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PhD Yearbook | 2016

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DOCTORAL PROGRAM IN ENVIRONMENTAL AND INFRASTRUCTURE ENGINEERING

The Doctorate in Environmental and Infrastructure Engineering has been operating since the academic year 2008/2009. The program introduces doctoral students to the world of research on key theoretical and technological elements associated with water, environment, hydraulic and transportation infrastructures, geology, as well as geomatics.

In this context, the program is grounded on environmental, civil, and industrial applications where water is the primary unifying element. The doctorate program is characterized by a strong inter- and multi- disciplinary structure and is organized according to the following key thematic areas.

1) *Hydraulic Engineering*, where major research themes include: fluid mechanics; fluid-structure interactions; hydraulic measurements; river hydraulics; sediment mechanics; hydraulic risk assessment and management; flow and transport processes in porous systems; hydraulic networks, hydro-energy; oil and gas development and applications.
2) *Hydrology, hydraulic structures, water resources and coastal engineering*, where the main research topics include: hydrology and water resources, with emphasis on the main physical processes of the hydrological cycle, water and energy budgets; hydrogeological hazard and mitigation strategies, including hydrological extremes, floods, droughts and precipitation, early warning operative systems, snow avalanching and flood risk; hydraulic networks engineering; and coastal engineering.
3) *Environmental technologies*, with focus on: water supply technology and treatment, (including disposal / reuse of wastewater, sludge management and disposal, anaerobic digestion processes); management and planning of environmental resources (including water quality modelling, knowledge-based decision support systems); solid wastes and sludge management; phenomenology of the atmospheric environment and treatment of gaseous emissions; contaminated soils and their remediation.
4) *Transport infrastructures and geology*, with focus on: transport networks, including functional interactions with regional, national and international territory; sustainable development, in terms of dynamics of development and its relations with the infrastructure system; technological innovation, including methods and indicators for performance characterization of infrastructure construction and maintenance techniques; hydrogeological risk, landslide hazard; water resources identification and management, pollution problems.
5) *Geomatics*, with focus on: physical geodesy and satellite geodesy; positioning and navigation; surface surveying with optical or other sensors, such as SAR, LIDAR; digital photogrammetry and image analysis; remote sensing; geographic information systems; cultural heritage reconstruction and archiving.

The curriculum of PhD students has been tailored to the general and specific research questions associated with the multifaceted interactions between the water sphere and the key evolving anthropogenic activities responding to the needs of modern society.

Career perspectives include opportunities at Universities, Research Centers, public bodies and Authorities, as well as private companies / industry. Small and medium size enterprises (SMEs) which cannot afford the development of an in-house specific know-how program may also require such highly professional profiles to guarantee critical innovation and competitiveness.

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NUMERICAL MODELLING OF HEAT TRANSFER IN AQUIFERS FOR ENERGY PERFORMANCE AND THERMAL IMPACTS EVALUATION: THE CASE OF A BOREHOLE HEAT EXCHANGER

Matteo Antelmi - Supervisor: Dott. Luca Alberti
Tutor: Prof. Laura Scesi

Geothermal energy and low temperature resources have a rising worldwide importance. Ground-Source Heat Pumps (GSHPs) have been increasingly used because they are among the cleanest and most energy efficient heating and cooling systems for buildings as alternative to traditional heating techniques. In GSHP systems the heat pump is coupled to a closed loop Borehole Heat Exchanger (BHE) buried into the ground, where a thermal-carrier fluid is circulated, extracting heat from the ground in winter and/or injecting it into the ground in summer. The PhD thesis focuses on the numerical modelling of a BHE and thermal effects produced in the subsoil, which at the same time influence the energy performances of a GSHP system. The correct design of BHEs is crucial for the operation and the energy performance of the GSHP. Numerical models are useful tools for the design of capable systems and they can be applied for a more efficient use of the subsoil for geothermal purposes. In hydrogeology, MODFLOW/MT3DMS are the most widespread programs to face environmental problems and forecast quantitative and qualitative impacts on groundwater resources; they can also be suitable to represent open circuit heat pump and BHE, even though their reliability in BHE simulation is not well known today.

In this PhD thesis, a numerical model was implemented to study BHE performances and thermal impacts in aquifer. In a first stage, MODFLOW/MT3DMS were used to simulate a 100 m U-pipe geometry of BHE in a saturated sandy porous medium, which implied strong grid refinement and extensive computational resources. A constant unperturbed temperature and a constant hydraulic gradient across the horizontal section in the medium were imposed as boundary conditions in the model domain. Varying hydraulic gradient, the groundwater Darcy velocity was varied. For the BHE, a constant mass flow rate and inlet temperature were imposed.

The first aim of the modelling phase was to simulate a BHE through MODFLOW /MT3DMS and compare its results with the analytic solution, known as linear source, for a case where groundwater flow was neglected; the analytic solution is generally used for thermal response test (TRT) interpretation, that determines the heat transport parameters of the subsurface as thermal conductivity and BHE thermal resistance. In most cases, the groundwater flow influence on the BHEs energy performance need to be assessed including the advection effects. Recently, the use of the Moving Line Source (MLS) solution has recently been proposed to examine BHE and groundwater flow interaction, by treating the BHE as a heat source with a given constant heat rate. Rather an integrated approach, where the BHE operation produces a thermal perturbation into the ground and the temperature field in the ground influences the BHE energy performance, would be more useful. The model predictions were compared with the MLS predictions, running the BHE model in constant heat rate mode. The aquifer temperature distribution, reproduced in the numerical model, was fitted with the MLS solution, using the heat rate as fitting parameter. The discrepancy between the numerical and the analytical predictions of the temperature distribution was converted into a discrepancy in energy terms. The latter ranged from 2%, for the null Darcy velocity case, to -9%, for the highest velocity case (10^{-5} m/s). Hence, the numerical model proved sufficiently accurate. In order to get the numerical case closer to reality, the grout material filling the BHE was implemented into the model in a small area, as in situ condition. Therefore, two cases were analysed and compared: without and with grout material. The latter led to less than 3% impact between the numerical and analytical solutions, so that the absolute difference accounted for nearly less than -12%. Being thus the effect of the grout negligible, it is not worth to get information on the physical characteristics and implement it into the model, further refining the grid.

The second aim of the study was to adapt the numerical model to a constant inlet fluid temperature case, in order to reproduce the typical operation of a geothermal system. In particular, the thermal-carrier fluid was circulated into U-pipes of BHE, extracting/injecting heat from/into the ground, for a 2 years period. The results achieved in these simulations concerned both aquifer predicted exchanged energy and temperature distribution: groundwater flow velocity (advection term), varied to represent a wide ensemble of hydrogeological systems, and thermal dispersivity coefficient (dispersion term), played an important role in the heat transfer. For the highest Darcy velocity case (10^{-5} m/s) a significant increase (up to 90%) in the extracted/injected energy was found, therefore neglecting the advection effect (as in most energy codes) can lead to significant errors in the BHE design. Similar results were observed considering the highest velocity case and varying the thermal dispersivity coefficient: the 1 m dispersivity configuration induced significantly higher exchanged energy values (nearly 49%) than when dispersion is not considered. Therefore, although generally neglected in simulations, the effect of this phenomenon was really important and heavily influenced the results, especially in terms of exchanged energy. Lastly, the heat rate increase was reported as a function of the Péclet number and compared to similar literature results, showing a good agreement.

This theoretical study was followed by a second stage, in which the numerical model was applied to the real low temperature geothermal plant installed during the EcoZoo project, funded by Lombardy Region and Ministry of Research and Education. In the framework of this project, Tethys Srl contracted Politecnico di Milano, in order to implement and monitor a pilot GSHP providing heating, cooling and ventilation to a piglet room in Experimental Didactic Zootechnical Centre in Lodi. The system is composed of five BHEs 60 meters deep, a heat pump and an Air Handling Unit, that recovers heat with an efficiency of 78%. The monitoring system, set up in this PhD thesis, comprised the measurements of a set of different parameters, concerning the energy and temperature in subsoil, to enable the numerical modelling of the environmental impact on groundwater system. This pilot plant is nowadays real time monitored, through a system set up in LabVIEW, an object base programming code, to assess the energy balance of the system and the interaction with the aquifer. The acquired parameters allowed the validation of the numerical model through the comparison with the monitored data. Through the calibration of hydraulic and thermal parameters, a good agreement between numerical simulations and real data was found: in the monitoring well located 2 m downstream the BHE, the mean error (RMSE) between real and numerical results was less than 0.07 °C; therefore, the numerical model reproduced correctly the heat transfer into the aquifer. It was also possible to deeply thermally typify the aquifer and to reproduce the real length of the thermal plume, after a typical heating operation. The presence of these experimental data allowed to evaluate the capability of MODFLOW/MT3DMS, providing for the lack of experimental data in literature.

Therefore the EcoZoo project demonstrated the feasibility to use BHEs in zootechnical production, improving the eco-sustainability of this area. Through this pilot plant an expected reduction in energy consumption was assessed in comparison with the pre-existing heating system (gas burner). Finally an increase in animal welfare due to the improved control of temperature and air exchange was also appreciated.

MEASURING AND MODELING WET SNOW MASS DYNAMICS: A HYDROLOGIC PERSPECTIVE

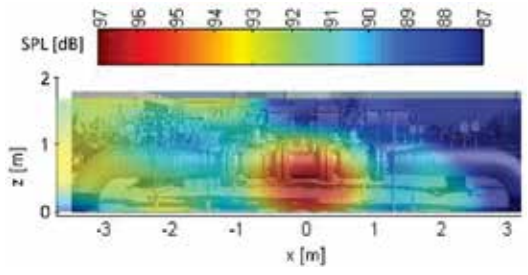
Francesco Avanzi - Supervisor: Prof. Carlo De Michele
Co-supervisors: Dr. Martin Schneebeli, Dr. Satou Yamaguchi, Dr. Hiroyuki Hirashima

This dissertation deals with the dynamics of liquid water in snow, including measuring and modeling activities. Liquid water in snow plays an important role in driving runoff timing and amount. It also rules snow albedo and viscosity during the melting season, provides suitable conditions for a variety of biological activities, and represents a key factor in triggering wet snow avalanches. Moreover, water storage capacity of snow and firn may play an important role in determining the time of sea level rise by Climate Change. However, wet snow mass dynamics are still a less investigated topic than dry snow dynamics. By way of examples, an exhaustive description and modeling of liquid water percolation in snow, as well as the set-up of non-destructive and automatic devices to measure the amount of liquid water in snow are still open issues. To gain more insight into this problem, a variety of laboratory experiments, field tests and modeling formulations are presented. First, a series of tomography-based observations of wet snow metamorphism during melt-freeze cycles was performed. These show a high degree of spatial heterogeneity in wet snow metamorphism, and a faster-than-expected decrease and a high variability in Specific Surface Area observations in time, if compared with a well-known model. Secondly, systematic laboratory-based observations of capillary barriers and preferential flow in layered snow were performed. These suggest that capillary barriers and preferential flow are relevant processes ruling water transmission in snow. An exhaustive inventory of capillary barrier properties was attempted. This shows peaks in Liquid Water Content (LWC) at the textural boundary up to ~ 33 vol% - 36 vol%. It was also found that heterogeneity in water flux increases with grain size. All experiments were reproduced using the model SNOWPACK: the water scheme chosen reproduces correctly the development of a capillary barrier. As a third step, the feasibility of a continuous-time monitoring of LWC using capacitance sensors was investigated by means of two field tests, two laboratory tests and a FEM model of sensors resonant circuit. Results are promising since it was observed that capacitance probes are sensitive to snow wetting and do not need a pit to be excavated. However, significant disturbances affect their measurement in continuous-time applications. As a final step, a one-dimensional one-layer model of snow mass dynamics is formulated. This considers the two phases of ice and liquid water separately, and implements a simple temperature-index or a coupled melt-freeze temperature-index approach to reconstruct hourly time-series of liquid water content, density, depth and snow water equivalent. It has been extensively evaluated in the US, in Italy, in France and in Japan. Results show that a calibrated melt-freeze temperature-index approach returns median absolute differences between data and predictions of volumetric liquid water content that are comparable with instrumental precision.

FLUID-DYNAMIC NOISE IN CONTROL DEVICES

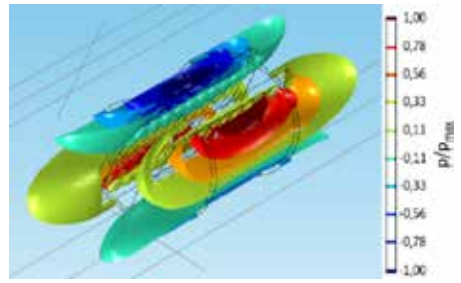
Filippo Carlo Bossi - Tutor: Stefano Malavasi
Supervisor: Stefano Malavasi

The high flow capacity of rotary control valves, increases the probability of noise generation in the plant. Depending on some geometric characteristics, the noise production can be characterized by broadband noise or tonal noise. When the latter condition occurs, the generated noise could overcome the limit of acceptance and the device does not respect the standard of usability. Fig. 1 is an example of tonal acoustic emission recorded on a gas pipeline. The sound pressure level (SPL) locally



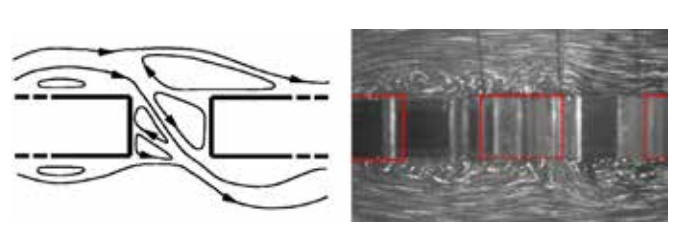
1. Map of the acoustic emission on gas pipeline with valve installed

increases due to the valves installed.
Perforated plates inserted in the valve trim were found to be responsible of the tonal emissions. To study the acoustic resonance, a series of experiments and numerical simulations were carried out on the plates. The first part of the research dealt with experimental analysis on a full valve assembly (valve + plates). The experimental tests were performed, according with International Standards, using a pilot plant feed by an air compression system. The characterization of the noise intensity, vibration and sound pressure level was measured by mean of a PCB accelerometer and a sound level meter. The experimental analysis showed the relevance of the fluid-structure interaction that causes the strengthening of a single frequency noise but only at certain flow speeds. The diameter of the perforated plates together with the angle of incidence were found to be the main parameters responsible for the acoustic resonance. In particular the characteristic frequency of the emission increases when the hole diameter decreases and no whistle was found for an angle of incidence higher than 10°. These first results of the experimental analysis allowed the solution of a specific problem of noise generation on this type of valve. Chancing the angle of incidence of the plates is, in example, a simple solution that can be easily adopted.
Moreover, the dependence of the whistle frequency on the dimension of the hole diameter is another significant result for the optimization of the trim.
Starting from the observations of the experimental results, in the second part of the research, the results of an acoustic modal analysis were compared with the previous outcomes. The natural frequencies of different perforated plates placed in a circular duct (configuration which mimics the full open control valve condition) were considered to verify which of them was responsible of the tonal noise observed in the experimental tests. To do this, diametral acoustic modes were numerically investigated by changing the geometrical characteristics of the device. In particular the effect of the plate thickness and the hole diameter were investigated. Different cross modes were found and a description in term of acoustic pressure distribution and frequency was done. The main outcomes has demonstrate the existence of trapped acoustic mode for geometry of that type and moreover one of the computed mode was comparable with the acoustic frequencies recorded during experimental tests. Fig. 2 shows an example of acoustic mode with its pressure distribution in a couple of perforated plates.
The increase of the plate thickness and the hole diameter determined a decrease in frequency without changing the mode shape. Instead, when a solid plate configuration was investigated, the absence of the holes determined really different frequency values.
However, these results must be coupled with the influence that the same geometry has on the vortex shedding and on the flow field since resonance occurs when the acoustic field interacts with the flow one.
With the aim of determine the relation between hole diameter and shedding frequency, in the final part of the research, tests were performed with plates in a free surface water channel. The devices were three perforated plates and solid plates, all at zero incidence, and at five different flow speeds. The aim of this study was to determine how the plate perforations interact with



2. Pressure distribution of a second harmonic acoustic mode

the fluid flow over the surface of the plate and how the core hydrodynamic quantities, such as drag forces and frequencies of plate vibration, deviate from those of the reference case of the solid plate. To achieve those goals, a triaxial load cell was employed to measure hydrodynamic forces and plate vibration frequencies, while flow visualization was employed to provide information about the flow structure.
The effect of the perforation diameter on the drag coefficient and Strouhal number was investigated.
The frequency spectra extracted from the force data measured by the load cell, showed a linear increase of the dominant frequencies with the flow speed in accordance with the Strouhal law, but the Strouhal number decresed as the hole diameter increased. The drag coefficient , in contrast to the Strouhal number, its value increased with the increase of the hole diameter. For all the cases of perforated plates, secondary peaks in the force spectra were detected, these were related to the perforation diameter which allowed development of unsteady flow structures inside the gaps.
The effect of the perforations on these data trends was explained through the qualitative flow visualization, which shows formation of recirculation zones inside the holes and quasi-periodic ejection of the trapped fluid from the perforations (Fig.3).



3. Flow structure: schematics and streaks of the instantaneous streamlines. The red dashed squares indicate the position of the holes

HUMAN ACTIVITIES AND CLIMATE CHANGE: EVALUATION OF THE IMPACTS ON MOUNTAIN RIVERS

Claudia Dresti - Tutor and Supervisor: Prof. Gianfranco Becciu

Nowadays, mountain rivers are one of the ecosystems that are more affected by human activities around the world. In the Alpine region, the hydropower production has caused alterations in the hydrological regime of most rivers, due to the massive withdrawal of water and to the construction of dams and reservoirs, which modify the natural flow duration curve of the river. In most cases, the infrastructures used for hydropower production cause severely altered hydromorphological conditions in mountain rivers, which cause modifications of habitat for rivers fauna and, in some cases, their destruction. In this framework, climate change has an important role, due to the modification of rainfall and snow regime, of temperature and finally of river flows, with significant impacts on both ecosystems (less water is available for aquatic invertebrates and fish) and water uses.
In this context, it is clear that it is important to analyse the effects of all the impacts due to human activities and climate change on mountain rivers, considering in particular different aspects: the hydromorphological conditions, the ecological flow evaluation, the combined effects of climate change and land use changes and the effects of reservoirs.
The first part of this research is focused on the evaluation of the hydromorphological state of some mountain streams located in the Italian Alps. The analyses were carried out using the method CARAVAGGIO (Core Assessment of River hAbitat VAlue and hydro-morpholoGIcal cOndition), which complies with the EC Water Framework Directive. An intensive campaign of field surveys was conducted and a great amount of data was collected to obtain specific synthesis indexes. In particular, the Habitat Quality Assessment (HQA) and the Habitat Modification Score (HMS) were used to determine the diversification of natural characteristics and the level of hydromorphological alteration in the study area. Furthermore, a Lentic-lotic River Descriptor (LRD) was used in support of the information obtained by HQA and HMS. Some regression analyses were implemented to search a relationship between HQA, HMS and some morphological parameters. LRD was correlated to some hydraulic parameters.
As a second step, a procedure able to merge the easiness of use of hydrological methods and the multi-factor approach of CARAVAGGIO was proposed to evaluate the ecological flow, i.e. a human modified flow regime that captures the natural flow variability in order to maintain the structure and the functional integrity of the aquatic ecosystem. The ecological flow was estimated from basic hydrological information, using a simple set of coefficients to take into account other quality issues, particularly the lentic-lotic features of flow regime.
The third aspect that was considered in the analysis of the impacts on mountain rivers was the combined effect of climate variability and human activities (land use change) on the natural streamflow. A case study based on a tributary of Lake Maggiore was carried out. A statistically identified change point was used to define the base period in the streamflow series. The recent concept of climate elasticity of streamflow in relation to precipitation and temperature was used to indicate to which of this parameter the streamflow is more sensitive. The application of different methods, hydrological sensitivity, climate elasticity, hydrological model and histogram matching approach allowed to estimate the anthropogenic and climatic effects on streamflow and to have an idea of the complicated non-linear relationship among streamflow, precipitation and temperature.
Finally, the effects of reservoirs on the hydrological regime of the river are discussed. In particular, a methodology able to evaluate the changes in the river flow variance due to reservoirs was proposed. The uncertainties in the estimation of Flow Duration Curves are discussed and evaluated.

AIRBORNE GRAVITY FIELD MODELLING

Ahmed Hamdi Hemida Mahmoud Mansi -Supervisor: Daniele Sampietro

Regional gravity field modelling by means of Remove-Compute-Restore (RCR) is nowadays widely applied in different contexts, by geodesists and geophysicists: for instance, it is the most used technique for regional gravimetric geoid determination and it is used in exploration geophysics to predict grids of gravity anomalies. Geodesists and geophysicists have been concerned with the computation of the vertical attraction of the topographic masses, the so called Terrain Correction (TC), for high precision geoid estimation and to isolate the gravitational effect of anomalous masses in geophysical exploration. The increasing resolution of recently developed Digital Terrain Model (DTM), the increasing number of observations due to extensive use of airborne gravimetry in geophysical exploration, and the increasing accuracy of gravity data introduce major challenges for the TC computation. Moreover, classical methods such as prism or point masses are indeed too slow, while Fourier-based techniques are too approximate for the required accuracy.

Chapter Classical Processing of Gravitational Data gave a comprehensive literature review, where we explained the different types of gravity data (e.g., Land, Marine, Airborne, and Satellite) and the main equipments used to acquire data and their accuracies, giving more attention to the airborne gravimetry. Then, the classical data reduction using the classical RCR procedure has been discussed enlightening the different modelling techniques implemented to compute TC with high accuracy (i.e., Point-mass, Prism, Tesseroid, and FFT models). Airborne gravity data processing requires data reduction through computing the TC and RTC, then data filtering, followed by the downward continuation, and finally a Least Squares Collocation (LSC) to represent the data in as a grid that is a must for the geoid computation through the evaluation of the Stokes' integral. In practice, each single computation involved within the classical processing is very time expensive. Therefore, my research introduced new techniques that are characterized with being fast and accurate.

Chapter Gravity Terrain Effects introduced the theory of a new hybrid prism and FFT-based software, named as Gravity Terrain Effects (GTE), from the mathematical point of view. Where, the Newtonian volume integral of the gravitational potential has been elaborated to be in the form of two terms, the former representing the effects of the planar approximation, and the latter is the spherical correction term. Similarly, the computations of the gravitational effects of the topographic masses, TC, was mathematically elaborated into a final expression that consists of two terms, each could be written as a convolution integral. The planar TC,, evaluates the major part of the topography, while the spherical correction term, , that is at least 3 orders of magnitude less than that of the planar TC.

GTE, which was thought explicitly for geophysical applications, allows the user to compute TC on grids of constant heights, sparse points, and on the DTM surface. It also permits to compute not only the effects of the topography but also the effects of the bathymetry, the sediment layers, and the Moho. The accuracy of the computation (i.e., the computational power) can be managed by the user who can select between different profiles. Using a single node of a supercomputer equipped with two 8-cores Intel Haswell 2.40 GHz processors with 128 GB RAM, the slow GTE profiler needs approximately 2.5 minutes to compute the effects of a 351 by 301 DTM on a grid of the same size at a constant height of 3500 m, which is almost 3.5 and 150 times faster than the GRAVSOFT package (Forsberg, 2003) and Tesseroids (Uieda et al., 2011), respectively. Although GTE and GRAVSOFT require almost the same time to compute the effects on sparse points, the standard deviation (SD) of the difference of the output and the reference prism solution are 0.14 and 0.31 mGal, for GTE and GRAVSOFT, respectively. Tesseroids is 70 times slower, while its results are accurate with a SD of the difference below 0.1 mGal. While GTE computes the TC on the surface of the DTM in about 10 seconds with differences smaller than 10^{-3} mGal with respect to pure prism solution, GRAVSOFT is 60 times slower, while Tesseroids cannot be used since the observation points are so close to the masses.

Chapter Along Track Filtering focused on filtering the gravimetric data collected from a dynamic platform that is characterized with a very high noise-to-signal ratio (NSR) through applying a Wiener filter (WF) in the frequency domain on a track-by-track basis so that the whole dataset could be utilized. WF removes the biases and systematic errors potentially present in the data. In order to use such a filter, we exploited the power spectral density functions of the reference signal and the noisy observation vector. The reference signal was computed by means of merging the synthesis of the EIGEN-6C4 (Förste et al., 2014) model and the RTC. A remove-like step has been done removing the low-to-medium and the high frequencies by EIGEN-6C4 and dV_ELL_RET2012 (Claessens and Hirt, 2013) models, respectively. This step helped to minimize the errors of the filtering as the values of the filtered signal and flight heights are small, beside that the observations should be downward continued for few hundred meters.

Filtering the CarbonNet dataset required almost 7 minutes when the TC and RTC were available and 30 minutes to compute all of the TC and RTC, and to filter the signal. Chapter Gridding introduced a new mathematical tool for the evaluation of the covariance matrix by fitting the empirical 2D power spectral density (PSD) with a series of n Bessel functions of the first order and zero degree that assures to gain a positive definite covariance matrix, and consequently allowing us to automatize the covariance estimation process.

The results showed that using smaller downsampling steps and compute few numbers of grids is better than using bigger downsampling steps and compute large numbers of grids. The area where the data were acquired exhibited small prediction error values, while the areas where the GGM model was used had higher prediction error values.

Chapter The Cross Over discussed how to perform the cross-over analysis to improve our knowledge about the noise. For the CarbonNet project, the realization of the expected noise illuminated a SD of 2.04 mGal. Finally, the study of the expected noise allows to estimate a covariance function of the noise itself giving valuable information to be used in the subsequent gridding step. In fact integrating the cross-over analysis within an iterative procedure of filtering and gridding would result in yielding better grids.

To conclude, the work done within this dissertation suits processing of airborne gravimetric data, filtering the noisy observations collected from a dynamic platform in order to perform a LSC yielding grids of filtered data and their prediction errors.

IMPACT OF RESERVOIRS, LAND USE AND CLIMATE CHANGES ON SUSPENDED SEDIMENT IN THE DA RIVER (CHINA – VIETNAM)

Van Thinh Le - Supervisor: Prof. Maria Cristina Rulli

Sediment issues have critical implications for aquatic ecology, agriculture, water supply and river navigation. In recent years, with the construction and operation of several reservoirs in Da river basin, such as Hoa Binh, Lai Chau,..., this issue has risen high interest and concern. Reservoirs have been built to meet several important needs including: increasing energy, irrigation, and drinking water demand. However, there are some important issues related to the construction and operation of reservoirs, which the decision maker should pay attention on: they trap sediments and reduce sediment concentration in rivers downstream reservoir, then increasing riverbank erosion and localized erosion around hydraulic structures. In addition, land use change, along with climate change are also to be considered as causing effects on sediment erosion and transport.

This study aimed to evaluate the effects of separate factors such as reservoirs, land use change, and climate change, and also the combination of such factors on sediment load in the Da river basin.

To make this evaluation, an updated and enhanced version of the soil erosion and transport model at the catchment scale, namely DIMOSHONG_RUSLE is applied to the Da river basin. More than 50 years of monthly precipitation, runoff and suspended sediment load data at the monthly scale are processed. Effect of land use, reservoirs, and climate change is taken into account and a projection of land use, climate changes in the future is assessed on the basis of trends observed in the last decades. The effect of land use change on sediment load is investigated by using historical land use map (1983, 2000,2009, the projection future land use 2020) and existing and future reservoirs. It is concluded that the construction of reservoirs occurred in recent years decreased dramatically the amount of sediment load. For example: Polex (72%), Lai Chau station (71%), Son La station (92%), Hoa Binh station (99%).

In order to assess the impact of future climate change on sediment load, plausible projection of climate change scenarios are developed. Climate change models can be driven with the output from a General Circulation Model (Watson et al., 1996). In my thesis, three GCMs are used, participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) experiment, and contributing to the IPCC Fifth Assessment Report (AR5), namely the EC-Earth, ECHAM6 and CCSM4 models.

SURVEYING, MODELING AND MANAGEMENT OF CULTURAL HERITAGE. DEFINITION OF GOOD PRACTICES THROUGH APPLICATIONS ON MONUMENTS AND ARTWORKS

Alessandro Mandelli - Supervisor: Prof. Francesco Fassi

Today is possible to acquire very detailed 3D description of artifacts and landscapes using semi-professional digital cameras thanks to the reduced costs of these devices, but: "*what is the reliability of the 3D products? Are fully automated methods able to derive accurate 3D results without any shape deformation? How can be used? Which are the steps in order to obtain a model at a fixed rendering scale?*"
These questions are fundamental for documentation, conservation, preservation and replica purposes, but not so relevant if a 3D model is produced for web, AR or visualization needs.
On the web and in literature there are many examples of building reconstructions, artifacts, architectures and even parts of cities obtained with nonprofessional cameras and with very trivial camera networks consisting only of overlapping images. Today, the importance of camera network geometry is often underestimated or neglected in the Cultural Heritage field. The purpose of these applications is not the accuracy and reliability of the models, but the success of a fully automated reconstruction process. The risk is that non-experts in photogrammetry deals with metrological projects without knowing that a wrong planning can lead to strong deformations in the 3D result. On the other hand, automatic tools and software, if properly used, are powerful.
This doctoral thesis deals with the survey of monuments and pieces of arts, but the principal aim is to provide precise metric information able to describe completely the objects of the survey. It tries to answer to these questions investigating, suggesting and defining some good practices that permit to perform fast terrestrial surveys aimed to produce 3D real based models.
The multiplicity of sensors and techniques to document Cultural Heritage objects demonstrates the growing interest in this field; however, a single method can not always guarantee the desired accuracy.
Obstacles, accessibility, problems, cost, time, complexity, size of the object and skill of the survey team play an important role in the choice of a surveying method, each has its own peculiar characteristics. Often a hybrid approach is the best way to achieve more accurate and complete surveying, modeling, interpretation, and digital conservation results.
The research is divided substantially in three parts: the Milan's Cathedral project, the definition of practice to produce 1:1 photogrammetric models and their applications.
The first section speaks about the main case study that permit to test, perform and define good practices, represented by the yards of Milan's Cathedral.
The project commissioned by Veneranda Fabbrica del Duomo in 2008 had its aim in surveying and modeling several parts of the building in order to renew the old drawings made at the beginning of the XX sec. The complexity and the dimension of the architecture suggested employing, in the first phase (2009), the laser scanner approach to survey the monument. Nevertheless, some problems linked to the penetration of the laser beam in the inner structure of Candoglia marble addressed the survey towards the use of photogrammetric technique. Simultaneously, the data acquired were processed in the modeling software comparing which was the best to perform the realization of the model.
The purpose of the survey campaign was also the knowledge of the state of health and the geometry of the monument in order to prepare and assist all the field operations. In the years, the research project evolved into something more stimulating and challenging. First, it was clear that a mere extraction of 2D drawings from a very complex 3D model was reductive so it was thought to use the model as a support to the operations of the restoration yard. The work has developed in different directions by touching some important topics related to: i) multi-sensor data acquisition, ii) multi-source data for 3d modeling, iii) integration of multi-source data, iv) parametric modeling, v) HBIM for yard management, vi) virtualization of very complex architectures and vii) 3d printing.
It must be underlined that the issue was not only the choice of a sensor, software, approach or technique, which will be used for the digital recording of the Cathedral but the need for the creation of an integrated and dynamic system that is able to manage this complex architecture, all the components of the model and the related information. In the last year, the works were focused mainly in finding an efficient method to visualize, use and share the 3D models. BIMDUOMO is a system developed by the 3D Survey Group of Politecnico di Milano and daily used in the yards of the Cathedral. It was created ad hoc in order to modify, update and interact with the surveyed objects both in the modeling software and through web, permitting not only mere visualization, but also to "read" and "write" information. In this sense, it allows wide collaborative activities and real time data updating. The conclusion of the project regards the possibility to develop the system in order to promote the participation of the society in the knowledge and conservation of the Cathedral.
The second part of the thesis is focused in the definition of procedures to obtain 1:1 models of objects belonging to statue and sculptures field, using as much as possible low-cost instruments. The interest in this sector is related to the possibility to use 3D models for: highly accurate geometry description of artifacts, georeferencing of several kind of analysis, management, supporting to restoration, art cataloging in addition to visual communication, prototyping, virtual reconstruction, assembling, and coloring. The spacing between points of the dense cloud (resolution) and the distance from the reference model (RMS error) were assumed as main parameters to discriminate if a model can be considered represented at 1:1 scale.
The theme is treated by using both the photogrammetric approach and two different structured light scanners produced by an Italian industry. The models obtained with the scanners are used as reference because the results in terms of precision are certified.
The tests object are three: a plane marble slab, a head of a statue and a sculpture; then are presented two applications of the method in daily working activity.
The first and the second case were useful to test in Lab some survey parameters: the need or less of targets in the scene, the presence of metric references, the minimum number of photos required to obtain exhaustive models, the geometry of acquisition and boundary conditions. The sculpture case was conducted within a research project financed by Lombardy Region which aim was the realization of a platform that gave the possibility to easily access to Cultural Heritage. The good results obtained in this phase permitted to approach with confidence two important works which goal was the realization of high detailed models addressed to prototyping.
Since that, Cultural Heritage field is no more only a domain for operators, but it is also a resource for economic development, in the last part of the thesis are investigated topics related to the possible use of 3D models in this scenario. In fact, new acquisition methods and instruments are becoming a powerful way to present and analyze artworks in virtual environment, such as web, and real places, such as museums. At the end of the section are studied in deep three examples of applications, namely visual communication, 3D printing and support for experts, using the 3D models obtained in the previous phases of the research.
In this way, the models have not an end in themselves but, with the development of IT tools, it is possible to use them for study, historical knowledge, conservation, management as well as visualization, communication and dissemination.

SURFACE MODIFICATION OF POLYAMIDE THIN FILM COMPOSITE MEMBRANES VIA ZWITTERIONIC POLYMERIZATION FOR BIOFOULING MITIGATION

Miguel Levi Marré Tirado - Supervisor: Prof. Roberto Canziani
Co-Supervisor: Prof. Viatcheslav Freger

In different places of the world, scarcity of water for agriculture irrigation is reaching a critical level. Countries in Africa and Asia as well as California in USA and Chile are being strongly affected by this problem. Constant droughts and the progressive growth in population are well known for being the main causes for the shortage of water. In the past decade, membrane-based treatment technology has proven to be a valid option to supply water for irrigation from non-traditional water sources, such as effluents from wastewater treatment. Membrane-based treatment technology provides a potential tertiary treatment that can remove undesired salts that would limit the growth of many crops. Biofouling of membranes is one problem that can increase costs and prevent a wide use of membranes. Membrane biofouling is the undesirable accumulation of microorganisms and biofilm formation on the membranes that can result in permeate flux decline, requires more frequent cleaning, which leads to increased energy consumption, shortens membrane lifetime and increases salt concentration in the permeate. Surface modification of membranes by polymerization of zwitterionic monomers has been proposed to reduce biofilm formation. Redox-polymerization during filtration and ultraviolet light (UV) polymerization are easily applicable and inexpensive techniques, to modify the surface of thin composite membranes.

In this study we tested the potential of zwitterionic(2-hydroxyethyl) dimethyl(3-sulfopropyl)-ammonium (SPE) via surface modification on nanofiltration NF-270 and on reverse osmosis ESPA-1 membranes for biofouling mitigation. Preliminary conclusions indicate that UV and redox technique modification were successful. However both of them should be optimized to avoid the formation of homopolymer in the process, which result in a reduced efficacy of the process. Contact angle tests allow us to evaluate the hydrophilicity of the membrane surface and were performed on both modified membranes, NF-270 and ESPA-1. A slight increasing trend of the hydrophilicity on the membrane surface was observed. Biofouling studies were performed using a real wastewater effluent collected after MBR treatment and spiked with LB extract as organic substrate for faster bacteria growth. Tests have been carried out at constant pressure and initial permeate flux for pristine and modified membranes. The flux decline was monitored for both membranes, pristine and modified. Cleaning was performed in the system at the beginning and the end of every biofouling experiment. Membrane was compacted with deionized water at a constant pressure until the permeate flux attained a constant value (usually after 6-12h). After attaining a stable flux with deionized water, membrane filtration with real treated wastewater started and both permeate and retentate were recirculated back to the feed reservoir at a constant recirculation rate. Cross flow velocity and shear rate were 14,1 cm s^{-1} and 281 s^{-1} respectively. At the end of the experiment, the biofilm formed on the membrane was analyzed by EPS extraction, ATR-FTIR, SEM and CLSM.

NF-270 membranes were modified with the redox-Concentration Polarization (CP)-polymerization method for biofouling tests. Cross-flow biofouling experiments were performed on modified and pristine NF-270 membranes for confronting to study the effects of poly-SPE for biofouling mitigation. In general, permeate flux decrease results from modified membranes do not show an improvement in membrane properties on biofouling. As for biofilm analysis, the results indicate no significant difference between modified and pristine membrane related to poly-SPE on growth biofilm. We believe that one of the reasons is related to the hydrophilicity and smoothness of NF-270. We think that NF-270 could be already sufficiently hydrophilic to improve its surface properties to avoid the attachment of microorganisms. This is related with the characteristic of the polyamide thin layer, which even if is slightly hydrophobic for salt rejection, low-roughness characteristic of NF-270 play an important role that can be supported by literature. The interaction between low-roughness polyamide layer and poly-SPE probably leads to a fragile physically surface modification, which can be rid off by the cross-flow from the filtration experiments. ESPA-1 membranes modification was performed by UV polymerization for biofouling experiments. The decrease of permeate flux with time through the modified membrane was slightly different if compared to pristine membrane (Fig.1). Biofilm analyses showed lower cell growth on modified membrane than on pristine membrane, but EPS were higher on the modified membranes (Fig.2). Membranes were washed with distillate water to study the flux recovery that confirmed these results. As a matter of fact, the washing was less effective for the modified membrane, as a consequence of a stronger attachment of the biofilm to the membrane surface. Nonetheless, after more than 50 hours of cross-flow biofouling experiment, poly-SPE was still observed on the membrane surface, as proved by ATR-FTIR measurements. On the whole, these results suggest that poly-SPE could mitigate biofouling formation only if attachment of the polymer is uniform and strong enough to resist the shear rate that is typical in cross-flow experiments. In turn, this will depend on the morphology of the polyamide thin film layer. NF-270 polyamide layer is very smooth if compared with ESPA-1, which is rough and presents valleys.

One of the main problems of biofouling is that each single case is particular and different from others: while in some cases the conditions for the development of biofouling can be controlled, in other cases the scenario could be totally different and the same modification method can be uneffective. There are current solutions in place, and even if they do not fully eradicate biofouling, they can help us to control it. Our job now is to know how to apply them considering every single case.

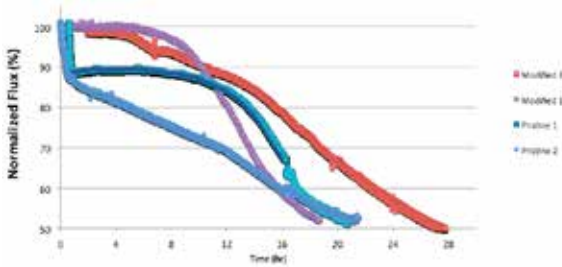


Figure 1: Normalized permeate flux as a function of the filtration time measured for pristine and SPE-modified ESPA-1.

1. Normalized permeate flux as a function of the filtration time measured for pristine and SPE-modified ESPA-1.

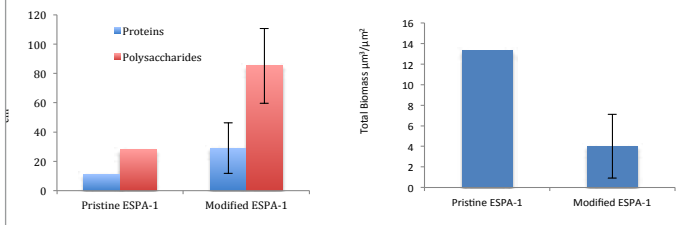


Figure 2 Left: Proteins and polysaccharides extracted from the grown biofilm; right: volume of grown biofilm cells.

2. Left: Proteins and polysaccharides extracted from the grown biofilm; right: volume of grown biofilm cells.

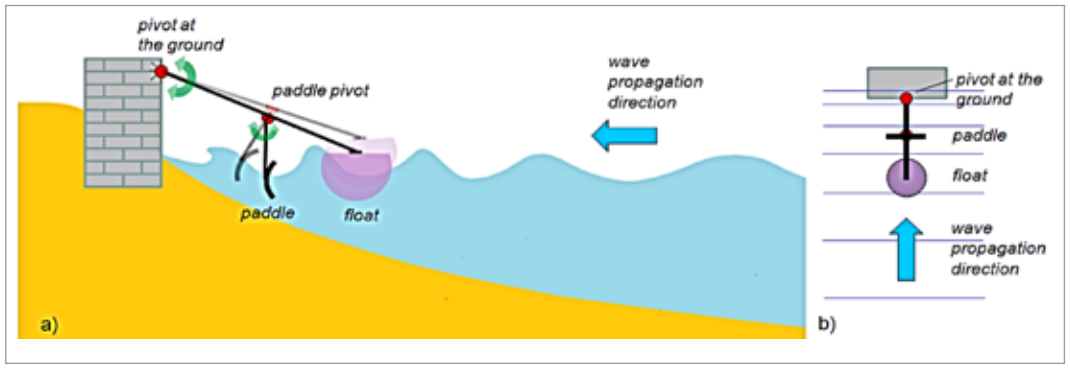
MODELING OF A TWO-OSCILLATING-BODY WAVE ENERGY CONVERTER FOR SHALLOW WATER

Marco Negri - Supervisor: Prof. Stefano Malavasi

Renewable energies are increasingly becoming a main topic of interest, due to the need for sustainable development, the increasing energy world request and the prevision of the running out of the fossil fuels. Among the third generation renewable energies, wave energy is one of the most promising, but its exploitation is not mature yet: unlike wind energy or solar energy, there is not a standardized technology for harnessing wave energy and no device has reach the full commercial state yet.

This PhD work deals with the development and study of an innovative wave energy converter (WEC) for shallow water, the EDS (Energy Double System). The scheme of the EDs system is reported in fig.1. This system has the peculiarity of being composed by two oscillating bodies with different motion modes: a pitching-heaving float and a surging paddle supported by the same arm, which is pivoted over the water and extends seaward. The EDS is a point absorber-type WEC. It is designed for harnessing waves before they break, where they have a relevant surge force and their energy content is still significant, say at depth of 5-10 m depending on the site wave spectrum and site characteristics.

A physical model of the EDS has been built and tested in the wave flume of the Politecnico di Milano. The laboratory model of EDS is reported in fig. 2. It is composed by a main arm which is pivoted at the ground. This arm supports the float at its extremity. Another arm supports the paddle and is pivoted on the main arm. The two degrees of freedom of the system are e, angles of rotation of the float around the pivot at the ground, and the pivot of the paddle arm respectively. The float is composed by a cylindrical upper part with radius r=0.102 m and a hemispherical part in the bottom. The length of the main arm is 0.4 m, the height of the paddle is 0.12 m, the width of the paddle is 2r. Float and paddle are provided with damping system in order to absorb energy, which has been measured by a load cell and a distance sensor (for each damping system). Both damping systems are heaving discs in not-pressurized oil, connected through leverages to the main arm or to the paddle arm. The whole EDS model is fixed on a structure placed over the channel borders, and it can slide along the channel. The EDS model has been tested at various distances from the shoreline, along a sloping beach. Monochromatic waves have been used to test the model, with frequency ranging between $\omega^2 r/g$=0.14÷0.39, where ω is the wave radian frequency and g is the gravity acceleration. Waves have been densely measured along the beach, getting the wave height envelope. Both paddle and float are "light systems", and they are not resonant with any of the waves tested.



1. Scheme of the EDS system. a) lateral view; b) top view.

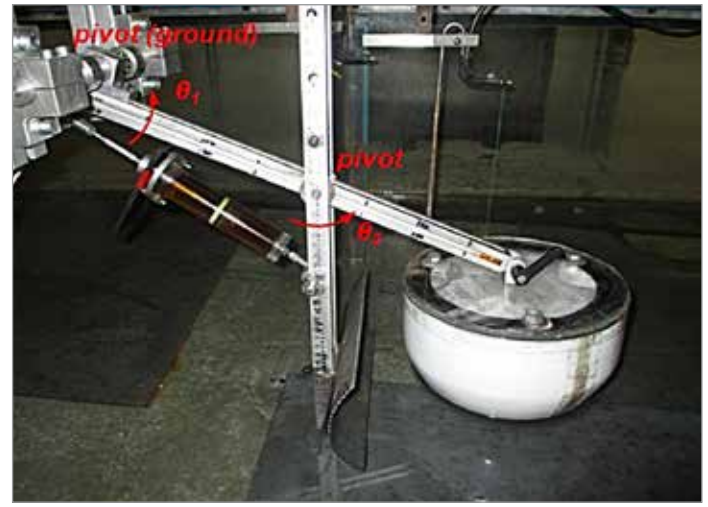
The main geometrical and mechanical parameters of the EDS model has been varied throughout the tests in order to maximize the efficiency of EDS for each wave and at each distance from the shoreline. These parameters are the distance between float and paddle and the external damping of float and paddle. As the EDS system is an evolution of the simpler pitching-heaving float, the latter has been tested too, in order to see the net advantage brought by the paddle to this system. In this way, the behavior of the pitching-heaving float in shallow water has been characterized too. The pitching heaving float is obtained by removing the paddle form the EDS.

The capture width ratio (CWR), or efficiency of the system has been calculated as:

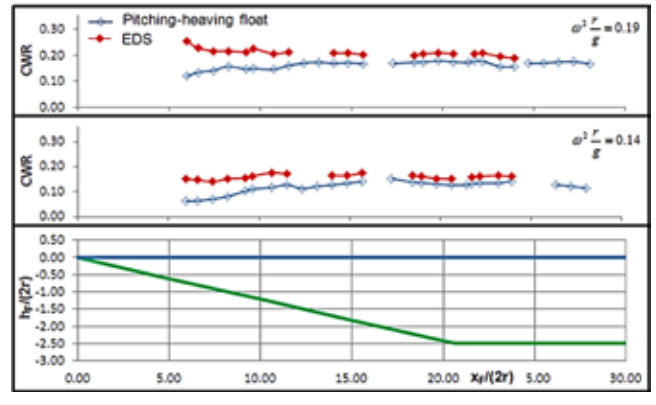
$$\mathrm{CWR} = \frac{P_{out}}{P_{wave} 2r}$$

Where P_{out} is the power absorbed by system, P_{wave} is the wave power per unit width, calculated through linear theory. In the case of the EDS, P_{out} is the sum of the power absorbed by float and by the paddle.

In fig. 3 the efficiency of the EDS system and the pitching-heaving float is reported, for two of the waves tested, as a function of the dimensionless distance of the float from the shoreline $x_F/(2r)$. $h_F/(2r)$ is the dimensionless water depth at the float. CWR varies with distance from the shoreline, for both the pitching-heaving float and the EDS. On average, the efficiency of the float increases as water depth increases. The efficiency of EDS in relation to water depth shows different trends depending on the incident wave. The partial efficiency of the paddle increases as water depth decreases. It has been shown that the EDS system reaches higher efficiencies than the pitching-heaving float, and this difference is significant especially in shallow water and for relatively big waves. For the wave with $\omega^2 r/g$=0.19, the highest efficiency was obtained in very shallow water.



2. Experimental model of the EDS system.



3. Efficiency of EDS system and pitching-heaving float.

ADVANCED METHODS FOR THE SUPPORT OF PLANNING, DESIGN AND MANAGEMENT OF DRINKING WATER SUPPLY SYSTEMS

Giulia Saccani – Supervisor: Manuela Antonelli

Background

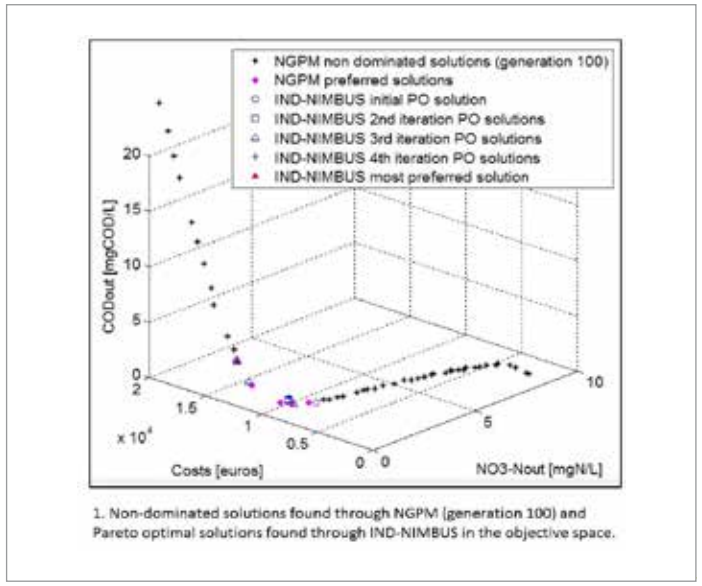
Planning, design and management of a drinking water supply (DWS) system, in industrialized and densely populated urban areas, deals with a high degree of complexity. Its optimization is difficult especially in the case of a relevant water demand to be satisfied through multiple DWS units, spread in the urban area and intercepting various punctual and diffuse pollution plumes. In these cases, an efficient DWS system relies on three main aspects: the deep knowledge of source water quality and its variability, the attentive and optimized design of water processes, and the wise management of water sources and treatment processes.
To correctly tackle these aspects, specific tools could be helpful; however, the application of the appropriate tools to support DWS managers and engineers is not a well-established practice, being support tools mainly reported in literature for research applications or to develop participatory processes for intervention planning.

Objective of the Research

The PhD thesis focused on the application of appropriate support tools in DWS planning, design and management. Three main engineering tasks have been considered: (i) the acquisition of information about source water quality and its variability, (ii) the design of treatment processes, (iii) the conduction and interpretation of pilot studies. The research work considered the DWS system of the city of Milan as a case study, and tackled each one of the above mentioned engineering tasks, proposing and evaluating appropriate support tools and improvements to face identified weaknesses. Doctoral research has been conducted in collaboration with and funded by Metropolitana Milanese s.p.a., that is responsible for the design, construction and management of the drinking water system supplying Milan city urban area.

Key Results

First of all, the evaluation of source water quality and its variability has been considered. Techniques of multivariate statistics were applied as appropriate support tools, namely, Principal Component Analysis (PCA) and Factor Analysis (FA). The application of these techniques is well established in the literature only for the characterization of water bodies; no reference has been found for multivariate statistics as an useful tool for DWS engineers in planning water resource exploitation and DWS treatment infrastructure. Furthermore, the interpretation of results is often poor, especially for what concerns the evaluation of the two distinct component of variability (spatial and temporal). Through the work developed and presented in the PhD thesis, a paradigm is proposed for the detailed study of FA regression scores, and appropriate techniques are applied for the evaluation of spatial and temporal components of variability. The analysis has been performed in a DWS design and management perspective: the improved interpretation of FA results coupled with the geo-referentiation of data through GIS maps has been proposed as a tool for DWS system planning, design and management. Indications for the optimization of water quality monitoring plan, source water exploitation and treatment train planning have been derived.
In particular, an upcoming groundwater pollution by nitrate has been characterized, asking for a dedicated treatment.
To treat nitrate pollution a biological denitrification process has been chosen as interesting technological alternative mainly because of its low management costs, compared to reverse osmosis separation. Beside economic advantages, typical process weaknesses are: a high sensitivity to feeding and operating condition variations, that can invalidate process design effectiveness, as well as possible inhibition mechanisms that organic and inorganic co-pollutant can exert on the denitrifying biomass. For these reasons carrying on a pilot scale test is a good practice for the feasibility study of a biodenitrification unit. Thus, in the second instance, the doctoral work considered the design of a pilot scale biodenitrification unit. The design depends on multiple objectives, often conflicting, as required water quality and treatment efficiency, economic feasibility, or other construction and operational constraints imposed by consideration of the whole treatment train. The choice of the best design solution involves trade-offs. Various multi-objective optimization (MOO) methods are available for trade-offs assessment and optimal design identification. However, neither the criteria adopted for the choice of the MOO method, nor a comparison of efficacy of different mathematical methods, are usually reported in literature. The work developed and presented in the PhD thesis showed how MOO can effectively support the design of a water treatment process and compares two different MOO methods highlighting specific advantages and drawbacks, looking for the most appropriate tool for the optimization of the biofilter design, simulated through a model derived from literature.
Then, an up-flow submerged biofilter was managed at pilot scale for about 3 months. Monitoring data were used for the validation of optimization outputs. At the same time the pilot scale test has been used to study process applicability and efficacy depending on feeding and operating conditions.
In literature, some laboratory or pilot scale studies are reported on heterotrophic denitrification, mainly evaluating the effects of various parameters on nitrate removal efficiency. However, in DWS applications, the evaluation of nitrate removal efficiency has to be completed by other two aspects: the completeness of denitrification reactions and the risk of bacterial regrowth in distribution network, as nitrous nitrogen, organic carbon and biomass concentrations in the treated water have important sanitary drawbacks and are not tolerated. The use of simulation models can then support treatment process management, optimizing its efficacy. In this case a model structure has to be defined, usually choosing among complex biofilm models and more simple models able to consider only removal kinetics. In the PhD thesis, a study based on the pilot scale biofilter experiments is presented, evaluating the effects of both operating and design parameters on denitrification efficacy from all mentioned points of view. A simple simulation model has also been proposed, with a little number of parameters to be calibrated, but able to predict both removal efficiency and biomass growth. Based on pilot scale data, kinetic parameters were calibrated and from their validation, indications for model improvement have been suggested.



1. Non-dominated solutions found through NGPM (generation 100) and Pareto optimal solutions found through IND-NIMBUS in the objective space.

1. Non-dominated solutions found through NGPM (generation 100) and Pareto optimal solutions found through IND-NIMBUS in the objective space.

POLLUTION TRANSFORMATIONS IN SEWER SYSTEMS: CASE STUDY OF THE CITY OF MILAN

Shervin Shahvi - Supervisor: Prof. Enrico Orsi
Co-Supervisor: Prof. Roberto Canziani

Sewers, among other city infrastructures, are of major importance because of their role in public health and the adjacent environment pollution condition. It is well-known that they are not just a conveyance system for urban sanitary and stormwater, but they also chemical and biological reactors where organic substances as well as non-organic ones transform considerably inside. To understand better the kind and extent of the pollution transformation within these systems, it is necessary to recognize and to classify the different substance flowing in sewers. It is also important to know the characteristics of the network under study: is it a combined or a separate system? Is it a fully-gravity systems or pumping stations are installed in some parts? Which redox condition dominating in each part of the network? And etc. Considering the importance of sewers, different benefits can be achieved by re-designing some parts of the network.
Through innovative use of sewer networks and of the treatment system one of the probable benefit may be to recycle part of the nutrients removed by harvest in agricultural soil, food safety, lower treatment costs and reduction of pollution in surface and underground water. Nutrient recovery is very important for food safety: primary sources are lacking and limited availability might curb agricultural production. To allow agricultural use of sludge to recover nutrients, wastewater carried by the sewer network must not contain concentrations of elements that might be potentially harmful to health (heavy metals, harmful, toxic, cancerogenic or mutagenic compounds and endocrine disruptors) especially if they are bioaccumulative and persistent.
In this study the west part of sewer network of the city of Milan has been studied. In order to come up with the results of the degradation of domestic organic matter in the network, the hydrodynamic model of the system should be coupled with its quality one. A well-calibrated hydrodynamic model is the main requisite of the research; hence the hydraulic results were compared with the measured data and a proper calibration obtained. The quality model was made assuming the standard values of per capita production of BOD, considering the different processes occurred in aerobic condition and was later calibrated against the real data where results showed proper fit. The project is planned to a future experimental campaign and in order to ensure the overall system operation, drain points will be detected and monitored, especially in production sites, and pre-treatment processes will be analysed. Hence sensitivity analysis of the organic matter fractions was necessary to do in order to estimate the importance and effect of each parameter.
The non-organic substances which study trough this research were some macropollutants including hydrocarbons, surfactants and heavy metals, usually discharging from particular industrial sites. To achieve this goal a list of the industries in the network and their probable pollution and concentrations were studied.
It is necessary in future to install a monitoring system for measurement of accidental discharge of pollutants from industrial activities and real time protection of the wastewater treatment plant (WWTP) by avoiding dangerous discharges entering the sewers. Heavy metals, surfactants and hydrocarbons have different behavior from biodegradable domestic sewage and can be modeled as conservative matter conveyed by advection and dispersion.
To summarize, this research will verify different types of operation of the sewer network through hydraulic modelling, monitoring and assessing the impacts of the different wastewater types in terms of quantity and quality. Some mathematical models were built and developed to simulate the different kinds of urban wastewater pollution. This study will estimate environmental benefits and both methodology and modeling techniques can be extended to other cities in Italy and Europe.

Keywords: Sewer systems, hydraulic model. quality model, aerobic condition, organic matter, non-organic substances.