometric unit measured along 3 mutually orthogonal axes fixed to the horse's body. Considering the measurements at withers along the progression direction as a reference, the principal harmonic components of the movement were determined with Fourier analysis. The frequencies of these harmonics were also present in the other two components (vertical and lateral) and in the measurements of the other two accelerometers. The Fourier analysis provides frequency, amplitude and initial phase for each harmonic component. In case the horse experiences suffering (emotional stress, or a physical injury), it is assumed the different signals are not always correlated. In this study, the measurements carried out on a healthy horse and on a lame horse are compared. In particular, the application of a rigorous approach for the analysis of horse's movement is highlighted in this research. In fact, the analysis of current literature on the topic revealed that, notwithstanding that several research works have been carried out and published, sometimes a lack of rigor and the presence of unmotivated assumptions and/or conclusions can be noticed.

Title	Cross border cooperation in Adriatic and Western Balkan area for a common <i>Territorial Information System</i> in the frame of European Territorial Cooperation
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Affiliation	¹ Consultant Engineer, collaborator of University of Trieste ² Project Manager at Central Directorate for infrastructure and territory in Autonomous Region of Friuli Venezia Giulia
Abstract	This presentation aims at putting in relief the importance of <i>territorial cooperation</i> for a Researcher and Teacher who put all his strength and passion in scientific research and dissemination, mainly considering the exchange of technical experiences and technologies among Universities and Institutions, but also among the involved persons: <i>Prof. Giorgio Manzoni</i>, who spent a relevant part of his professional and human life in developing these concepts, especially participating to European calls, in particular in the field of European Territorial and <i>cross-border cooperation</i>. He strongly believed in it and in the importance of having an open mind and work together in an enlarged Europe. In 2003, he conceived the idea for an interesting project: “<i>SISA (Survey and Information System of Adriatic roads)</i>” that obtained a relevant financing, thanks to European, National and Regional funds and became real, thanks to the help and efforts of different collaborators of the <i>Centre of Excellence for the Research in TeleGeomatics and Spatial Information (CER)</i>. The project, in the frame of the past so called INTERREG IIIA Adriatic Cross Border (2000-2006) entered in the specific Measure of “development and strengthening of the infrastructures and the cross border transport and telecommunication networks”. The Lead Partner of the Project was the <i>Autonomous Friuli Venezia Giulia Region, Directorate for infrastructure and territory</i>, in Trieste, Italian Partner of the project and the performer subject was <i>CER, University of Trieste</i>. The Eastern Adriatic Countries Partners involved in the project were: <i>University of Novi Sad, University of Sarajevo, University of Rijeka, Polytechnic University of Tirana, Institute of Transport Studies of Tirana, University of Podgorica</i>. SISA project had the purpose of realizing a multi-theme information cartography integrated by territorial data (<i>Road Information System</i>), carrying out road surveys in the area of west and east Adriatic Sea, constituting also a support to the maritime inter-Adriatic connections. For that reason, a special attention was paid in the survey of roads connecting Adriatic harbors. Many persons actively collaborated at the realization of the project, from an administrative point of view - <i>CSPA (Centro Sviluppo Progetti e Apparecchiature)</i>, University of Trieste and F.V.G. Region, and from a technical point of view - personnel from <i>CER</i> and <i>GeoNetLab</i>. The project's survey technical phases were realized in Italy (<i>Friuli Venezia Giulia region</i>) and East Adriatic countries (<i>Croatia, Bosnia and Herzegovina, Serbia, Montenegro, Albania</i>) with the <i>MMS (Mobile Mapping System) “GIGlone” (GPS Integrated with GLONASS and INERTIAL Navigation unit)</i>, a van ideated and equipped by Prof. Giorgio Manzoni, since 2003. Nearly 1200 km of roads in the <i>East Adriatic coast</i> area were surveyed, thus creating an archive of data and digital photograms describing as a prototype the principal road network involved. The implementation of the project permitted to establish deep collaboration relationships with the partners of all <i>East Adriatic countries</i>. Methods and technologies were transferred to those countries and a precious exchange of knowledge was realized, thus putting the basis for possible future exchanges continuing the experiences developed by the <i>SISA Project</i> and keeping alive the passion and the spirit of <i>cross border cooperation</i>.

An integrated approach of GNSS and GIS for Land Use Monitoring”

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The integration of GNSS and GIS provides useful information for land use monitoring. GNSS provides locations for recording of vehicles positions over time. GIS on the other hand plays the role of data base integrator by superimpositioning separate map layers of the database. Remotely sensed imagery is beneficial for temporal and spatial coverage. GIS, Remote Sensing and Global Navigation Satellite System are the most widely used tools for land use planning and decision support system (Yaolong Zhao, 2012). In this paper we used LISS III data (23.5 m) of 2005 to 2013 over a period of eight years which were downloaded from Bhuvan site to review different techniques for various applications of GNSS, GIS and Remote Sensing for land use changes and classification. The land use classification were categorized into six different classes, namely Forest, Area under Non-agricultural Uses, Barren and un-cultivable land, Permanent pastures and other grazing lands, and Land under miscellaneous tree crops and groves. The paper highlights the importance of geospatial techniques for land use monitoring of the Ajmer city, India.