REGISTA: A Reality Emulating and Geographical Information System for Territorial Analysis

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Abstract. The REGISTA project intends to create an integrated platform for a joint use of GIS and cellular-automata-based modelling for the construction of scenarios applied to territorial contexts. The combined use of the two has recently found space in Italy, but has been essentially circumscribed to the academia – in some cases within collaboration frames with local authorities – and without significant technological transfer towards commercial contexts- Such transfer represents the principal objective of the project, aiming at widening of offer of products that could respond to a growing need of the off-the-shelf software for territorial simulation dedicated to policy- and decision-makers. Test application case-studies will regard the prediction of the evolution of marine biological systems, the monitoring of crops specialised for prevention and prompt treatment of phyto-pathologies, and the use as the support for excavation strategies in the archaeological field.

1 The Geographical Information Systems

The Geographical Information Systems (GISs) are information systems dedicated to the management of geographical data aiming at the development of analytical models of the territory and the production of digital cartography.

The GISs effectively substitute the traditional cartography and are *de facto* standard for the spatial data management. Generally, such systems are designed in order to store data and to provide models according to the users' informational and representational needs. Normally, a GIS includes the following fundamental elements:

- a geo-referenced database (or a spatial database),
- an alpha-numeric database, defining geo-referenced data according to a specific spatial ontology,
- an user interface.

Thanks to a series of functionalities, the GISs result to be of a fundamental importance for the elaboration of spatial information. Among the main functions, we would like to mention:

- the storage of a great quantity of heterogeneous data, as long as they are spatially defined;
- spatial or non-spatial querying of the database related to the presence, localisation and characteristics of different types of territorial objects;
- high interactivity in the definition of queries and in the requests for data elaboration and data access.

Along with these characteristics related to the management of digital spatial information, the GISs offer solutions to traditional cartographical representation, providing a wider set of possibilities with respect to the analogical cartography.
The GISs platforms usually integrate commercial or open-source relational databases (RDBMS). The products nowadays available range from simple but powerful client applications for spatial data querying and analysis, to complex applications deployed in distributed architectures for management of large territorial databases.

2 The REGISTA Project: Reality Emulating and Geographical Information System for Territorial Analysis

The REGISTA project aims at integrating cellular-automata based techniques within a GIS architecture. The final objective is thus the development of a software product useful as a purposeful decision support system in territorial contexts with particular reference to sustainable development policies.

Via the definition of rules of the automata behaviour, and given a dataset collected on the field, it will be possible to simulate scenarios and to evaluate territorial impacts of interventions and policies through interactive cartographical visualisation.

The system will be validated in three specific applicative contexts of noteworthy relevance:

- the prediction of the evolution of marine biological systems;
- the monitoring of crops specialised for prevention and prompt treatment of phyto-pathologies;
- as the support for excavation strategies in the archaeological field.

The project is articulated in three macro-phases:

1. development of the GIS environment starting from commercial and open-source components and its integration with the cellular-automata algorithms;
2. design and structuring of the modelling methodologies and adaptation/perfection of the software environment;
3. validation of the software through selected case-studies.

3 Why REGISTA?

A sustainable management of the territory, with the consequent safeguard of the natural environment and the cultural heritage, constitutes nowadays the strategy at the basis of the social and economical local development.

Such centrality is widely recognised at the directive level by the EU development guidelines and by national economical policies, which have put in evidence the potentials in terms of scientific and technological research, as well as in occupational terms.

However, the reception of such directives and guidelines is contrasted by different structural weaknesses of many European regions, characterised by low employment rates, massive presence of illegal and grey economy and generally by a low economical activity. That notwithstanding, frequently these regions are exactly those that, given the richness of their environmental and cultural heritage, could benefit most from activities oriented toward a valorisation of such heritage. In that sense, the main deficiencies that are seen as obstacles for the development of the sector are the absence of effective control and management tools, the lack of interventions aiming at creating synergies among multiple possibilities of use and the reduced infrastructural capacities of the interested areas.

It must be underlined that a conscientious, sustainable-development-oriented management of the territory cannot elude an accurate knowledge of dynamics and emergencies that characterises it. In that sense, the information technology provides by now hardly substitutable instruments and tools for knowledge and decision support. For example, the use of GIS has brought about a growing accumulation of structured geographical information directly usable in territorial analysis and management.

The growth of available data notwithstanding, deficiencies can still easily be adverted in the use of analytical tools which permit an adequate management of such information. Therefore, wide spaces are opening to those operators placed in advantage positions in offering, providing and deploying services related to those tools.

In that sense, particularly significant are technologies and modelling techniques oriented towards prediction, future scenarios construction, and decision support. Given a known situation, these technologies permit the formulation of hypothesis about the evolution of a system based on the variation of parameters and variables that condition it. Technologies that have been used successfully, mainly in the scientific fields, in predictions of systems' behaviour of various kinds: physical, chemical, biological, economical, urban and environmental.

The REGISTA project intends to create an integrated platform for a joint use of GIS and cellular-automata-based modelling for the construction of scenarios applied to territorial contexts. The combined use of the two has recently found space also in Italy, but has been essentially circumscribed to the academia – in some cases within collaboration frames with local authorities – and without significant technological transfer towards commercial contexts.

Such transfer represents the principal objective of the project, aiming at widening of offer of products that could respond to a growing need of the off-the-shelf software for territorial simulation dedicated to policy- and decision-makers.

4 The Cellular Automata

The cellular automata (CA) are a family of techniques for describing and simulating dynamic phenomena evolving within time and space.

The particularity of this technique consists in the mechanism of simulation used: rather than *globally* simulating the behaviour of a system, which is the case in many other simulation techniques, in CA the interaction among parts are always calculated locally, within neighbourhoods of cells suitably defined.

Examples of phenomena evolving with time and space that can be effectively simulated with the use of CA are the diffusion of gases and liquids, the growth of vegetation population, the diffusion of a fire, the territorial transformations, and so on. Even the disposition of artefacts within an archaeological site during the excavation phase – as we shall see – could potentially be determined simulating the spatial development in the past whose dynamics are not know to us.

The mentioned phenomena, all clearly spatio-temporal in nature, possess different grades of difficulty of description in terms of deterministic mathematical or logical models which can accurately describe their behaviour.

In fact, some of them are completely deterministic, some are less deterministic, and in some other phenomena the non-deterministic component clearly prevails, with further complications related to the variability of different spatial components of the system, and to the possibility of "accidental" events during the course of time.

In such cases, there is a need for a "fragmentation" or "discretisation" of the description of the phenomenon, regarding both the temporal and the spatial aspects, as well aspects related to modelling "rules" describing the system's behaviour. Therefore, we can distinguish:

- a temporal discretisation, where the time is subdivided in discrete elements;
- a spatial discretisation, where the spatial continuum is subdivided in a lattice of cells;
- a discretisation of mathematical and logical expressions defining the phenomenon, where there is no single expression with all parameters related to the evolution of the phenomenon, by a series of distinct expressions (or rules), each describing a single aspect of the phenomenon's evolution and each including only some of parameters considered relevant for the comprehension of the whole phenomenon.

A cellular automaton can thus be seen as a (virtually unlimited) lattice of "cells" in a multi-dimensional space where the cells "evolve" through an imaginary time, determined by a suitably programmed clock.

In a given time t, each cell assumes a state out of a finite set of possible states. The state of a cell in time $(t+1)$ depends not only on its state in the time t, but also on the states of the neighbouring cells in the time t.

A set of rules determine the transition of cells from one state to another.

Essentially, the cellular automata are discrete dynamical systems which can exhibit complex and self-organising behaviours even starting from a much reduced number of possible states and transition rules, and whose global behaviour are exclusively determined by local interactions.

The use of cellular automata can be useful when:

- only some aspects of the phenomenon are known initially;
- the knowledge on the phenomenon grows with time, and on the basis of results of executed simulations;
- the model of the phenomenon has to be developed rapidly and refined only subsequently;
- the model of the phenomenon is expected to change and evolve with time, on the basis of more specific knowledge and simulations; only the dynamic local behaviour of some action zones of the phenomenon is known, while the behaviour of other parts, and ultimately the general behaviour, are not known.

In the recent years, the simulation techniques of natural and human-driven phenomena based on cellular automata have found their way in the field of the so called territorial decision support. Such techniques seem to be a valid alternative to the multi-criteria analysis, which has traditionally been employed for the structuring of decision-making problems with spatial components.

5 Cellular automata and Decision Support Systems

The term Decision Support System (DSS), or a more recent term Problem Solving Environment (PSE), denotes software application which assists user during the course of a decision-making process. The base idea is that the decision-making process is a sequence of elementary activities taking place in the moment an individual or an organisation is taking a decision.

From the information technology standpoint, a DSS is a software system with a series of functionalities at user's and decision-maker's disposal. These functionalities permit an interactive and simple use of models and data-analysis features, for the purpose of a greater efficiency and effectiveness of the decision-making process. The adopted analytical methodologies (such as modelling, simulation and prediction of a phenomenon) have the purpose of structuring of alternative solutions for the examined problem. The progression of the decision-making process has a strongly interactive character and is distinguished by single decisions taken at every step of its realisation.

The essential element of an effective DSS are:

- easy to use and flexible user interface
- interactive environment
- support for non-structured or only partially structured problems
- efficacy in the use of models in the data analysis
- possibility that the system becomes an integral part of the decision-making process

Most frequently, a DSS is based upon three fundamental components: a database, a set of models and a software system. The database contains data and information that directly or indirectly are of user's interest. The set of models contains all models or procedures required for the solution of user's problems (where with model we intended an automatic procedure of data analysis as a response to a determined problem).

In the specific area of DSSs for territorial management and government, the development of DSS-like tools has essentially regarded two fields: the environmental policies and the management of natural resources. In this context the selection of criteria, determinant factors, constraints and rules governing the decision-making processes has found a wide use and has obtained significant success. In such applications, the techniques of Multi-Criteria Decision Analysis (MCDA) have proven to be particularly important. The MCDA is a decision-making process where different factors are jointly evaluated. Tools implementing MCDA are present in the great majority of GIS packages available on the market.

The second important procedure in know as Weighted Linear Combination (WLC). Here, the continuous variation of decision factors is expressed in numerical values subsequently combined in a weighted average. The result is a continuous mapping of the opportunity of an alternative that can be combined with one or more Boolean constraints and thus represented in classes to obtain the final decision.

It appears clear that the MCDA, efficacious for example in the hydro-geological risk assessment, is by its nature inadequate for scenarios with a strong correlation among factors and an elevated dynamicity with time. In fact, the MCDA does not provide models of evolution, but only maps of probable values.

The adoption of cellular automata, for the peculiar dynamicity of simulations, has appeared in recent years as a natural way for the development of DSSs applicable to complex scenario analysis. Their ability of "mimesis" of complex natural and social behaviours has made them candidates for a new generation of DSSs.

It is interesting to underline that CA-based and GIS techniques have a high degree of compatibility and share many common base "metaphors" regarding the structuring of the information and the spatial nature of processes they are able to handle.

At the present moment, the main problem in the diffusion of these methods is related to the absence of software solutions implementing jointly the two techniques. This barrier forces those operating in the field of territorial simulation to spend most of their effort and time in technical problems related to the integration of the two environments. Therefore, it seems that the conditions are mature for the development of integrated packages as REGISTA, representing a user-friendly solution to integration problems.

All this was the departure point for the integration between commercial and open-source information technologies, methodological practice, modelling techniques, and a specific know-how converging towards the development of an integrated simulation environment REGISTA.

The following table enlists the main advantages of the integration of a GIS environment with CA-based simulation techniques.

Table 1. Comparison of standard GIS-MCDA features vs. proposed improvements

[illegible]	[illegible]
Difficulty in construction of models starting from poor or incomplete databases.	The implementation of CA algorithms allows the prediction of the evolution of a spatial variable starting from data sets hard to treat with geo-statistical methods.
Inability to predict the evolution of known time series.	The CA algorithms are able to "learn" upon the evolutional characteristics of systems, allowing the extension of traditional time series analysis in GIS environments with extrapolations of future dynamics.
Limitations in the non-uniform modelling of the system	In the CAs, the attention is focused on parts of the system, and this allows the employment of local behaviours and non-homogeneities.
Static predictions	The DSSs based on MCDA and on cost-benefits analysis support only the structuring of decisional problems. On the other hand, the application of CAs allows the construction of complex simulations useful in the scenario analysis and in the evaluation of impacts of decisions with time.

6 How does REGISTA work?

6.1. The Architecture

The REGISTA software platform will be based on the integration of a static (GIS) module and a dynamic (CA) module or subsystem. The system will have a "bi-polar" architecture where the GIS subsystem is clearly separated from the CA simulation subsystem. The two will be configured to communicate via a data exchange protocol adequately defined.

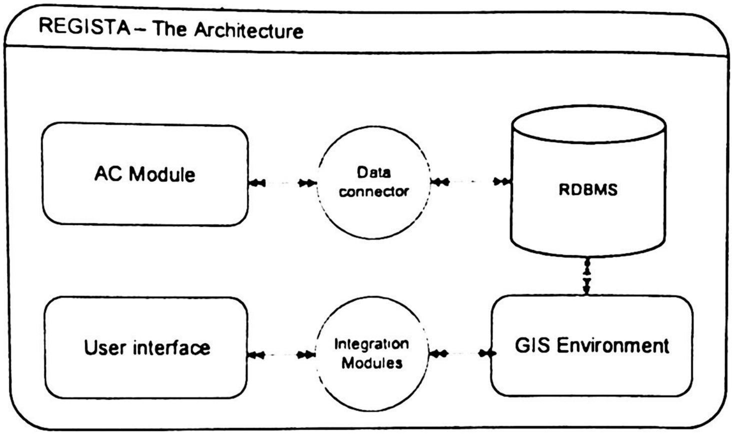

Fig. 1. The general architecture of REGISTA framework

6.1.1. The GIS Module

The GIS is configured as the main environment for spatial information management within the whole system. The GIS is based on a geographical relational database queried via the standard Structure Query Language (SQL). Its internal structure is articulated in homogeneous informative layers, each potentially containing more thematic levels. The GIS module collects, and organises in a structured form, all the geographical information inserted in the database.
Within this module, all the basic cartographical and thematic data will be stored. Such data will be archived in raster, vector, CAD, TIN and database formats.

Tools typical to the GISs will be used to execute common operations like initial data homogenisation, spatial analysis, map-algebra, and all the other preparatory operations, as well as the conversion of data to be transmitted to the simulation sub-system.

The software module will have to offer high qualitative standards, and should thus combine management of geographical information with raster analysis.

The preferential vector file exchange format will be ESRI ArcView's Shapefile, while for the raster file it will be adopted the GeoTiff format.

6.1.2. The CA Module

The CA module executes elaborations oriented towards the production of scenarios. The data elaborated by the GIS module will be exported, and that data will be the base for the extraction of rules necessary for the functioning of the CA.

The automata thus designed will be tested against limited sets of data, and subsequently refined on a wider scale along the application to different specific cases.

6.1.3. The Data Exchange Format and Interface

The integration between the two constitutive modules will be obtained via the principle of data sharing. Both GIS and cellular automata are able to manage data structures based on lattice. The exchange format will thus be of a raster kind. The two modules transfer the results of the respective elaborations in a temporary database. The exchange of data takes place in two directions: from GIS to CA and vice versa.

The exchange interface will be organised as one or more file exchange directories. placed on local or remote hard disks. accessible to various application involved in the data processing. The functioning of the exchange will be regulated by the security and integrity rules for data providing and retrieval.

6.2. Definition of the Modelling Methodology

One of the main objectives of this project is the definition of a reference methodology for the design of models and the subsequent configuration of the software environment in order to reduce to minimum the computer and information technology skills required by user for the logical configuration of cellular automata and their rules of behaviour starting from a data model of a geographical type.

The reference procedure will be refined around a cyclic model to be reiterated several times over the data set with growing complexity. or every time the obtained results do not prove to be satisfactory.

Every such cycle is typically composed by four main phases:

- Analysis
- Preparation of data in GIS environment
- Extraction of rules
- Application of rules

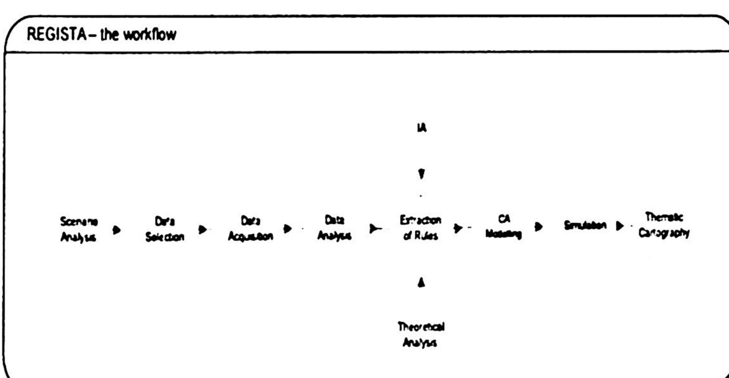

Fig. 2. The scheme of the common workflow use-case

6.2.1. Analysis

In this phase the system constituting the case-study gets examined. The bibliography and all the available materials are collected. The contributions by the field experts are considered and analysed. The system gets decomposed on its constitutive logical parts through the construction of a model where the real world phenomena are translated into entities of a model. Such "model of reality" it hence used for the definition of the data model required for the design of the geographical database describing the base knowledge on the examined system.

6.2.2. Preparation of Data in GIS Environment

Using the data model designed previously, the initial geographical database is built. In this phase the base cartographical and thematic data are inserted through the GIS environment. Furthermore, the choice of the operative scale and the consequent data homogenisation is performed. The geographical database thereafter obtained is complete of all the preliminary available information and is characterised by the existence of the data in raster, vector and database formats.

The inserted data are then processed with a series of operations necessary for their exchange with the simulation subsystem. The following operations are undertaken:

- Choice of the cells' dimensions;
- Creation of a vector lattice;
- Choice of spatial analysis operators used for the elaboration of the raster data to submit to the simulation module;
- Creation of tabular reports on results of the spatial analysis.

6.2.3. Extraction of Rules

The results of the cartographical analysis, formalised in the tabular reports, are used in the process of "extraction" of transition rules necessary for the definition of cellular automata.

The extraction of the rules can be obtained in two distinct ways:

- Automatically, using artificial intelligence techniques, some of which already are present in the GIS module (creation of self-training tables – training sets – and application of automatic classification criteria);
- Through the formalisation of the existing knowledge on the behaviour of the studied system.

The application of the automatic procedure seems possible in those cases where consistent time series are available for the same area. The training sets are tables consisting of a set of records representative of portions of the studied area. Each record presents multiple attributes, including the classification target attribute. The records included in the training set are analysed in order to develop a model of each class, and to use it for further classification of other and future cases. The adopted tool, known as the Decision Tree, is a tree-like logical structure able to correctly classify objects in the training set. The classification rules used are of an "IF ... THEN" kind, where "IF" describes both the observed state as well as a single rule to apply, while "THEN" assigns a codification, or a transition from one state to the other between two different temporal sections. The possibility to conduct training on the known time series permits the calibration of models.

In parallel (or alternatively), particular constraints, even if not explicitly "discovered" during the use of AI-base systems, but imposed by the specialist knowledge of the examined system, can be introduced in the design of the CA model.

6.2.4. Application of Rules

Once defined, the transition rules are implemented in the cellular automata model in order to simulate the behaviour of the system. The insertion of rules and the design of the cellular automata take place in a special modelling environment. The execution of the CA produces scenarios that can be imported back in the GIS environment. Once inserted in the geographical database, the results can be used for the production of thematic prediction and decision support cartography.

7 Validation Through Case-studies

The software modules and the developed methodology will be validated through the application to three specific case-studies.

The chosen examples regard:

- the sector of **analysis and environmental** rehabilitation, with the simulation of dynamics of marine phanerogama,
- the **cultural patrimony**, with the definition of prediction models for the selection of sites for archaeological excavation,
- the **agronomical sector**, with the definition of a prediction models on the diffusion of phyto-pathologies in specialised lighthouse cultivations.

In the first case, starting from known time series, we will try to simulate possible evolution of the *Posidonia Oceanica* prairie related to the variation of some environmental parameters. The experimentation will determine transition rules, the CA model and subsequently the future scenarios whose use could improve the operative capacity of authorities responsible for the management of coastal and marine environments.

In the second example, of remarkable interest for the specific segment of potential clients, it will be attempted to design and develop models predicting the disposition of an archaeological site for the purpose of orienteering the excavation campaigns.

In the final concrete application scenario, we will attempt to simulate the diffusion dynamics of the phyto-pathologies, in a confined farming environment, with the purpose to develop a DSS able to assist in the process of definition of low-environmental-impact control and defensive strategies.

7.1. The First Validation test: Simulation of the Marine Phanerogama Prairie Evolution

The choice of this validation field derives from the consideration the conservation of the marine environment is of a great importance for the Mediterranean countries. The definition of a reliable monitoring strategy – based on geo-morphological, biological, chemical and physical indicators – capable of controlling the quality of the sea, and in particular the state of the coastal marine environments, is by now considered indispensable and of vital importance.

In numerous Mediterranean coastal areas, there are neither data nor sufficient knowledge on the existing marine biocenose, and thus even less in known about its quality. Another example is the frequent lack of information about the functioning of water-treatment facilities, above all related to their impact on the coastal water quality and on the biocenose.

Analogous situations are encountered with respect to the state of marine ecosystems, generally highly sensible to the effects of human activities taking place along the coastal stripes: sewage and industrial pollution, coastal dumping, construction activities (seaports and dams), driftnetting fishery, etc. The most important ecosystem, and unfortunately the most sensible to such impacts, is without any doubt the prairie of *Posidonia Oceanica*. It is a marine phanerogama, a most remarkable Mediterranean endemism, normally developing along the seabed up to 20-40 meters deep. The *Posidonia Oceanica* prairie exercises an important ecological role along the coastal stripes as a natural habitat and nursery for numerous valuable fish species, as protection against beaches erosion, as producers of oxygen, all functions comparable to those of the tropical forests. For these and many other reasons, the *Posidonia Oceanica* is a protected species by the European legislation and by global conventions and treaties.

Therefore, for an effective safeguard strategy of this ecosystem, the knowledge about the extension and the "state of environmental health" of *Posidonia Oceanica* prairie is of fundamental importance. Generally, that is obtained through the study of some intrinsic parameters of the plant (micro-repartition) and through the study of the extension of the prairie, its morphological characteristics and the density of plants (macro-repartition). In parallel to the need for better insight into the environmental state of the prairie, often there is the problem of its recuperation, especially in areas that in the past were massively exposed to the effects of human activity which have destroyed large extensions of the original prairie or have strongly deteriorated its vitality. On that regard, in the recent years, there have been attempts of reforestation, using techniques that transplant into the damaged areas seeds or taleas collected nearby. Such activity is however highly expensive and labour-intensive.

Some recent observations have came to the conclusion that the "natural" recovery of prairie is possible and relatively rapid, under the conditions the causes of the damage cease to exist or are strongly limited, and that the base seabed is adequate for the planting of the taleas.

One of the studied examples of re-colonisation is the gas pipeline between Italia and Algeria. Its construction has destroyed a wide stripe of the prairie: the excavations for the placement of the pipeline have been covered by ballast that with time was naturally re-colonised by the *Posidonia Oceanica*, a re-colonisation favoured by the wide presence of the living material (taleas) available in the area. It has been noted that is just few years, and without any human intervention, the prairie has regained various hectares of the seabed, thus commencing a, still only partial, recovery of the damaged seabed.

The existence of techniques for the reconstruction of the rhizomes age as well as for the estimation of the velocity of plants' growth, nowadays largely used world-wide in the research on the marine pharenogama, represents an excellent application field for the REGISTA predictive models. This could have a relevant influence on the management policies, for example in definition of an efficacious strategy of localisation of sites adequate for the re-planting of taleas, for optimising the time of recovery, helping in the same time to avoid the waste of economical resource and human labour in a "carpet" reforestation.

All that could bring improvements on the methodological level and of the know-how related to the large-scale rehabilitation and recovery of this utterly important ecosystem, with potentially remarkable positive effects on numerous economical sectors, such as tourism, fishery, the coastal protection, etc.

The methodology that will be applied to the pilot-study in the Gulf of Palermo will be the following:

1. Acquisition of the datasets necessary for the development of the project (cartography, bathymetry, seabed mappings, time series of aerial photogrammetry, scientific publications, "grey" literature, database on vital parameters of the *Posidonia Oceanica*, etc.), part of which will be appropriately elaborated and made homogeneous and usable in the REGISTA GIS environment. In this sense, the fundamental data to be used in the definition of the cellular-automata-based model are the following: coverage, density per stripes, rhizomes vertical and horizontal speed of growth, data on hydrodynamic, physical and chemical characteristics of the waters, sedimentological and geo-morphological data.
2. Data-entry and elaboration of collected data through the GIS environment.
3. Design of the cellular automata and the extraction of transition rules.
4. Production and iterative verification of scenarios against available time series.
5. Importation of results in the GIS environment and the production of the output cartography.

7.2. The Second Validation Test: Predictive Models for the Selection of Sites for Archaeological Excavations

The adoption of techniques related to the geographical information (e.g. essentially GIS-based technologies) has in the recent years significantly improved the effectiveness of the archaeological management and research activities.

In the last two decades, the use of such technologies has been growing world-wide not only in the monitoring and census of the archaeological areas, but also in the development of the so called predictive models. The use of such models is strictly connected to the need to operate a preliminary selection of excavation sites. In these cases the most common question is: what is the probability that a given area contains archaeological artefacts?

The models developed for coping with that question use two kind of information:

- theories related to the spatial distribution of archaeological sites;
- empirical observation of the archaeological records.

The two classes of information correspond to two different conceptual approaches: the first one is purely of inductive kind. the second is exclusively deductive. Even if it is possible to create purely inductive models. or models exclusively based upon past observations. such a distinction appears significant only on the theoretical ground. In fact. the collection of data always takes place within theoretical contexts that can be validated of falsified by the collected data. A mixed approach keeping together both data and theories seems hence more equilibrated.

Reduced to its essential terms. a predictive model consists of one of more final elaborations produced from a series of input data. The singularity with the archaeological models is that while the output data are of the archaeological kind. rarely the input data are such. In fact. in the great majority of cases. the departure data are constituted by the "landscape" characteristics where the purpose is to spot the presence of relevant artefacts. These characteristics are transformed into a numerical form in order to be embedded in a raster-data model. to a suitable lattice resolution. and subsequently elaborated.

Generally. the input data can be subdivided into four main categories:

- Spatial parameters:
- Characteristics of the physical environment:
- Economical characteristics of the territory:
- Cultural characteristics.

Among the spatial parameters. there are normally the known spatial trends in the distribution of the sites (e.g. if in a given area the sites tend to be aggregated or dispersed). These trends can later be used as rules for the predictive model.

The characteristics of the physical environment are normally more useful in GIS-like contexts and consequently employed as the input data in the construction of models. The choice of parameters to be used can be determined by the experience or specialists' knowledge. and by statistical analysis performed on known sites. Typically. the used parameters are: elevation. inclination. exposition. drainage index. local landscape. geological and pedological information. classification of forms. distance to natural resources (e.g. water). and classification of the vegetation. Clearly. these parameters ought to be used cautiously. since are representative of the modern environment. but not necessarily of the studied historical period.

Particularly interesting are the economical characteristics of the territory such as the soil productivity. The usage of these parameters requires by norm an economical inference referring to palaeo-economical criteria. and an assessment of the soil characteristics and its suitability to particular cultivations.

Finally. although traditionally less used. the cultural characteristics of the natural landscape are of remarkable relevance. These can comprise the natural communication routes. the presence of central or "focal" places within the landscape that can be used as indicators of probability of the presence of an archaeologically relevant site.

Once selected and defined the input data. the outputs of the predictive models are represented in the form of thematic maps indicating the following information for a given area:

- Presence/absence of archaeologically relevant sites (binary output referred to a particular culture or age):
- Classes of sites (e.g. no sites. site of type A. ...):

- Density of sites and artefacts (with adequate resolution);
- Value of the sites (in some cases there have been attempts to classify units of the landscape in order to express the perception of the importance of archaeological artefacts) ;
- Probability of occurrence of an archaeological site.

The methodology adopted will be the following:
1. Collection of the data necessary for the project (bibliography, thematic and general cartography, scientific articles, environmental and palaeo-environmental data).
2. Data-entry of the collected data in the GIS environment.
3. Choice of the significant parameters.
4. Extraction of rules for the comparative analysis of known settlements and design of the cellular automaton.
5. Production of scenarios on the basis of the pre-selected parameters.
6. Importing of results in the GIS environment and the production of the output cartography.
7. Analysis of the behavioural trends deriving from the application on predictive models to existing and known archaeological data.
8. Final analysis of the settlement and land-use dynamics of the territory.

7.3. The Third Validation Test: Evolution Models of Phyto-pathologies in Greenhouse Environment

This use-case regards a topic of a notable interest for the economy of rural areas. The aim of this experiment is to validate the REGISTA as the support system for epidemiological monitoring of phyto-pathologies in sensible cultivations, for the purpose of defining effective defensive strategies of products and cultivations.

The problem of the optimisation of phyto-sanitary treatments in specialised cultivations, and particularly those in greenhouse, is nowadays extremely vital.

The growing awareness of consumers regarding the food safety and the necessity to reduce the exposition of operators to harmful substances, forces into the direction of a progressive reduction of traditional chemical treatments, especially in closed environments where more consistent is the permanence of residuals on the agricultural products and in the environment.

In the greenhouse cultivations, besides the classical phyto-sanitary and biological treatments, the defensive strategies also include the control of the micro-climatic conditions, in particular for the prevention of cryptogamic diseases.

Here, a particular relevance is given to the information technology able to correlate the insurgence of infestations to the climatic conditions, and to assess the impact the control of these conditions can determine on the evolution of the phenomenon.

For the purpose of the REGISTA system validation, few test micro-systems will be built, where the environmental input data will be collected, and all the insurgences and evolutions of phyto-pathologies will be registered.

Once these environments are reproduced as simulations, the evolution model will be "trained" with the representative subsets of real data.

At that point, the model will be used to simulate the evolution of other micro-systems and the obtained results will be confronted with the already known data, in order to verify the capacity of the REGISTA system to predict the effects of focused defensive interventions or of particular strategies of biological measures.

The profusion of applications of information and communication technologies in the agro-alimentary sector notwithstanding, the software decision support systems for the defence of cultivations are still modest. The test will hence offer the opportunity to validate the REGISTA system as an innovative tool for decision support, dedicated to technician and agricultural operators involved in the effort of low-environmental-impact production and in the reduction in the use of phyto-pharmaceutical products.

The development of a reliable simulation model will allow users:

- to evaluate the risks of phyto-pathologies diffusion in valuable cultures grown in controlled environments;
- the precocious diagnosis of phyto-pathologies;
- the capacity to produce informative maps for analysis and verifications.

8 Appendix – About the partners

This project is jointly developed by the *Laboratory of Analysis and Models for Planning* and the *TICONZERO Consortium*.

Laboratory of Analysis and Models for Planning

The Laboratory of Analysis and Models for Planning (LAMP) established by the Faculty of Architecture – University of Sassari in cooperation with other Italian Universities is a Research Group and centre of excellence involved in development of techniques and methodologies, and in production and realisation of models related to Cellular Automata, Gaming Simulation, Decision Support System, Concept maps and their application on Urban, Territorial and Environmental studies.

In particular, the Laboratory has developed the CAGE software (Cellular Automata General Environment), a simple, but robust environment for creation, execution and management of multi-payer cellular automata.

For more information visit http://lamp.sigis.net.

TICONZERO Consortium

Constituted in the 2004, the TICONZERO Consortium capitalises the experiences of the homonymous incubator of enterprises active since 1999 and recognised by the BIC Point network promoted by BIC Sicilia S.p.A. (today merged into Sviluppo Italia

Sicilia S.p.A.). with the mission of incubating new entrepreneurial initiatives in the field of information technologies and advanced services.

The TICONZERO Consortium is a centre for technological innovation in the field of information and communication technology and its use at the service of a sustainable development of the territory. The human and technological resources affiliated to the Consortium permit to offer an articulated set of services:

- design and development of informative and collaborative systems for knowledge management;
- technical assistance with information systems;
- CAD/CAM industrial design;
- production engineering;
- development of Territorial Information Systems;
- implementation of e-learning platforms;
- environmental research services;
- technical services and support for the management and valorisation of Cultural and Environmental Heritage

Through numerous participations in research projects, the companies affiliated to the Consortium have developed solid collaboration relations with reference operators in the field of territorial development, scientific research and with providers of state-of-the-art technologies in the field of software and information systems.