Social Layers and Population Models Directed by Intelligent Agents for Estimating the Impact of Operations and Investments

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Keywords: Intelligent Agents, Human Behaviour Modelling, Country Reconstruction, CIMIC, PSYOPS.

Abstract: This research aims to support operations planning and management in complex scenarios where population and interest groups are critical elements; in particular the paper propose experimental analysis carried out on a complex South Asia scenario by running an HLA Federation driven by Intelligent Agents; the context is allows to simulate investments and operations over a an asymmetric mission environment with insurgents, terrorists, different parties and articulated social frameworks. The proposed scenario is characterized by various degrees of freedom and it needs to be modelled and simulated in order to evaluate the evolution of human behaviour and socio-psychological aspects. The authors have developed special models in which Computer Generated Forces (CGF) are driven by Intelligent Agents (IAs) that represents not only units on the battlefield, but also people and interest groups (i.e. Middle Class, Nomads, Clans); the study is focused on Civil Military Co-operations (CIMIC) and Psychological Operations (PSYOPs); while the simulation has been developed using an architecture that involves various federates in different roles. Along the entire life cycle of the research processes of Verification, Validation and Accreditation have been applied in order to determine the correctness and effectiveness of the results and the paper proposes experimental results obtained during the dynamic test of the federations.

1 INTRODUCTION

The human factors is a critical element when investments and operations are planned over a region; indeed the impact of population point of view and the interests of related social layers is often affecting effectiveness and efficiency of operations, it could introduce risks and/or provide opportunities; these elements are obviously pretty difficult to be investigated therefore they strongly affect the overall success; normally it is fundamental to identify all the stakeholders and to consider their interests and their attitude, this require to consider for instance economic, religious, ethnic groups as well towns, villages, local leaders as key factor to be consider in planning.

In several geo-political areas it is required to plan new investments and activities devoted to stabilize or normalize the situation respect previous critical conditions (i.e. civil war, insurgency, terrorism, etc); in these case it is common to develop initiatives devoted to get support of the local population as well as to improve the quality of life from several point of view (i.e. economy, health, civil rights, security, education, etc.); in order to achieve these results Civil Military Co-operations (CIMIC), Information Operations (INFOPS) and Psychological Operations (PSYOPs) need to be prepared and carried out properly.

So it is evident the interest in being able to model these activities as well as the dynamic interaction with the population over a specific framework; indeed such interactions could be pretty complex involving many interest groups representing the different social layers of the population as well as their distribution over the terrain; obviously these elements need to be considered even in reference to the existing situation of the area from many point of view: infrastructures (i.e. roads, hospitals, schools), environmental conditions (i.e. weather), specific actions (i.e. strikes, demonstrations, intimidation activities).

The authors currently have developed models for these context by creating a new generation of intelligent agents representing population and interest groups to drive complex simulation related

G. Bruzzone A., Massei M., Bartolucci C. and Capponi D'Agostino L..
Social Layers and Population Models Directed by Intelligent Agents for Estimating the Impact of Operations and Investments.
DOI: 10.5220/0004635704120419
In *Proceedings of the 3rd International Conference on Simulation and Modeling Methodologies, Technologies and Applications* (SIMULTECH-2013), pages 412-419
ISBN: 978-989-8565-69-3

to these mission environments; therefore it is important to state that these models and the previous considerations could be effectively tailored and applied also in relation to civil scenarios where new investment (i.e. industries and infrastructures) have to be plan over a domestic region or a district as well as during promotional campaign in marketing initiatives.

2 SIMULATION OBJECTIVES

Therefore the international context in unstable areas introduce a good motivation to investigate these population models (i.e.country reconstruction operations); currently there it is expected that these models could be very useful for evaluating alternative planning considering risk, opportunities, times, resources costs over a complex and stochastic framework, vice versa the predictive capability of these simulators is still pretty limited due to the high degree of uncertainty affecting human elements and the high influence of specific spot events (Bruzzone and Massei, 2010). Due to these considerations, the proposed agent-driven simulations are devoted to conduct experimental analysis and decision support by providing reliable estimations and useful risk analysis, but not the of the exact time and location of a new riot; indeed these events are generated usually by an ignition factor that is highly unpredictable (i.e. a single phrase or shot in a specific moment).

Considering the proposed context it is evident that nowadays military mission environments, especially within countries characterized by different cultures, society organization and changeable political situations, require a new approach to tactical and strategic operations which not only appreciates military engagements, but also relationship between civil population, military forces as well as community evolution and interest groups.

The problem of this analysis is that there are not universally accepted simulation models and that the human behaviour modifiers (HBM) are very difficult to be represented; in addition it is even necessary to create models of specific operations that are currently not covered by the existing simulators in order to take of Civil-Military Cooperation, INFOPS, PSYOPS as well as of psychological consequences over population during mission execution; therefore some existing model/simulator is currently taking into account these not-kinetic operations, but usually it is just a qualitative on/off parameters or a manual script affecting the scenario evolution; this obviously don't allow to consider the complex dynamic of the interaction among different interest groups that is the basis for situation evolution.

3 APPLICATION FRAMEWORK AND PROPOSED APPROACH

The simulator should consider for instance that digging a well within an area could generate positive effects on some part of population (i.e. people hired to carried out the work, owner of the land) as well as negative effects on other ones (i.e. opposite clan respect well owner, opposite political party respect that one involved); these actions generated direct impact on element of the population living in the area as well as on the their related interest group and in addition produce a cascade effect on all the social networks among people and interest groups. In addition if due to weather conditions and/or lack of resource the well constructions result to be affected by delays this could produce negative impact on the people that expect the completion to get benefits of this asset.

All these elements as well as the cascade of effects could result positive or negative with a strong influence due to the dynamically evolving relationships among people and interest groups and also due to the importance of the specific actions, the cultural background and the communications (Seck et al., 2005).

Indeed the diffusion in the region and among the people and interest groups of the effects of the actions is modelled based on communications over different supports (face to face, media, phones) and considering specific factors; therefore these communications introduces attenuation factors and delays; due to the computational workload (i.e. in our case 300'000 people and 60 interest groups) the cascade effect could slow down simulation on single workstations, for this reason it is possible to run the simulation with correct diffusion models or by considering that the diffusion happen with fixed stochastic delays along each single operation phase (this reduces of drastically the events to be considered); considering multiple actions on going concurrently and the main interest to measure final effects this simplification resulted acceptable, therefore if computation power is available it is possible to run the simulator using more correct models.

In the proposed models it was required to model these elements and to create a simulation able to reproduce a scenario where CIMIC and PSYOPS were conducted; the interest group and populations were modelled based on a multilayer approach that consider both population elements deployed over the terrain and interest groups; in addition these entities interact with the units of the different parties (i.e. coalition forces and insurgents).

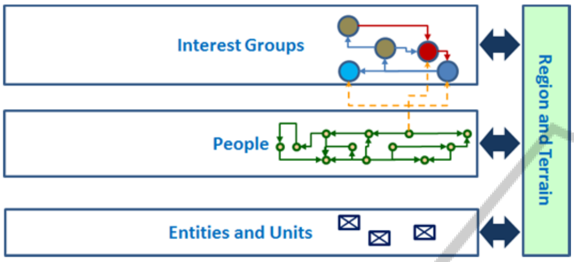

Figure 1: Multilayer Model including Population, Interest Groups and Units.

Due to the fact that the intelligent agents reproduce population behaviour within operations, the model allows the users to correctly evaluate the reaction of the civilians not only to military actions, but also during peace keeping and reconstruction phases.

The research has been developed and tested through the involvement of Subject Matter Experts (SME) from different countries; in particular the proposed scenarios was developed as demonstration for a R&D (Research and Development) project named CIMIC and Planning Research in Complex Operational Realistic Network (CAPRICORN).

4 INTELLIGENT AGENTS AND SIMULATION DEVELOPMENT

These models have been created in order to support operational planning decisions and to be integrated with other systems previously developed; it is able to work as single user or within a federation architecture (HLA standard); this was motivated not only by the needs of respecting existing standards, but even for the opportunity provided by developing an open architecture to be further integrated with other simulations in order to cover complex problems. Due to these reason interoperability requirements are pretty important and represent a strategic advantage of the proposed approach (Bruzzone et al., 2007); (Zacharewicz et al., 2008)

In fact IAs (Intelligent Agents) have a big potential in addressing these kind of problems (i.e. Yilmaz and Ören, 2010).

The most important feature of the models is represented by the intelligent agents that are able to simulate human behavior of people modeling their characteristics; this not only in term of their party side (neutral forces, friends, enemies and civilians), but even in reference to their liaisons to different interest groups and social networks. The capability to use this approach it is an important support for applications involving federations of simulation to address complex scenarios and multiple threats for training and it is pretty interesting to investigate their use for supporting operational planning

In the past the authors set up libraries of innovative models able to simulate different society attributes represented by riots, agitators and terrorists (RATS) and IA-CGF modules (Bruzzone et al., 2008); (Bruzzone, 2008); in some case it was possible to simulate the whole population of a large area reacting to a natural disasters (Bruzzone and Massei, 2006), of a big town respect humanitarian activities (Bruzzone et al., 2011) or in relation to health care issues (Bruzzone et al., 2012); therefore in this case the intelligent agents were extended to cover, not only entities and units operating on the field as well as single individuals/families within the population, but even social objects such as interest groups.

In order to succeed in this process it becomes necessary to properly design, tailor and experiment the scenario considering the very large quantity of elements, variables and parameters; due to these reasons the M&S (Modeling and Simulation) process is formulated over three phases: simulation development, specific mission environment tailoring and simulation experimentation over the specific mission environment.

The authors decided to develop an innovative model of a whole country, taking into account the features that involve agents able to correctly interact in the agent based environment; obviously considering the very broad spectrum of applications and elements affecting these operations it is critical to restrict the range of validity and the components to model based on a detailed analysis to be carried out among trans-disciplinary teams involving scientists and operative people (Bruzzone, 2012).

Indeed considering the possibility to use these agents in order to support decision makers on the field for planning operations in overseas scenarios it could be very important to develop a simulator able to be used by people with no strong scientific background and using limited computing capability.

Therefore it is necessary to develop models and simulators able to run correctly based on an installation and configuration that should be operated and maintained on field with the kind of resources that are expected to be available on that context; users should be able to configure and create a mission environment; therefore considering the complexity of these applications it is expected that a team of experts and analysts will proceed to create a configuration of the simulator for a specific region and timeframe (i.e. Kapisa District in Afghanistan 2010) to be used as reference by final users eventually deployed on site.

More in detail, the first step approached by the scientists consist of Modelling phenomena, actions and elements that are specific for a socio-political-cultural framework. During the conceptual model creation, simulation expert contributions are essential to building a proper and effective set of models and to properly approach the problem thanks to their knowledge of specific operations and scenarios; for instance for a region could emerge the necessity to include nomad behaviours among the possible alternative occupation of the population.

The second phase regards precisely the knowledge management: info sources are used in order to achieve the knowledge basis in order to tailor parameters and entities of a specific region or context; indeed to the necessity to determine a reference scenario a specific mission environment has to be defined; for instance it is necessary to collect information about the different political and economic groups as well as to tailor the importance of religion and clan factors in term of their influence in creating a family respect the specific cultural area.

Obviously along the entire M&S process the VV&A has been performed to ascertain their formal correctness and their usability effectiveness according to the imagined use; therefore during the simulation experimentation is the critical moment to dynamically test the validity of the models as well as the functionality of the simulator

A set of mission environment hypothesis are defined by planners and/or analysts in order to choose alternative friend course of action (F-COA) and opposite course of action (O-COA); by this approach it is possible to plan investments and operations; a COA could involve CIMIC or PSYOPS targeting different interest groups over a specific zone, affecting people in the area as well as social layers; in addition the decision maker could define the operation time plan of the investment, the assigned resource in term of money as well as equipment and people; obviously during the simulation multiple operations could be planned and carried out concurrently or sequentially and the simulator allow to consider availability of resources, influence of opposite force actions as well as weather condition influence (i.e. weather working days for external constructions).

Each CIMIC or PSYOPS evolves based on different phases (i.e. for a CIMIC planning, engineering, acquisition of resources, erection, commissioning) each one affected by specific needs in term of money, resources, boundary conditions (i.e. weather).

The agents are currently driving the behaviour of population and interest groups respect their perception of the general situation and their "feelings" respect on-going activities; the models use fuzzy rules to estimate the effect of the different operations respect their nature and their attitude respect the actors.

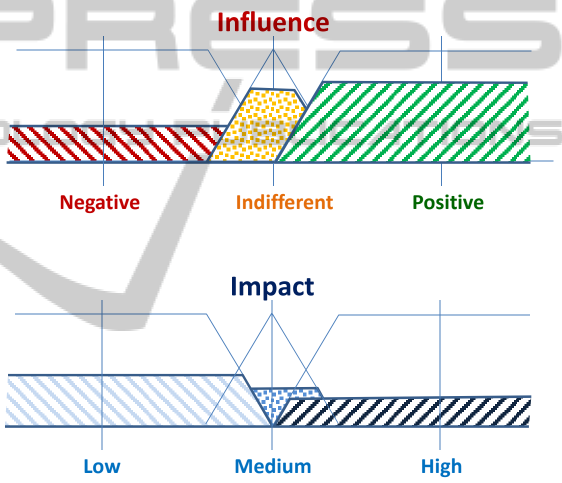

Figure 2: Fuzzy Membership for evaluating Mutual relationships between two Groups of Interest.

Relationships among entities are usually defined usually by two functions (impact and influence) that could be defined in term of ownership to membership functions respect the following classes (low, medium, high and negative, indifferent and positive) as proposed in the following graph.

By this approach it is possible to express quantitative estimations about the effectiveness of the actions conducted; for instance it is possible to apply defuzzification in order to transform the relationships among different critical interest groups or people over an area in order to estimate their trustiness respect specific players; for instance the Overall Trustiness of the Population respect the Coalition could be estimated or that one of a specific religious group, village and/or district.

For each mission environment the simulation parameters have to be set according to the initial conditions and hypothesis; then predefined settings represent the base for the execution of the simulator, which outputs has to be analysed.

The simulation execution could run in different operative modes according to the context and user requirements: stand alone, federated with other simulators, multiple replicated runs etc.; at the end the outputs are collected for each single run and statistically analysed; these results are evaluated during the simulation experimentation (Spiegel and Schiller, 1999); a classic and simple approach for analysing the results it is based on what if analysis consists of the simulation of different hypothesis previously formulated (Hill, 1996). Another possibility that is allowed by simulator is to compare the Desired Final Effect (DFE) of a scenario with the Simulated Course of Action (COA).

The user can also first define Key Performance Indexes (KPIs) and then compare final results of different planning alternatives basing evaluation on them; an effective approach to perform a ranking of different alternatives consists of creating a target function which has to be able to appreciate and involve all these Key Performance Indexes. The latters also represent the reference in order to develop the cost-benefits analysis, which, together with risk analysis, gives to the user all the elements for choosing the best planning alternative.

Considering the complexity of the mission environment usually Design of Experiments (DOE) is used in order to complete analysis and produce synthetic reports (Montgomery, 2000).

Through the feedback from military users with operational experiences and subject matter experts on the specific disciplines, it was possible to develop the models as well as to define the specific user needs; by this approach to develop and validate the conceptual models, to perform the definition of the specific mission environment created for CAPRICORN Demonstrator and to validate the functions; during the last phase related to use the Demonstrator for testing and analysing simulation results it was possible to complete the dynamic VV&A of the proposed approach over a specific case study.

In particular the involvement of the users for VV&A was based on different phases; during the first one the focus was to review of key concepts and operational planning requirements; this allowed to generate a common synthesis about CIMIC and PSYOPS, decision making processes, scenario analysis methodologies, training and risk analysis requirements; most of the activities carried out in this phase was organized mostly by desk-top review and face validation performed through organization of meetings and workshops; therefore in this phase some preliminary simplified model was presented and even executed to share concepts and to validate and verify model assumptions and IA basic behaviours.

In the following phases the work was based on running of the simulation in front of the users and on analysing experimental results: during this phase operational planning was carried out through the cooperation of users, analysts, subject matter experts, development team and operational planners.

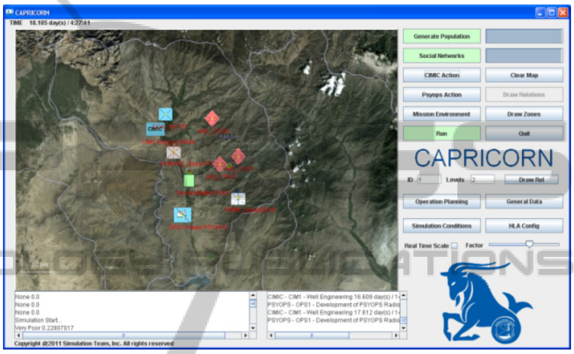

Figure 3: Simulation Interface.

5 POPULATION MODEL

For a tactic scenario, such as the real recently warfare where Northern Atlantic countries are involved, is necessary to model civil status and characteristics like:

- Ethnic and Clan
- religion;
- Psychology status;
- Cultural / educational level;
- Social and Economic Status
- Geographic location of object;
- Gender;
- Age;
- Health care status;
- Political party;

And especially are considered particular modifiers of person features, such as:

- Stress;
- Fear;
- Aggressiveness;
- Fatigue;
- Trustiness.

People relationships, friendships and social relationships are also considered in agents algorithms and distributed in a stochastic manner using Monte Carlo techniques based on consistency algorithms able to aggregate people respect the socio-cultural-economic background.

The layers used to model this context includes the following classes:

- Terrain — Infrastructure Layers (i.e. Roads), Terrain Elements, Weather Conditions
- People — The Population Entities on the Terrain (i.e. Mrs.Baran and/or Sakhi Family)
- Groups — Interest Groups (i.e. Sunnis, Honey Producers, Hotaki Clan, Tajik Ethnic Group, Hamnazar Political Party)
- Entities — Units on the Terrain (i.e. Coalition Platoon, Insurgent Group, Riot)

The People have their social networks interconnecting the population elements based on familiar and friendship relationships; while each people object is connected to multiple interest groups based on his nature with dynamic links representing his affiliation and the related strength; in addition groups and interconnected by mutual hostility and friendship over the social layer, obviously also these connections evolve dynamically during the simulation due the actions carried out; in addition the terrain and Entities affect the behaviour of people and social layers, while the Intelligent Agents are in charge of directing the objects during the simulation for completing tasks and for reacting to stimuli and to their own situation awareness.

6 DEMONSTRATOR RESULTS

The Capricorn Demonstrator consists of a Simulator including the Mission Environment Generator based on Monte Carlo technique applied on statistical database of the population; by this approach the whole people objects representing population and all related interest groups are created and interconnected by the reference relationships over the different layers.

It is proposed an example specific to a CIMIC/PSYOPS mission environment in the Kapisa Afghan region, considering the related COA and parameters concerning population, social networks and groups. The simulation paradigm is based on stochastic discrete-events simulation and it is federated within an HLA Federation (High Level Architecture) both referring to original and IEEE1516 standards; models were implemented in Java with different RTI (Run Time Infrastructures) were tested including Portico, Pitch, VT Mäk. During the test federation integrated CAPRICORN Simulator and IA-CGF E&U (Intelligent Agent Computer Generated Forces Entities and Units) developed by Simulation Team for modelling units on the battlefield; the simulation were carried out over Kapisa Region in South Asia considering presence of several companies of Coalition Forces, several units of Insurgents able to carried out O-COA (i.e. Intimidation), Demonstrations and Riots generated based on the population behaviours and simulated within IA-CGF E&U; the operations (i.e. CIMIC and PSYOPS) as well as the Interest Groups and Population were simulated by CAPRICORN Demonstrator over a timeframe corresponding to 1 year. ANOVA (Analysis of Variance) was applied in order to measure the confidence band on the controlled variables and the optimal duration time (Mosca et al., 1993).

As anticipated the population and social networks, within the simulation, are generated by CAPRICORN Demonstrator basing on Monte-Carlo techniques; Groups and people so generated relate with entities and units as well as with PSYOPS/CIMIC operations; the actions and events are affected by stochastic factors considering time, cost and effectiveness elements as well as all human behaviour factors.

The outputs of CAPRICORN are related to performances in term of times, costs and involved resources during the planned operations as well as a KPI concerning the evolution of the mutual behaviour between the critical groups represented in the chosen scenario (i.e. trustiness of the target groups of the operation respect coalition forces, or overall trustiness of the population versus coalition forces).

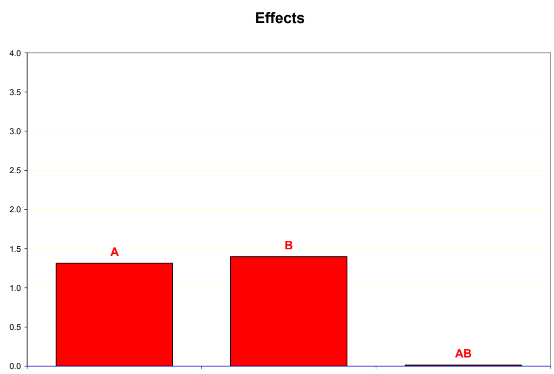

Figure 4: Estimation of Trustiness among the two critical Groups of Interest (Coalition and Target Group).

A sensitivity analysis based on DOE was carried out respect different independent variables such as:

A: Budget Allocated to the main Operation

B: Staff and Resources Assigned to the main Operation

In the figure 4 the effect represents the influence expressed as ratio between contrast and the square pure error of trustiness scalar of the target function "overall trustiness"; the analysis propose the effect of single independent variables and of their combination respect this output.

At the end of the simulation process the user knows the effective schedule of the different operation phases (i.e. planning, preparation, supplying, erection/execution, commissioning/follow-up) and the overall duration as well as costs, cash flow, impact on the population.

The figure below shows the evolution of trustiness during the simulation of the CIMIC action well digging COA; it is evident that the deliverables of the different phases introduce major changes; in fact the simulation in this case was executed with the simplified algorithm for diffusing of positive/negative reinforcement due to the action among the population the cascade.

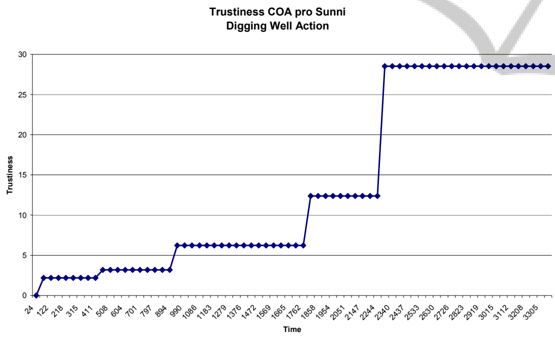

Figure 5: Trustiness evolution with simplified model.

The model allow simulating multiple CIMIC and PSYOPs actions within different zones and affecting different groups; these could be planned and studied over a single simulation run: in this case report concerns information about their changing along the time and their effect on the population. So for example the solution which determines the best impact on civilians could be identified and quantified as well as risk estimation could be used to support decision making.

The figure below represents the mean square pure error diagram for a CIMIC action Digging Well from COA in term of variance of the trustiness respect the replicated runs carried out by changing the random seeds of the statistical distributions; it is evident with 25 replications it is possible to obtain results stable with acceptable confidence in term of trustiness (~15%).

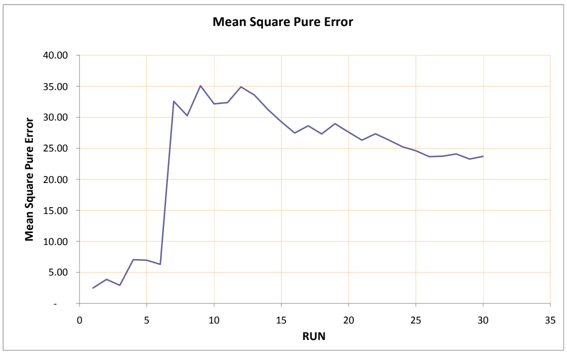

Figure 6: Digging well action error analysis.

The model is available to be used for several different kind of investments and infrastructures such as school construction, police station installation and digging wells and it could be extended easily to irrigation infrastructures, buildings and apartment constructions, roads; in addition in term of INFOPS and PSYOPS it is already possible to simulate use of Radio and TV Media as well as leaflet campaign over a region.

In the figure below the contrast represent the influence of factor expressed respect the target function "Trustiness among Coalition and Sunni Interest Group".

7 CONCLUSIONS

This paper propose an approach to model operations devoted to create infrastructures and actions on a area to improve the social economic situation; the authors developed innovative models for the population and the interest groups devoted to reproduce their behaviour and to estimate the impact of the new actions the context is referring to the case of CIMIC, INFOPS and PSYOPS conducted in South Asia and consider both economic and operational aspects as well as weather conditions and possible hostile actions by insurgents.

The research proposed by the authors represents a modelling approach for reproducing complex behaviour among population and interest groups during specific operations.

The experimental analysis provided interesting results and confirmed the potential of this approach; currently the authors are working for further extend the current models for different applications including industrial and civil cases over domestic scenarios.

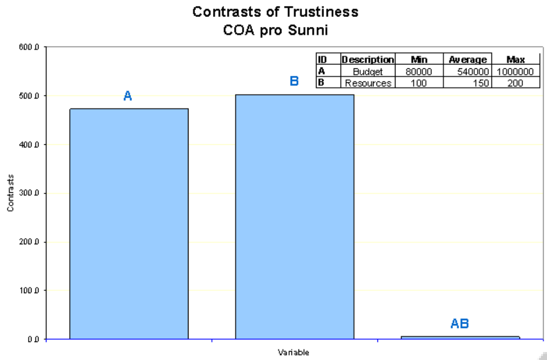

Figure 7: Sensitivity Analysis over Specific Trustiness.

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