PARAMETER TUNING IN MODELLING HUMAN BEHAVIOURS BY USING OPTIMIZATION TECHNIQUES

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ABSTRACT

The authors propose an approach for developing complex models integrating different components and including human behaviour; in these problems the data uncertainty as well as their availability is a major criticality; the paper proposes an approach for a mutual validation of the model and a fine tuning process based on integrating simulation with optimisation techniques.

INTRODUCTION

Modelling human interactions is a very challenging problems especially if it have to be faced in relation to other issues such as technical/operative aspects (i.e. modelling team working within a production cell or simulating a group reactions in a battlefield). The paper proposes the issue of modelling human behaviours with special attention to their interactions while working/operating in teams; the complexity of such models are related to the multidisciplinary aspects involved. The knowledge of these processes as well as the quantitative data are very difficult to be caught and normally are affect by high degrees of uncertainty.

Currently most of these aspects are modelled in existing simulators as component based on estimations provided by subject matter experts (SME); therefore a proper VV&A (Verification, Validation and Accreditation) of the resulting simulators is complicated by individual estimations, complexity in reproduction of boundary conditions and difficulties in quantitative measuring of both input/output affecting such aspects. Considering the human behaviour just as an object model to be integrated in a wider simulation the stochastic nature of several external factors is a further complexity element for proper design and testing of this components. However human behaviour and team working performances are often affecting overall performance and some kind of modelling could be requested for constructing a correct model (i.e. fear effect on troops attacking under enemy fire or people efficiency in a company just acquired and subjected to personnel reduction procedure). In particular considering industrial plants, production facility or business process it is evident that the introduction of this aspects could be pretty useful, while it is very important to avoid the introduction of just noise factors in simulation when it is impossible to proceed to their proper identification, definition, measure and testing. The paper will concentrate in proposing a general methodology and a more specific approach for proceeding in modelling in this area of interest.

GENERAL APPROACH FOR COMPLEX HUMAN BEHAVIOUR MODELS

The first general question to be solved is the evaluation of the importance of Human component modelling in the real system and the fidelity level requested. A good example to be used for clarify this aspect could be related to the case of modelling a production facility; in this experience is often requested to model the pause/coffees of the workers; in this case we can adopt different approaches such as:

- Considering just net available time of the workers without break times
- Generating events related to the coffee breaks randomly for the same amount
- Construct a model that consider the aggregation phenomena and chatting aspects

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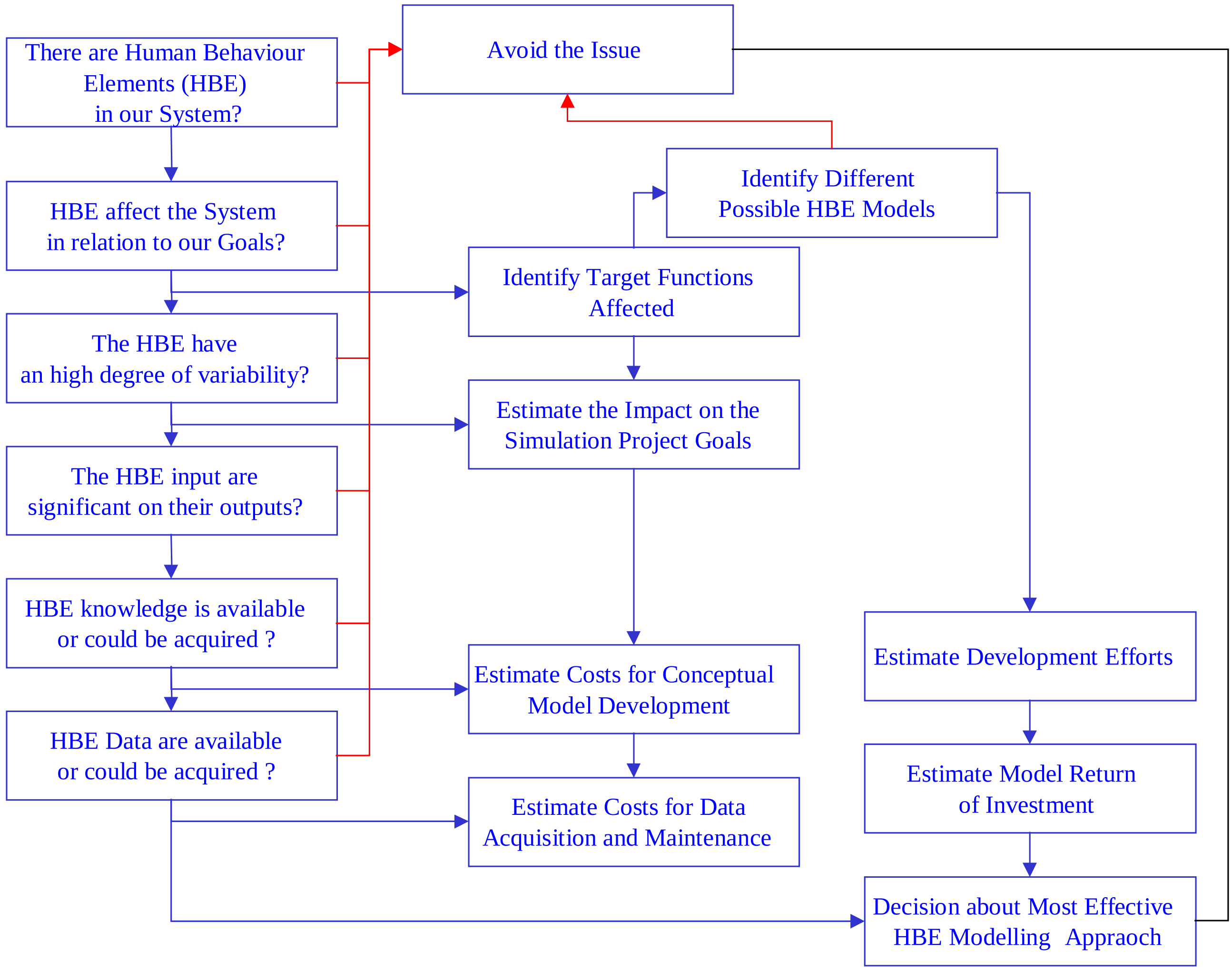

Figure 1: Procedure for Evaluating Best Modelling Apporach related to Human Behaviour Elements

The approach to be chosen should be based on the benefit it provides to the usability of the model and to the profitability of the results provided; so it is strictly related to the context (i.e. in a regular facility it could be a simple approximation, while in a reality where there are high rate of absenteeism this factor could require additional attention). Another important aspect it is to identify how much this components affect the overall performance. Therefore the critical point it is to estimate the costs and benefits related to each model; as much as we detail this component as much as additional knowledge and data are requested to feed the model this normally provide additional development time, additional testing time and especially higher costs for maintaining the model in the future. In effect it could be critical to develop a very effective model and expend a lot of resources in his VV&A, if just after one year being changed procedures, people or other boundary conditions the human behaviour model become obsolete and requires another big effort; in this case it could be much better to approach the case by developing a simplified model that takes into account just parameters that could be update with reasonable efforts. In general the overall procedure it is summarised by flow chart in figure 1. If we consider to operate in an application case where human factors are significant and needs to be integrated with overall processes and to create a detailed model component the suggestions proposed by this approach is to proceed through a "reverse engineering" problem in best fitting the relative parameters for the model.

PARAMETER TUNING

Often the human behaviour component can be developed based on available experiences and bibliography, however a critical aspect is always connected with the fine tuning of the factors affecting each model (i.e. people attitudes, psychological indexes, etc.). Obviously simulation is a wonderful approach for estimating the consequence of some configuration, while it is pretty difficult to identify "a priori" the proper set of input that represent our system. Due to these consideration a possible approach is to investigate a specific scenario where several overall performance is available and to proceed by "reverse engineering" in the identification of the proper configuration that respect such result.

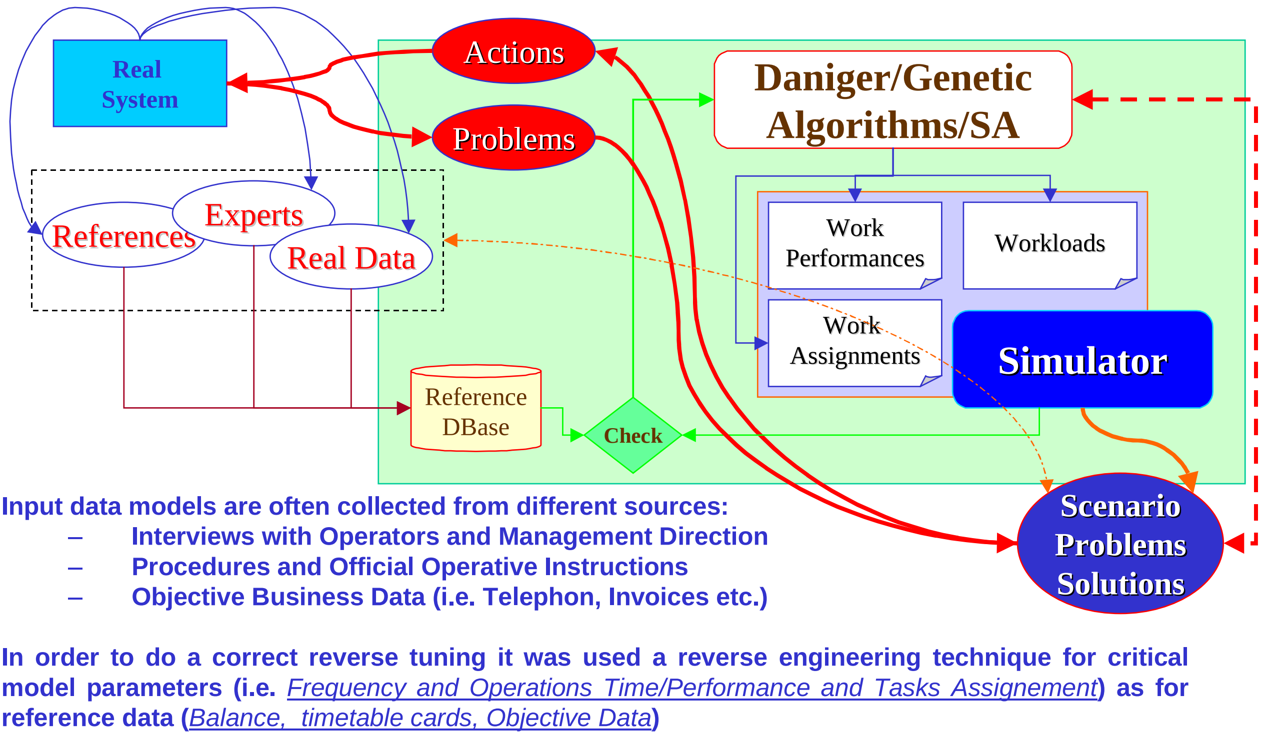

Figure 2: Overall Best Fitting Procedure for Human Resource Modelling in BPR application

For example if we have the case related to the business processes in a company we can try to set the psychological factors and human parameters of the available personnel trying to reproduce the last year overall behaviour based on the knowledge of general data (working hours, effective work carried out, costs, extra time, success rate in different business processes etc.).
Obviously these parameters involves a very large number of factors; to provide an example a company reorganization involving administrative and commercial offices introducing these aspects could require to tune over 300 parameters for just a small department of 20 people (i.e. different operation service time identification, work sharing configuration, etc).
Therefore the best approach is to adopt some automated procedure based on optimisation that drive the simulation input in order to obtain a proper overlapping with the real value of overall target function on the reference scenario.
This approach could be obtained especially by techniques based on approaches that avoid gradient methodologies in favour of area or stochastic optimisation; in effect the stochastic nature of these phenomena introduces complexity even in the optimum definition.
The very complex relations among factors based on highly non linear relations involve risk of being engulfed in local minimum configurations.
Considering these aspects it is preferable the use of nongradiental algorithms for optimisation of the best fitting procedure.

The detailed methodology for this tuning process could be based on the use of genetic algorithms and/or stochastic adaptation in order to face the high dimension of the analysis space and the complexity of the fitness functions; a general architecture is summarised in the figure 2.

APPLICATION EXAMPLES

The authors experienced different case where human behaviour had significant influence over the target functions, in the following some examples are summarized

Human Behaviour in Health Care

The organization of Surgery Divisions in an Hospital introduces different aspects related to human behaviour such as :

- Team Harmony
- Individual Attitudes

In the model developed these factors was introduced as characteristics of the single operator based on interview with the responsible of each Surgery Division; the simulator developed was used as reference for a planning system devoted to increase throughput and reduce costs with heavy constraints in term of resources and technical parameters.
The introduction of human factor it was possible to improve the efficiency of the system by combining in efficient way the resources guaranteeing best harmony

during surgery operations; the comparison obtained between simulated planning and effective operations was very satisfactory.
A similar approach was used to organise hospital Analysis Department where the different profiles was used to consider the behaviour and the interactions during diagnostic meetings among technicians and doctors.

Quality of Life in Vessels and Oil Platforms

Ships and vessels represents a challenge for guarantee efficient quality of life; today new developments in technologies, in automation and especially in system reliability allows to reduce/change processes and systems; in military ships this allows to reduce drastically personnel, increasing the living spaces and providing more support to other services (i.e. fuel, weapons etc.)
The authors was involved in several projects where simulation models was requested to estimate these benefits in projects related to ships and oil platforms.
One project was devoted to create a ship restaurant model for estimating the benefits for introducing new technologies (i.e. passing from kitchens to catering for fast ferries); it was necessary to consider the interference and behaviour of people during the meals in term of grouping attitudes in references to different cultural framework; in this context detailed micrologistics models was developed in order to reproduce the interference and interaction among people; the human attitude was based on bibliography experiments and introduced in the model, while validation on existing case study allowed to complete the best fitting of these parameters.

Public Facility Evacuation

The authors developed in the past models for studying crowd control especially during emergency; the study was applied to stations and museums in order to evaluate the effectiveness of emergency exits and evacuation procedures. In this context the human factor was mostly focusing on the people behaviour that is related to friendship, family structure and other relations keeping together groups and or requesting single individuals to search their relatives.
In this case we model the people as single individuals with specific attributes and types that define their behaviour and reactions to emergencies.

Business Process Re-engineering

Another interesting case study related to the development of integration of human behaviour components in a simulation model was recently developed for studying business reorganisation. In our case the human parameters was concentrating in two major aspects:

- Team Working Performance
- Reaction to Reorganization

In effect the model was devoted to estimate the benefits of a business reorganization in a medium size company, so the impact of the process over the people and their attitude in reacting to the reengineering heavily affects the overall company performance.
In this case most of the parameters was provided by the human resource division and by interview with managers, parameter best fitting was achieved by automated optimization using as reference value people workload extracted from work tables recorded by the collection system respect the simulation estimation.
In this application case it was performed a double stages best fitting devoted to a general tuning followed by a more detailed fitting on the more significant factors.
Different Techniques was used for the best fitting and the Experimental results obtained allowed to complete the model validation as well as the checkup for this proposed approach. Some results about experimental results are proposed in figure 3 as example.
In effect the process is based on the integration between the simulator and the optimisation algorithms; currently the authors implemented, in reference to this BPR applications, a system working in Office Suite™ using different optimisation techniques (i.e. Genetic Algorithms, Random Search, Stochastic Adaptive Search and custom systems); therefore in addition to regular optimisation techniques a customised approach developed from "branch and bound" was used in order to try to create an ad hoc robust system: Tiger DNL is in effect an Optimisation techniques implemented for comparing different approaches devoted to identify cluster of input for proper tuning of the parameters that is inspired by Tiger life cycle.

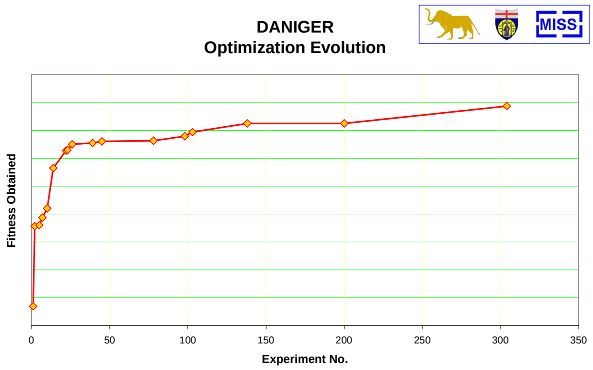

Figure 3: Fitness Function Obtained during Best Fitting

The fitness function for automated optimisation is based on output of simulation runs operating on a scenario with over 150 variables to be tuned representing human factors that affect the work efficiency of administrative department people.
In effect the target function for best fitting is based on the measure of the sum square error between reference target functions over pre-existing scenario and simulated data.

CONCLUSIONS

In human behaviour related to industrial facilities and business process it is very critical the proper identification of the final goal of simulation project; the final objectives become in effect the reference baseline for defining the fidelity and detail level for these aspects considering the benefits obtainable by including these components respect simplified modelling.
The factors to be considered in order to estimated the benefits are maintainability, usability and effectiveness.
Obviously a very critical aspect is related to the possibility to tune the human parameters considering the complexity of measuring and validating these aspects; the use of best fitting procedures integrating optimisation techniques within the simulation and using reference baseline on quantitative measure related to historical scenario is the innovative methodology proposed; the approach is very promising and effective and allows to complete robust validation and verification.
The example proposed confirm that the human factors are often introduced in model in explicit way, and that the benefits obtainable are significant.

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BIOGRAPHIES

Agostino G. Bruzzone is full Professor in the Department of Production Engineering at the University of Genoa where he specialises in the field of simulator-based applications for industrial plants, developing new methodologies and intelligent system integration techniques.
Currently, he is serving as Industrial Relations Chair in SCS Europe and as Director of Technical Council for Management and Forecasts Application in the Board of Directors of the Society for Modelling & Simulation International.
He is Director of the McLeod Institute for Simulation Science involving over 20 centers worldwide.
He is also a founding member and the president of the Liophant Simulation Club. He has written more than 100 scientific papers in addition to numerous technical and professional reports in partnerships with major companies (i.e. IBM, Fiat Group, Contship, Solvay) and agencies (i.e. Italian Navy, NASA, National Center for Simulation, US Army).

Matteo Brandolini get his degree in Management Engineering and Logistics Engineering at the University of Genoa. He is a founding member of the Liophant Simulation Club and has been involved in several simulation projects related to military and industrial businesses. Presently, he is working as consultant in the fields of Port Environment, Professional Training, Retail Reorganization, ERP projects, E-Commerce and Project Management with major Italian companies. Matteo Brandolini is currently senior partner of BRB Studio a consulting firm devoted to apply advanced modelling and simulation techniques in different sectors.

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