IN PARTNERSHIP WITH:
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Institut polytechnique de Grenoble

Université Joseph Fourier (Grenoble)

Activity Report 2012

Exploratory Action STEEP

Sustainability transition, environment, economy and local policy

IN COLLABORATION WITH: Laboratoire Jean Kuntzmann (LJK)

RESEARCH CENTER
Grenoble - Rhône-Alpes

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Exploratory Action STEEP

Keywords: Modeling, Simulation, Environment, Socio-economic Models, Territorial Scales

Creation of the Exploratory Action: January 01, 2010 .

1. Members

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2. Overall Objectives

2.1. Overview

STEEP started in January 2010, initially as an Inria "Action Exploratoire" (2010+2011). It is currently an "équipe centre" of Inria Grenoble - Rhône-Alpes and is also affiliated with the Jean Kuntzmann laboratory (LJK [1]). The process of creating an EPI (équipe projet Inria) is underway and planned to be completed in 2013.

STEEP is an interdisciplinary research team devoted to systemic modelling and simulation of the interactions between the environmental, economic and social factors in the context of a transition to sustainability at local (sub-national) scales. Our goal is to develop decision-making tools to support decision makers in the implementation of this transition by developing simulation and optimization programs. In other words, our objective is to set up some mathematical and computational tools which enable us to provide some parts of the answer to the challenges *how to operate the sustainable development at local scales? and which local governance for environmental public policies?*.

This theme is new at Inria, but also for the researchers of STEEP who previously worked in other fields. Elise Arnaud, Emmanuel Prados and Peter Sturm worked on computer vision and Pierre-Yves Longaretti is a physicist. Some STEEP staff are still in the process of their own thematic transition and a significant part of their activity is not or only briefly mentioned in this document.

[1] http://ljk.imag.fr/

The work of STEEP follows several research directions, covering different application domains; these are described in “Scientific Foundations” and “Application Domains” respectively.

2.2. Sustainable development: issues and research opportunities

Sustainable development is often formulated in terms of a required balance between the environmental, economic and social dimensions, but public policies addressing sustainability are in practice dominantly oriented towards environmental issues in Western countries. However, the numerous and interrelated pressures exerted by human activity on the environment make the identification of sustainable development pathways arduous in a context of complex and sometimes conflicting stakeholders and socio-ecological interactions.

The sustainability of urban areas is one of the key issues of this century. As focal points of human activity, urban areas concentrate and amplify environmental pressures in a direct or indirect way. Urbanization is a global process, with more than half the human population living in cities, an ever-increasing trend. Furthermore, urban sprawl is a ubiquitous phenomenon showing no sign of slackening yet, even in countries where rural depopulation has long been stabilized. Urban sprawl in industrialized countries is largely driven by residential peri-urban growth. This phenomenon has both social and environmental consequences, like an increased vulnerability of some population categories or a fragmentation of ecological habitat. Controlling urban sprawl is therefore a key sustainability issue.

The issues just described require a panel of policy measures at all institutional levels, as they illustrate the existence of both local-local and local-global feedback loops. The regional (sub-national) and more local levels are of particular importance for the transition to sustainability, especially in a “think global/act local” approach that is up to now mostly oriented towards local climate and territorial energy plans. In this context, more local decision levels have real political and economic leverage, and are more and more proactive on sustainability issues, either independently or in coordination through nationwide or European networks.

STEEP, with its strong background in various areas of applied mathematics and modeling, can be a game changer in three connected key domains: urban economy, and related transportation and land use issues; material flow analysis and ecological accounting; and ecosystem services modeling. The group potential on these fronts relies on its capabilities to strongly improve existing integrated activity / land use / transportation models at the urban level on the one hand, and on the other, to build new and comprehensive decision-help tools for sustainability policies at the local and regional levels, in particular through the analysis of strategic social–environmental trade-offs between various policy options.

2.3. Highlights of the Year

A highlight of our young team has been the successful submission of a multi-disciplinary ANR project coordinated by us (CITiES project, see further below). It is our first significant grant and creates a formal framework for our already existing collaborations with various partners throughout France.

Amaël Delaunoy has been the recipient of the annual PhD thesis award of AFRIF (Association Française pour la Reconnaissance et l’Interprétation des Formes), for his thesis *Modélisation 3D à partir d’images : contributions en reconstruction photométrique à l’aide de maillages déformables*, supervised by E. Prados and P. Sturm.

3. Scientific Foundations

3.1. Development of numerical systemic models (economy / society / environment) at local scales

The problem we consider is intrinsically interdisciplinary: it draws on social sciences, ecology or science of the planet. The modeling of the considered phenomena must take into account many factors of different nature which interact with varied functional relationships. These heterogeneous dynamics are *a priori* nonlinear and complex: they may have saturation mechanisms, threshold effects, and may be density dependent. The difficulties are compounded by the strong interconnections of the system (presence of important feedback loops) and multi-scale spatial interactions. Environmental and social phenomena are indeed constrained by the geometry of the area in which they occur. Climate and urbanization are typical examples. These spatial processes involve proximity relationships and neighborhoods, like for example, between two adjacent parcels of land, or between several macroscopic levels of a social organization. The multi-scale issues are due to the simultaneous consideration in the modeling of actors of different types and that operate at specific scales (spatial and temporal). For example, to properly address biodiversity issues, the scale at which we must consider the evolution of rurality is probably very different from the one at which we model the biological phenomena.

In this context, to develop flexible integrated systemic models (upgradable, modular, ...) which are efficient, realistic and easy to use (for developers, modelers and end users) is a challenge in itself. What mathematical representations and what computational tools to use? Nowadays many tools are used: for example, cellular automata (e.g. in the LEAM model), agent models (e.g. URBANSIM), system dynamics (e.g. World3), large systems of ordinary equations (e.g. equilibrium models such as TRANUS), and so on. Each of these tools has strengths and weaknesses. Is it necessary to invent other representations? What is the relevant level of modularity? How to get very modular models while keeping them very coherent and easy to calibrate? Is it preferable to use the same modeling tools for the whole system, or can we freely change the representation for each considered subsystem? How to easily and effectively manage different scales? (difficulty appearing in particular during the calibration process). How to get models which automatically adapt to the granularity of the data and which are always numerically stable? (this has also a direct link with the calibration processes and the propagation of uncertainties). How to develop models that can be calibrated with reasonable efforts, consistent with the (human and material) resources of the agencies and consulting firms that use them?

Before describing our research axes, we provide a brief overview of the types of models that we are or will be working with. As for LUTI (Land Use and Transportation Integrated) modeling, we have been using the TRANUS model since the start of our group. It is the most widely used LUTI model, has been developed since 1982 by the company Modelistica [2], and is distributed *via* Open Source software. TRANUS proceeds by solving a system of deterministic nonlinear equations and inequalities containing a number of economic parameters (e.g. demand elasticity parameters, location dispersion parameters, etc.). The solution of such a system represents an economic equilibrium between supply and demand. A second LUTI model that will be considered in the near future, within the CITiES project, is UrbanSim [3]. Whereas TRANUS aggregates over e.g. entire population or housing categories, UrbanSim takes a micro-simulation approach, modeling and simulating choices made at the level of individual households, businesses, and jobs, for instance, and it operates on a finer geographic scale than TRANUS.

On the other hand, the scientific domains related to eco-system services and ecological accounting are much less mature than the one of urban economy. Nowadays, the community working on ecological accounting and material flow analysis only proposes statistical models based on more or less simple data correlations. The eco-system service community has been using statical models too, but is also developing more sophisticated models based for example on system dynamics, multi-agent type simulations or cellular models. In the ESNET project, STEEP will work in particular on a land cover model (CLUE-S [4]) which belongs to the last category.

In the following, our three main research axes are described.

3.2. Model calibration and validation

The overall calibration of the parameters that drive the equations implemented in the above models is a vital step. Theoretically, as the implemented equations describe e.g. socio-economic phenomena, some of these parameters should in principle be accurately estimated from past data using econometrics and statistical methods like regressions or maximum likelihood estimates, e.g. for the parameters of logit models describing

[2] http://www.modelistica.com/english
[3] http://www.urbansim.org
[4] http://www.ivm.vu.nl/en/Organisation/departments/spatial-analysis-decision-support/Clue

the residential choices of households. However, this theoretical consideration is often not efficient in practice for at least two main reasons. First, the above models consist of several interacting modules. Currently, these modules are typically calibrated independently; this is clearly sub-optimal as results will differ from those obtained after a global calibration of the interaction system, which is the actual final objective of a calibration procedure. Second, the lack of data is an inherent problem.

As a consequence, models are usually calibrated by hand. The calibration can typically take up to 6 months for a medium size LUTI model (about 100 geographic zones, about 10 sectors including economic sectors, population and employment categories). This clearly emphasizes the need to further investigate and at least semi-automate the calibration process. Yet, in all domains STEEP considers, very few studies have addressed this central issue, not to mention calibration under uncertainty which has largely been ignored (with the exception of a few uncertainty propagation analyses reported in the literature).

Besides uncertainty analysis, another main aspect of calibration is numerical optimization. The general state-of-the-art on optimization procedures is extremely large and mature, covering many different types of optimization problems, in terms of size (number of parameters and data) and type of cost function(s) and constraints. Depending on the characteristics of the considered models in terms of dimension, data availability and quality, deterministic or stochastic methods will be implemented. For the former, due to the presence of non-differentiability, it is likely, depending on their severity, that derivative free control methods will have to be preferred. For the latter, particle-based filtering techniques and/or metamodel-based optimization techniques (also called response surfaces or surrogate models) are good candidates.

These methods will be validated, by performing a series of tests to verify that the optimization algorithms are efficient in the sense that 1) they converge after an acceptable computing time, 2) they are robust and 3) that the algorithms do what they are actually meant to. For the latter, the procedure for this algorithmic validation phase will be to measure the quality of the results obtained after the calibration, i.e. we have to analyze if the calibrated model fits sufficiently well the data according to predetermined criteria.

To summarize, the overall goal of this research axis is to address two major issues related to calibration and validation of models: (a) defining a calibration methodology and developing relevant and efficient algorithms to facilitate the parameter estimation of considered models; (b) defining a validation methodology and developing the related algorithms (this is complemented by sensitivity analysis, see the following section). In both cases, analyzing the uncertainty that may arise either from the data or the underlying equations, and quantifying how these uncertainties propagate in the model, are of major importance. We will work on all those issues for the models of all the applied domains covered by STEEP.

3.3. Sensitivity analysis

A sensitivity analysis (SA) consists, in a nutshell, in studying how the uncertainty in the output of a model can be apportioned to different sources of uncertainty in the model inputs. It is complementary to an uncertainty analysis, which focuses on quantifying uncertainty in model output. SA's can be useful for several purposes, such as guiding model development and identifying the most influential model parameters and critical data items. Identifying influential model parameters may help in divising metamodels (or, surrogate models) that approximate an original model and may be simulated, calibrated, or analyzed more efficiently. As for detecting critical data items, this may indicate for which type of data more effort must be spent in the data collection process in order to eventually improve the model's reliability. Finally, SA can be used as one means for validating models, together with validation based on historical data (or, put simply, using training and test data) and validation of model parameters and outputs by experts in the respective application area. All these uses of SA will be considered in our research.

The first two applications of SA are linked to model calibration, discussed in the previous section. Indeed, prior to the development of the calibration tools, one important step is to select the significant or sensitive parameters and to evaluate the robustness of the calibration results with respect to data noise (stability studies). This may be performed through a global sensitivity analysis, e.g. by computation of Sobol's indices. Many problems will have to be circumvented e.g. difficulties arising from dependencies of input variables, variables that obey a spatial organization, or switch inputs. We will take up on current work in the statistics community on SA for these difficult cases.

As for the third application of SA, model validation, a preliminary task bears on the propagation of uncertainties. Identifying the sources of uncertainties and their nature is crucial to propagate them via Monte Carlo techniques. To make a Monte Carlo approach computationally feasible, it is necessary to develop specific metamodels. Both the identification of the uncertainties and their propagation require a detailed knowledge of the data collection process; these are mandatory steps before a validation procedure based on SA can be implemented. First, we will focus on validating LUTI models, starting with the CITiES ANR project: here, an SA consists in defining various land use policies and transportation scenarios and in using these scenarios to test the integrated land use and transportation model. Current approaches for validation by SA consider several scenarios and propose various indicators to measure the simulated changes. We will work towards using sensitivity indices based on functional analysis of variance, which will allow us to compare the influence of various inputs on the indicators. For example it will allow the comparison of the influences of transportation and land use policies on several indicators.

3.4. Modeling of socio-economic and environmental interactions

Considering the assessment of socio-economic impacts on the environment and ecosystem service analysis, the problems encountered here are intrinsically interdisciplinary: they draw on social sciences, ecology or Earth sciences. The modeling of the considered phenomena must take into account many factors of different nature which interact *via* various functional relationships. These heterogeneous dynamics are *a priori* nonlinear and complex: they may have saturation mechanisms, threshold effects, and may be density dependent. The difficulties are compounded by the strong interconnections of the system (presence of important feedback loops) and multi-scale spatial interactions. The spatial processes involve proximity relationships and neighborhoods, like for example, between two adjacent parcels of land. The multi-scale issues are due to the simultaneous consideration in the modeling of actors of different types and that operate at specific scales (spatial and temporal). For example, to properly address biodiversity issues, the scale at which we must consider the evolution of rurality is probably very different from the one at which we model the biological phenomena. The multi-scale approaches can also be justified by the lack of data at the relevant scales. This is for example the case for the material flow analysis at local scales for which complex data disaggregations are required.

At this stage, it is crucial to understand that the scientific fields considered here are far from being mature. For example, the very notions of ecosystem services or local ecological accounting are quite recent and at best partially documented, but advances in those fields are essential, and will be required to identify transition paths to sustainability. Nowadays, the analyses are only qualitative or statistic. The phenomena are little understood. Our goal here is then to do upstream research. It is to anticipate and to help the development of modeling tools that will be used tomorrow in these fields.

Developing flexible integrated systemic models (upgradable, modular, ...) which are efficient, realistic and easy to use (for developers, modelers and end users) is a challenge in itself. What mathematical representations and what computational tools to use; cellular automata, multi-agent models, system dynamics, or large systems of equations describing equilibrium models? Is it necessary to invent other representations? What is the relevant level of modularity? How to get very modular models while keeping them very coherent and easy to calibrate? Is it preferable to use the same modeling tools for the whole system, or can we freely change the representation for each considered subsystem? How to easily and effectively manage different scales? How to get models which automatically adapt to the granularity of the data and which are always numerically stable? How to develop models that can be calibrated with reasonable efforts, consistent with the (human and material) resources of the agencies and consulting firms that use them?
Providing satisfying answers to these questions is a long term goal for STEEP.

4. Application Domains

4.1. Urban economy and land use and transport modeling

Modern urban regions are highly complex entities. The understanding of the phenomena underlying urban sprawl and peri-urbanization is a key element to control the dynamics structuring urban space. Clearly, urban transport systems are intricately linked to urban structure and the distribution of activities, i.e., to land use. Urbanization generally implies an increase in travel demand. Cities have traditionally met this additional demand by expanding the transportation supply, through new highways and transit lines. In turn, an improvement of the accessibility of ever-farther land leads to an expansion of urban development, resulting in a significant feedback loop between transportation infrastructure and land use, one of the main causes of urban sprawl.

Several models have been developed in the field of urban economics to understand the complex relationship between transportation and land use and to facilitate the urban planning process. They enable the simulation of public policies and the quantification of indicators describing the evolution of urban structure. Key factors such as transport congestion, energy consumption, CO2 emissions etc., can be evaluated or estimated, and different urban development scenarios can be tested in a quantitative manner.

Yet, very few local authorities in charge of planning issues make use of these strategic models, mostly because they are difficult to calibrate and validate, two critical steps where systematic improvement would increase the level of confidence in the obtained results. These limitations prevent dissemination in local agencies. One goal of STEEP is therefore to meet the need of better calibration and validation strategies and algorithms. This research is the core of our projects CITiES (ANR Modèles Numériques) and TRACER (Ecos Nord Venezuela).

4.2. Ecological accounting and material flow analysis

One of the major issues in the assessment of the long-term sustainability of urban areas is related to the concept of “imported sustainability”. Indeed, any city brings from the outside most of its material and energy resources, and rejects to the outside the waste produced by its activity. The modern era has seen a dramatic increase in both volume and variety of these material flows and consumption as well as in distance of origin and destination of these flows, usually accompanied by a spectacular increase in the associated environmental impacts. A realistic assessment of the sustainability of urban areas requires to quantify both local and distant environmental impacts; greenhouse gas emissions are only one aspect of this question.

In order to produce such an assessment for a given territory or urban area, one must first establish different types of ecological accounting: one must identify and quantify the different types of material and energy uses on the one hand, and the different types of impact associated to these uses. The first task is the object of Material Flow Analysis (MFA), while the second is more directly related to the logic of Life Cycle Analysis (LCA). One of the major challenges here is to obtain reliable MFA data at the region and *département* scales, either directly, or through appropriate disaggregation techniques.

The STEEP group has started a research program on this theme with three major aims in mind: 1) Creating a comprehensive database enabling such analyses; 2) Developing methodology and models resolving scaling issues, and developing algorithms allowing to rigorously and automatically obtain the adequate assessments; 3) Providing a synthetic analysis of environmental impacts associated to the major material flows, at various geographic levels (employment catchment area, *département* and *région*, for France). The database elaboration is already well underway, and apparently does not yet have any equivalent elsewhere in France. The impact evaluation and decision help strategy (i.e., evaluating alternative policy options in term of environmental impact) will be developed in collaboration with a private company ARTELIA, through a CIFRE PhD thesis that is scheduled to start early 2013, and will be based on existing LCA databases. The PhD student is co-directed with Denis Dupré from CERAG (Centre d’Etudes et de Recherches Appliquées à la Gestion).

4.3. Eco-system services

Long-term sustainability is closely related to the underlying ecosystems, on various fronts: production of renewable resources (either energy or biomass), waste and pollutant resorption, local and global climate regulations etc. These various functions constitute the “ecosystem services” provided to society by our natural environment.

The reduction of the adverse impacts of urban areas on the environment is linked not only to limiting urban sprawl and making more efficient use of the available resources, but also to developing a better grasp of the interrelations between urban/peri-urban areas and their agricultural and semi-natural surroundings. In particular, reducing distant impacts while making a better use of local resources is a major challenge for the coming decades.

In this context, the STEEP team is involved in a project bearing on the characterization of local Ecosystem Services NETworks (ESNET), piloted by LECA (*Laboratoire d’Ecologie Alpine*), and in collaboration with a number of other research laboratories (most notably, IRSTEA Grenoble) and a panel of local stakeholders; the scale of interest is typically a landscape (in the ecologic/geographic sense, i.e., a zone a few kilometers to a few tens of kilometers wide). The project aims at developing a generic modelling framework of ecosystem services, and studying their behavior under various scenarios of coupled urban/environment evolution. The contribution of the STEEP team is centered on the Land Use/Land Cover Change (LUCC) model that will be one of the major building blocks of the whole model, with the help of specifically hired personal.

The project has been supported by FRB (*Fondation pour la Recherche en Biodiversité*) and will be funded by ONEMA (*Office National de l’Eau et des Milieux Aquatiques*) for the three years of its duration.

5. Software

5.1. TEOS: Tranus Exploration and Optimization Software

Participants: Anthony Tschirhard, Mathieu Vadon, Elise Arnaud, Emmanuel Prados.

The TEOS software offers a set of tools to help the calibration of the land use and transport integrated model TRANUS. It uses some exploration and optimization procedures of the relevant parameters.

6. New Results

6.1. Calibration of TRANUS Adjustment Parameters

One of the most difficult steps in calibrating the parameters of the TRANUS land use model, concerns the estimation of its adjustment parameters (so-called shadow prices), that allow to “absorb” imperfections of the model or the data. The main difficulties are the non-linearity of the underlying equations and the fact that some of these equations give rise to loops between intermediate system variables: modifications of some of these variables entail modifications of others and vice-versa. In other words, the concerned part of TRANUS is a dynamic system. Currently, users of TRANUS perform the calibration by semi-automatic (at best) trial-and-error.

We have started investigating more systematic solutions to this. A first step has been to explicitly pose the estimation problem in the form of an optimization problem, with clearly stated cost function and constraints. Next, we have found ways of splitting the problem into separable subproblems, concerning the estimation of adjustment parameters for different economic sectors. In particular, the housing/land sectors can be calibrated independently of the others. A simple gradient descent was shown to be sufficient, both theoretically and experimentally, to achieve this calibration. We are currently investigating strategies to estimate the adjustment parameters of the remaining sectors.

6.2. Calibration of TRANUS Using Maximum Likelihood Estimation

Calibration of the TRANUS land use module typically involves determination of key parameters which dictate land use assignments and prices. As mentioned earlier, It is a difficult task to calibrate a LUTI model as the number of parameters involved are large and are uncertain. Traditionally, these models are calibrated manually by experts, who try to estimate the parameters using their prior experience. However, such a method is difficult as well as time consuming, especially when the parameter space is large and uncertain. Hence, an algorithmic procedure to estimate parameters from mathematical model is desired.

We have proposed an algorithm to calibrate the land use module of TRANUS using maximum likelihood estimation (MLE). The observed outputs of the land use module is modeled to follow a Gaussian process. The covariance matrix is represented as a function of inputs of the land use module and hyperparameters. A MLE optimization problem is then formulated to estimate the parameters of the land use module and the hyperparameters of the Gaussian covariance kernel. The resulting nonlinear programming (NLP) problem is then solved using NLP solvers based on sequential quadratic programming.

The proposed calibration algorithm has been successfully applied to the model of Grenoble, France ; and the performance of the proposed calibration methodology, has been compared to traditional calibration techniques. The metric to judge performance is assumed to be the $\mathcal{L}_2$ norm of the difference between observed and calculated land use assignments obtained using the calibrated model.

Before this calibration task is performed, a sensitivity analysis has been carried out. Hence, sensitivity analysis of the parameters on the output is important as is helps us identify major sources of uncertainty in terms of their contribution towards output space variability. Here, the *total effect* of the land use parameters on a *quantity of interest* or *QoI* is assessed. The *QoI* is assumed to be the $\mathcal{L}_2$ norm of the difference between observed and calculated land use assignments. For this Grenoble model, the number of uncertain parameters involved are 100, and finally is is observed that only 3 amongst them contribute towards 99.2% of *QoI* variability. [14], [13]

6.3. Material flows, production and consumption at sub-national geographic levels

As explained earlier, estimating the actual environmental impact of an urban area on the one hand, and the efficiency of (local or national) policy options in reducing these impacts on the other, requires an understanding of the material flows and material uses generated by the considered urban area. It is important to realize that impacts (both local and distant) can vary greatly from one region or departement to the next, depending on its agricultural and industrial characteristics. The whole point of this work is to evaluate as best as possible these variations, in order to best adapt public policies in terms of environmental impacts, for given socio-economic conditions and objectives.

The first step in this analysis is to establish a database of production, consumption and exchanges (import and export) at the various geographic levels of interest, and for the various types of material of interest. In practice, the finest scale of available data is a French *département*, and the publicly available data refer to the national, regional or "departemental" level. Only major primary materials are accounted for, through the content of end products and waste in these primary materials (toxic waste are accounted for separately). For example, for cereals such as wheat, production at the departement level is available through the national *Agreste* database, variations of stock are small once averaged over a few years period, import and export are obtained from the *Sitram* database (a database initially elaborated by the ministry of transportation and now maintained by the Ministry of Environment), which follows all national and international transport by transportation mode and by type, through annual stratified polls of transportation companies. Productions of non-agricultural products in France is very low except for construction materials (most notably cement), for which the industry maintains its own publicly available database. Following transformations requires information from various industrial sectors, e.g., the flour trade and food industry for wheat use, taking into account animal farming which consumes a non-negligible fraction of primary agricultural products.

Once this database is constructed, one also needs to estimate production, consumption and imports and exports at finer scale than the departement. In practice, this is performed by correlating the desired information at the national, regional and departemental scale with another auxiliary quantity serving as proxy, that is also known at the desired smaller scale. For example, wheat production can easily be correlated with available surfaces in wheat growing areas, that are known from the Corine Land Cover database at scales of the order of a few hundred meters. More generally, auxiliary quantities are constructed from relevant demographic and economic and geographic data, that are mostly available through the various INSEE databases. This requires some educated guess-work to find the most likely auxiliary quantities, and evaluate their correlation with the quantities of interest at scales where data on both are available. This aspect of the problem has been completed only for food staples at this stage.

An important aspect of the problem is to estimate the errors in the data. Errors can be detected when quantities of a given material are not conserved through transportation and transformation processes. It appears that the largest source of error comes from the transportation database, because the stratified polling methodology is optimized with respect to total transport from a pair of origin and destination, independently of the nature of the transported goods. It is in principle possible to compute confidence intervals per type of material and not only on total volumes of exchanges, but this requires access to some non public information. Discussions have been initiated with the Ministry to have access to this information, in order to estimate the reliability of this method of transport quantification. If the *Sitram* database turns out to be too imprecise, the method described above to estimate lacking data can be applied to transport as well with appropriate auxiliary quantities, but the results also suffer from various sources of error.

This first stage of the Material Flow analysis is nevertheless largely underway. The two next steps consist in environmental impact evaluation on the one hand, at the present date, and in developing a method of analysis of changes of such impacts under various policy scenarios and options. Bith will rely on the use of Life Cycle Analysis databases, as mentioned above.

6.4. Computer vision

Three of our permanent staff have previously been active in computer vision. This activity is gradually coming to an end: the last PhD student has defended his thesis in 2012 and no new projects are started. Since this topic is not central to STEEP, results are only summarized very briefly. The main scientific result has been the development of a novel approach for 3D modeling of semi-transparent objects, which couples both, geometric and photometric information [1]. This allows 3D modeling with fewer input images than previously and potentially, with a higher accuracy. Besides this, our main activity in computer vision has been related to industrial projects, the main goal being to finalize our work of the last years with an industrial transfer.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts with Industry

EADS Astrium We have been sub-contractors of EADS Astrium in several national and international application-oriented projects. This activity is related to the previous research in computer vision of some team members.

7.2. Bilateral Grants with Industry

ARTELIA We have agreed on a CIFRE scheme for a PhD on the topic: Material flow and environmental impact analyses at local scales, from labor pools to regions. We are currently waiting for the validation by ANRT.

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. ANR

CITiES (*Calibrage et valIdation de modèles Transport - usagE des Sols*)
Program: "*Modèles Numériques*" 2012, ANR
Duration: 2013 – 2016
Coordinator: Emmanuel Prados (STEEP)
Other partners: LET, IDDRI, IRTES-SET ("Systemes and Transports" lab of Univ. of Tech. of Belfort-Montbéliard), IFSTTAR-DEST Paris (formerly INRETS), LVMT ("*Laboratoire Ville Mobilité Transport*", Marne la Vallée), VINCI (Pirandello Ingenierie, Paris), IAU Île-De-France (Urban Agency of Paris), AURG (Urban Agency of Grenoble), MOISE (Inria project-team)
Abstract: Calibration and validation of transport and land use models.

8.1.2. FRB (Fondation pour la Recherche sur la Biodiversité)

ESNET (Futures of ecosystem services networks for the Grenoble region)
Program: "Modeling and Scenarios of Biodiversity" flagship program, Fondation pour la Recherche sur la Biodiversité (FRB). This project is co-funded by ONEMA (*Office National de l'Eau et des Milieux Aquatiques*).
Duration: 2013 – 2016
Coordinator: Sandra Lavorel (LECA)
Other partners: EDDEN (UPMF/CNRS), IRSTEA Grenoble (formerly CEMAGREF), PACTE (UJF/CNRS), ERIC (Lyon 2/CNRS)
Abstract: This project explores alternative futures of ecosystem services under combined scenarios of land-use and climate change for the Grenoble urban area in the French Alps. In this project, STEEP works in particular on the modeling of the land use and land cover changes, and to a smaller extent on the interaction of these changes with some specific services.

8.2. European Initiatives

8.2.1. Collaborations in European Programs, except FP7

Program: European Space Agency call: "Camera-aided Mars Landing and Rendezvous Navigation System"

Project acronym: MREP Camera

Project title: Camera-aided Mars Landing and Rendezvous Navigation System

Duration: Apr 2012 – Dec 2013

Coordinator: EADS Astrium (France)

Other partners: DEIMOS (Portugal), TNO (Netherlands), Sodern (France), NGC Aerospace (France)

Abstract: Our main goal in this project is the 3D modeling of planetary surfaces and the detection of potential landing zones of space vessels.

8.2.2. Collaborations with Major European Organizations

Partner 1: organisme 1, labo 1 (pays 1)

Sujet 1 (max. 2 lignes)

8.3. International Initiatives

8.3.1. Inria International Partners

Universidad Central de Venezuela (Urban Department) and its spin-off Modelistica: The TRANUS model was developed there. Prof. Tomás de la Barra visited us in 2011 and is an associated partner of our ANR project CITiES.

8.3.2. Participation In International Programs

TRACER (*TRanus, Analyse de la Calibration et des Erreurs, Retours sur Grenoble et Caracas*)
Program: ECOS NORD Venezuela
Duration: 2012 – 2016
Coordinators: Laurence Tubiana (IDDRI), Tomás de le Barra (*Universidad Central de Venezuela*)
Other partners: IDDRI, STEEP, Universidad Central de Venezuela (Urban Institute)
Abstract: The objective of this project is to study robustness and calibration issues on the TRANUS land use model.

8.4. International Research Visitors

8.4.1. Visits of International Scientists

Juho Kannala, Feb+Mar 2012, Oulu University, Finland

8.4.2. Internships

Franco Pestarini (from Apr 2012 until Sep 2012)

Subject: Re-implementation of a land use / transport model

Institution: National University of Rosario (Argentina)

Martin Crespo (from Jul 2012 until Dec 2012)

Subject: Parameter optimization algorithm for a Transport/land use model via adjoint method.

Institution: Universidad National de Rosario (Argentina)

8.4.3. Visits to International Teams

Anthony Tschirhard carried out his MSc project at UC Berkeley, under the supervision of Paul Waddell, the chief developer of the UrbanSim model.

9. Dissemination

9.1. Scientific Animation

- E. Prados is member of the scientific and technical Committee of the GIS (Groupement d'intérêt scientifique) Modélisation urbaine since January 2012.
- E. Prados has been member of the steering committee of the FRB (Fondation pour la Recherche sur la Biodiversité) program modelling and scenarios for the biodiversity from June 2010 to June 2012.
- P.-Y. Longaretti manages the informal SOCLE[3] group. This group brings together researchers from various fields of expertise in exact, environmental and social sciences, with the objective to coordinate their respective research programs on the question of sustainability transition at local scales.
- P. Sturm has been Program Chair of RFIA 2012 – Congrès de Reconnaissance des Formes et Intelligence Artificielle, Lyon, France
- P. Sturm has been Area Chair of ECCV 2012 – European Conference on Computer Vision, Florence, Italy
- P. Sturm has been Area Chair of ICPR 2012 – International Conference on Pattern Recognition, Tsukuba, Japan
- P. Sturm is Associate Editor of IEEE Transactions on Pattern Analysis and Machine Intelligence, Journal of Mathematical Imaging and Vision, and Image and Vision Computing Journal.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

E. Arnaud, Introduction to applied math, 16,5h, L1, Université de Grenoble, France

E. Arnaud, Statistics, 18h, L1, Université de Grenoble, France

E. Arnaud, Image project, 22h, M1, Université de Grenoble, France

E. Arnaud, Introduction to image analysis, 10h, M1, Université de Grenoble, France

E. Arnaud, Computer vision, 39h, M2, Université de Grenoble, France

E. Arnaud, Multimedia indexing, 24h, M2, Université de Grenoble, France

E. Arnaud, Supervising of apprentices, 15h, Université de Grenoble, France

P. Sturm, Informatique visuelle, 37.5h, M2, Université de Grenoble, France

P. Sturm, Computer vision, 13.5h, M2, Université de Grenoble, France

9.2.2. Supervision

HdR: Emmanuel Prados, Recherches en reconstruction 3D photométrique [2], Université Joseph-Fourier – Grenoble 1, 04/04/2012

PhD: Visesh Chari, Shape Estimation for Specular Surfaces [1], Université de Grenoble, 20/11/2012

PhD in progress:

- Anthony Tschirhard, Calibration and sensitivity analysis of a micro-simulation LUTI model, Oct 2012, E. Prados, E. Arnaud, P. Sturm
- Julien Alapetite, part-time PhD student who carries out part of his work in STEEP, graduation expected in 2013, advisor Denis Dupré (CERAG).

9.2.3. Juries

- E. Arnaud has been member of one recruitment committee of a assistant professorships (Grenoble).
- P. Sturm has been reviewer of six and examiner of two PhD theses outside Grenoble.
- P. Sturm has been member of two professorship recruitment committees (Clermont-Ferrand and Evry).

9.3. Popularization

- P.-Y. Longaretti has given four conferences on Environmental Impact and Human Development for a general audience in the last two years.
- P.-Y. Longaretti has coordinated the translation team of the latest book of the American agro-economist Lester Brown, "World on the Edge" (French title: Basculement).

10. Bibliography

Publications of the year

Doctoral Dissertations and Habilitation Theses

[1] V. CHARI. *Shape Estimation for Specular Surfaces*, Université de Grenoble, November 2012.

[2] E. PRADOS. *Recherches en reconstruction 3D photométrique*, Université Joseph-Fourier - Grenoble I, April 2012, HDR, http://tel.archives-ouvertes.fr/tel-00747867.

Articles in International Peer-Reviewed Journals

[3] J. COURCHAY, A. DALALYAN, R. KERIVEN, P. STURM. *On Camera Calibration with Linear Programming and Loop Constraint Linearization*, in "International Journal of Computer Vision", March 2012, vol. 97, n$^{\mathrm{o}}$ 1, p. 71-90 [*DOI :* 10.1007/S11263-011-0483-6], http://hal.inria.fr/hal-00705804.

[4] S. HINTERSTOISSER, C. CAGNIART, S. ILIC, P. STURM, N. NAVAB, P. FUA, V. LEPETIT. *Gradient Response Maps for Real-Time Detection of Texture-Less Objects*, in "IEEE Transactions on Pattern Analysis and Machine Intelligence", 2012, vol. 34, n$^{\mathrm{o}}$ 5, p. 876-888 [*DOI :* 10.1109/TPAMI.2011.206], http://hal.inria.fr/hal-00746534.

[5] L. PUIG, J. BERMÚDEZ, P. STURM, J. GUERRERO. *Calibration of omnidirectional cameras in practice: A comparison of methods*, in "Computer Vision and Image Understanding", 2012, vol. 116, n$^{\mathrm{o}}$ 1, p. 120-137 [*DOI :* 10.1016/J.CVIU.2011.08.003], http://hal.inria.fr/hal-00644989.

[6] L. PUIG, P. STURM, J. GUERRERO. *Hybrid Homographies and Fundamental Matrices Mixing Uncalibrated Omnidirectional and Conventional Cameras*, in "Machine Vision and Applications", 2012 [*DOI :* 10.1007/S00138-012-0424-6], http://hal.inria.fr/hal-00746469.

[7] K. VARUN RAJ, P. STURM. *Collective-Reward Based Approach for Detection of Semi-Transparent Objects in Single Images*, in "Computer Vision and Image Understanding", 2012, vol. 116, n$^{\mathrm{o}}$ 4, p. 484-499 [*DOI :* 10.1016/J.CVIU.2011.11.004], http://hal.inria.fr/hal-00746538.

International Conferences with Proceedings

[8] E. ARNAUD, P.-Y. LONGARETTI, E. PRADOS, P. STURM. *Modelling for local scale sustainability and decision-making support: reflections and difficulties*, in "Proceeding of the conference on Flow modeling for urban planning", Lille, France, Groupement d'Intérêt Scientifique " Modélisation urbaine " (GIS MU), 2012, http://hal.inria.fr/hal-00748618.

[9] J.-Y. COURTONNE, J. ALAPETITE, P.-Y. LONGARETTI, D. DUPRÉ, E. ARNAUD, E. PRADOS. *Study of cereals flows at local scales: Examples in the Rhône-Alpes région, the Isère département and the SCOT de Grenoble*, in "3rd International Conference on Computational Sustainability", Copenhagen, Danemark, July 2012, http://hal.inria.fr/hal-00748581.

[10] J.-Y. COURTONNE, J. ALAPETITE, P.-Y. LONGARETTI, D. DUPRÉ. *Etude des flux de céréales à l'échelle locale : Exemples en Rhône-Alpes, en Isère et dans le SCOT de Grenoble*, in "conference on Flows modeling for urban planning", Lille, France, 2012, http://hal.inria.fr/hal-00757768.

[11] A. DELAUNOY, K. KANANI, P. STURM, O. DUBOIS-MATRA. *Multi-View 3D Reconstruction of Asteroids*, in "International Conference on Astrodynamics Tools and Techniques", Noordwijk, Pays-Bas, 2012, http://hal.inria.fr/hal-00746667.

[12] P. DUTTA, H. ABHISHEK, B. RAKTIM. *Uncertainty Quantification for Stochastic Nonlinear Systems using Perron-Frobenius Operator and Karhunen-Lo'eve Expansion*, in "IEEE Multiconference in Systems and Control", Dubrovnik, Croatia, IEEE, October 2012, http://hal.inria.fr/hal-00741997.

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[15] A. NATRAJ, P. STURM, C. DEMONCEAUX, P. VASSEUR. *A Geometrical Approach for Vision Based Attitude and Altitude Estimation for UAVs in Dark Environments*, in "IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)", Vilamoura, Portugal, 2012, http://hal.inria.fr/hal-00746664.

[16] C. UNGER, E. WAHL, P. STURM, S. ILIC. *Stereo Fusion from Multiple Viewpoints*, in "DAGM-OAGM Joint Pattern Recognition Symposium", Graz, Autriche, A. PINZ, T. POCK, H. BISCHOF, F. LEBERL (editors), Lecture Notes in Computer Science, Springer, 2012, vol. 7476, p. 468-477 [*DOI :* 10.1007/978-3-642-32717-9_47], http://hal.inria.fr/hal-00746543.

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[17] E. ARNAUD, P. STURM. *Modèles LUTI - des modèles numériques*, in "2me Journée d'études sur les modèles Occupation du sol - Transport", Paris, France, Ministère de l'écologie, du développement durable et de l'énergie, December 2012, http://hal.inria.fr/hal-00763144.

[18] E. PRADOS, P.-Y. LONGARETTI, E. ARNAUD, P. CRIQUI, D. DUPRÉ, B. LEFEVRE, M. SAUJOT, P. STURM, J.-Y. COURTONNE, J. ALAPETITE. *Integrated Urban Modelling for Sustainable Policies: Considerations and Difficulties*, in "Proceeding of the conference on Flow modeling for urban development", Lille, France, Groupement d'Intérêt Scientifique " Modélisation urbaine " (GIS MU), June 2012, http://hal.inria.fr/hal-00747871.