MODELING WITHIN A SYNTHETIC ENVIRONMENT THE COMPLEX REALITY OF MASS MIGRATION

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ABSTRACT

This paper proposes a modeling approach to represent the complex reality of current mass migrations. In this case the demographics and generic statistics are used as input data, while human behavior models are used to represent the phenomena as well as the interactions among the different key factors. The development of the envisaged conceptual model addresses the migration flows between Africa and Europe in order to conduct verification and validation, and focuses on a specific case inspired by the recent agreement between European Union (E.U.) and Nigeria.

Keywords: Human Behavior Modeling, Intelligent Agents, Mass Migrations

1 INTRODUCTION

International migration flows towards developed countries are continuously growing, creating complex scenarios from several points of view including social, political and economic aspects (Ratha et al. 2016). In particular the global labor market, immigration policies and geopolitical situations are crucial drivers that affect these aspects since several years (Johnston 1991; Fehr et al. 2004; Castles 2004, Samers 2004; Smith 2013). Traditionally these phenomena have been analyzed by geopolitical point of view or just by statistics (Levine et al. 1985, Sames 2004); the presence of so many factors dynamically interacting and affected by human behavior and stochastic factors suggest to develop quantitative models, able to address these scenarios as it has been done already in similar cases (Bruzzone 2013). Therefore the authors propose the use of advanced Human Behavior Models based on dynamic stochastic simulation to address a specific context, focused on the evolution of European - African Agreements. The proposed instance address a specific African area, inspired to Nigeria case (Parfitt 2016), that is currently subjected to be regulated by a special agreement with EU, "Migration Compact" (EC 2016). Announced by the European Commission in June 2016, "Migration Compact aims to create a Partnership Framework to mobilize EU action and resources on managing migration the priorities are saving lives at sea, increasing returns, enabling migrants and refugees to stay closer to home and, in the long term, helping third countries'

development in order to address root causes of irregular migration..” (European Commission press release, Strasbourg, 7 June 2016).

From this point of view, it is not by chance that sometime this problem is referred as *Male Nostrum*, a Latin phrase that is inspired by current situation; indeed *Mare Nostrum* was the name of a successful operation led by Italy to protect Mediterranean Sea Border and to guarantee Safety of Life at Sea for African Immigrants sailing to South Europe on poor boats, this operation has been afterwards enhanced by *Triton* operation led by EU (Bjarnesen 2015). So, migration flows are a framework so interdependent, complex and vast to require simulation even just to understand the whole boundaries of the problem and the potential of the different Courses of Actions.

This paper represent a preliminary research on modeling complex immigration scenarios considering human factors and stochastic elements related to multiple layers; the proposed Model combines previous cases based on Intelligent Agents Computer Generated Forces (Bruzzone et al. 2011b, 2014a).

2 MODELS OF WORLD DEMOGRAPHICS

Along the last decades the immigration flows in Europe were subjected to a steady increase due to many reasons, wherever economic aspects are generally dominant (Borjas & Crisp 2005). As a result, such flows are mostly moving towards the most rich parts of the European Continents from some major directives as summarized in table I (DESA2013). .

Table 1: Overview of Migration Flows to Europe.

Continent of Origin of the Immigrants to EU	**Immigrants to Europe [millions of people]**	**Percentage respect EU Population [%]**	**Percentage of Total EU Immigrants [%]**
Europe	37.8	7.48%	52.28%
Asia	18.6	3.68%	25.73%
Africa	8.9	1.76%	12.31%
Latin America	4.5	0.89%	6.22%
Oceania	1.6	0.32%	2.21%
Northern America	0.9	0.18%	1.24%
Total	72.3	14.31%	100.00%

These phenomena are results of the world wide demographics and several social, political (Ratha et al.2016; Joly 2016) and economical (Scheve et al.2001; Bourguingno & Morrison 2007) aspects. Indeed also the demographic pressure related to the world population growth is by itself a very important factor, considering that is expected to increase from the current 7.4 billion to 10 in 2053 (DESA2015; Infoplease 2016, PRB 2016).

In order to describe these phenomena under an analytical perspective, it is possible to adopt a non-sophisticated but effective model inspired to GDP (Gross Domestic Product), GNI (Gross National Income) and GNDI (Gross National Disposable Income) indicators (Samuelson & Nordhaus 2009; Ladenfeld 2000; Yaşar 2015; Yoshihara et al. 2016).

It is possible to define an average level of per capita income for a Nation expressed as:

$$\mathrm{NAIC} = \mathrm{kx}\frac{\mathrm{C+I+G+TB+NFS+NUT}}{\mathrm{PP}} \quad (1)$$

$$\mathrm{NUT} = \mathrm{UF_{In}} + \mathrm{UT_{Out}} \quad (2)$$

$$\mathrm{NFS} = \mathrm{EX_{FS}} + \mathrm{IM_{FS}} \quad (3)$$

$$\mathrm{kx} = \mathrm{k_{cul}} \cdot \mathrm{k_{nat}} \cdot \mathrm{k_{pp}} \quad (4)$$

NAIC	National Average Income per Capita	PP	Population
C	Personal Consumption Expenditures	I	Gross Private Domestic Investments
G	Government Spending	TB	Trade Balance
NFS	Net Factor Income from Abroad	NUT	Net Unilateral Transfer
IM_{FS}	Value of Imports of Factor Services	EX_{FS}	Value of Export of Factor Services
UF_{Out}	Value of Income Transfer Given	UF_{In}	Value of Income Transfer Received
k_{nat}	corrective factor based on National Characteristics	kx	National Corrective Factor
k_{cul}	corrective factor based on National cultural background of the population		
k_{pp}	corrective factor based on National Purchasing Power		

It is evident that this approach is very simplified and miss to consider important aspects such as internal inequalities, relative purchasing power, etc. (Salustri 1927; Arghiri 1972; Fox 2012; Kakwani et al.2016):

It is interesting that while NAIC should be used to consider the differential between nations to estimate desire to migrate of the population, the advances in communication and transportations are making evident that emigrants moves towards most attractive countries on a global scale considering global differential. Due to these reasons it is introduced a factor corresponding to Global Average Income (GAI) that is expressed as

$$\mathrm{GAI} = \frac{\sum_{i=1}^{\mathrm{NW}} \mathrm{kx_i(C_i+I_i+G_i+TB_i+NFS_i+NUT_i)}}{\mathrm{WPP}} \quad (1)$$

NW	Total Number of Countries of the World
X_i	Indicator for the i-th Country
WPP	Overall World Population

The GAI (Table 2) could be used as a rough estimation of country population desiring to migrate comparing their NAIC with GAI as threshold level; obviously this provide just an order of magnitude to estimate the quantity of people motivated to move.

Table 2: Regions & People under Average Income.

Region	Regional Population [millions]	People under GAI [%]	People under GAI [millions]	Region vs. World Population [%]
Large Europe	831	10.6%	89	15.3%
North America	360	0.0%	0	6.6%
Latin America	600	26.1%	157	11.0%
Oceania	29	0.0%	0	0.5%
Middle East	127	46.3%	59	2.3%
Central Asia	1,840	85.9%	1,581	33.8%
Far East	2,393	86.9%	2,079	43.9%
Africa	1,214	99.6%	1,209	22.3%

It is important to consider that just 2.08 billion people (28%) live in countries that are over NAIC (around 15'690 USD/year) of the whole planet based on some available data (DESA2015; Infoplease 2016, PRB 2016, CIA 2016).

Considering the improvements in communications and mobility this obviously generate an huge flow, that is expect to growth in future despite specific spot events (e.g. wars, revolutions, famine) occurring periodically (Ratha et al.2016; UNHCR 2015b; Kegley 2015). The aging of the population in rich countries (fact that is even present in poor countries due to improvements by health support) is another important drive for migration, which compensate the need of non-skilled labor force of consolidated economics (Johnston 1991; Magnus 2012; Paradiso 2016).

More recent analysis (DESA2015) confirms statistics and highlights an huge flow overpassing 70 million people arriving mostly from Africa, Asia and Easter parts of Europe. These phenomena needs to consider as well human factors, religion, ethnics, cultural background in order to evaluate consequence of these decisions and not just statistics (Lavine et al. 1985; Levitt 2007; Bruzzone A., Sokolowski 2012).

From this point of view, simulation could contribute providing a framework to develop valuable models including HBM (Human Behavioral Models) (Bruzzone et al.2013) bestowing quantitative results that could support evaluation of risks and effects of alternative decisions (Bruzzone & Massei 2010).

3 THE PROPOSED MODEL ARCHITECTURE

Human behavior models could rely on different data provided by Subject Matter Experts (SME), statistics data, etc. (Jennings 1987; Capone & Mey 2016). Recently use of Internet of Things (IoT) and Social Networks is enabling new opportunity to model Human Behaviors (Eagle & Pentland 2006; Lane et al.2010; Kalter 2016): in facts the use of intelligent agents for creating HBM resulted very flexible and effective (Bonabeau 2002; Bruzzone et al.2011a).

It was decided to adopt a multi-layer approach able to combine different Modeling and Simulation (M&S) techniques including stochastic discrete event simulation and agent driven simulation. It is proposed the tailoring of the IA-CGF through the creation of a NCF (Non-Conventional Framework) simulation derived from DIES IRAE (Disasters, Incidents and Emergencies Simulation Interoperable Relief Advanced Evaluator) used in previous scenarios (Bruzzone et al.2016). Indeed the architecture is similar to that one developed for SIMCJOH project (Simulation of Multi Coalition Joint Operations Involving Human Modeling) adapted as proposed in Figure 3 (Bruzzone et al. 2015). In facts the DIES IRAE is

based on MS2G (Modeling, Interoperable Simulation and Serious Game) Paradigm (Raybourn 2012; Bruzzone et al.2014b) and it is composed by different simulators that are open to be federated by HLA (High Level Architecture):

- DIES IRAE VIS (Virtual Interoperable Simulator): as stochastic discrete event agent driven simulation based on IA-CGF; this model includes HBM and simulates the actions of components, equipment, units and population.
- DIES IRAE VIC (Virtual Interoperable Commander) is a Virtual Simulator adopting Serious Game approach that generate the Synthetic Environment where the events are occurring in order to be able to support individual and collective training and education.
- DIES IRAE SOCKS (Social Kinematics Simulator) is a discrete event model able to take care of demographics and social dynamics to incorporate the high level prototypes of social inferences.

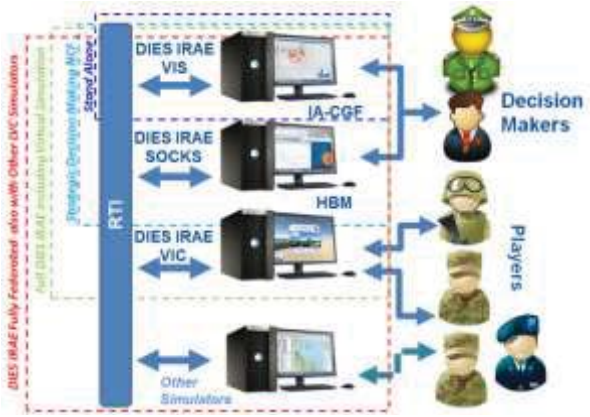

Figure 3: DIES IRAE VIS/VIC/SOCKS: Architecture.

This extension of DIES IRAE is further expendable by the use of HLA (High level Architecture) interoperable standard that allows to federate this structure with other models and simulators; it could be possible to combine this simulation with other war-gaming solution to support Experimentation, Policy Definition, Operational Planning as well as training within CAX (Computer Assisted Exercise).

As proposed in Figure 3 the DIES IRAE could operate in multiple modes including among the others:

- Stand Alone: Just DIES IRAE VIS simulating by IA-CGF the population dynamics of the migration in the scenario
- Strategic Decision making NCF: combining DIES IRAE VIS and SOCKS to reproducing strategic dynamics as well as impact of COA (Course of Actions)
- Full DIES IRAE: DIES IRAE complete NCF combining VIS-VIC-SOCKS to include also virtual representation
- DIES IRAE Fully Federated also with external LVC Simulators: in this open case the HLA allows to federate the whole DIES IRAE NCF also with other Simulators (Live, Virtual, Constructive) compliant with HLA.

It is possible to use the simulator from stand-alone structure to fully federate, being the architecture flexible and supporting single user/wide distributed simulation. The authors are working in tailoring the DIES IRAE VIS and VIC and in developing the conceptual models to be implemented in DIES IRAE SOCKS. The following variables are considered to be included in the DIES IRAE SOCKS:

Independent Variables

- Birth Rates
- Population at Origin Country
- Family Structures
- Population at Host Country

- Distribution of Incomes per capita at Origin Country
- Distribution of Incomes per capita at Host Country
- Political Situation in the Country of Origin
- Criminality exploiting Human Trafficking
- Unemployment Rate at Host Country
- Existing Migration Flows
- Percentage of Regularized Immigrants
- Political Situation in the Host Country
- Unemployment Rate at Country of Origin
- Attitude of the Security Council Members
- Special Interest of major Players (Western Nations Europe / China and Russia)

Directly Controlled Variables

- Immigration flows from Africa along the period 2026-2030 from sub-Saharan Areas
- Evolution of Migration Flows
- Evolution of Population at Origin Country
- Evolution of Population at Host Country
- Change in Distribution of Incomes per capita at Origin Country
- Change in Distribution of Incomes per capita at Host Country

In addition to the Controlled Variable by applying DOE it could be possible to estimate the following Key Performance Indexes (Montgomery 2008):

- Influence of Birth Rate on Migration Flows
- Influence of unemployment on Migration Flows
- Influence of per capita income on Migration Flows
- Influence of social policies of countries of origin and destination countries on Migration Flows
- Effect of the Migration Compact in EU Migration Flows
- Xenophobia Level in host countries
- Success Rate of Populist Parties
- Terrorism Level in Host Countries

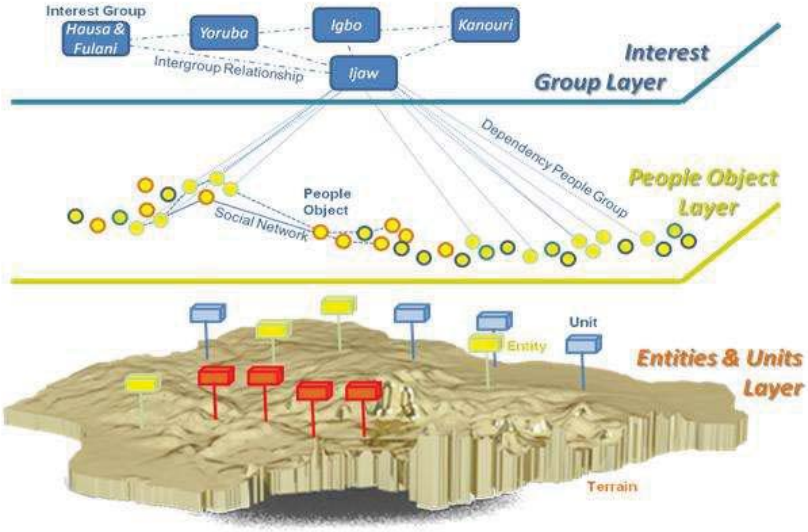

Figure 4: IA-Multilayer Modeling.

The IAs (Intelligent Agents) used reproduce population based on the approach used in IA-CGF (Bruzzone 2013). The multiplayer approach proposed in figure 4 reproduce three different layers: operational, individual and groups. The first level deals with entities & units moving on the map able to merge and

split based on their status, these entities includes camps, caravans, checkpoints, etc. The second layer is composed by people objects and their social networks and interacts with first layer based on the map locations and state of operations of the entities and people over it. The third layer is composed by interest groups representing mutual attitudes among themselves and relationships with people objects belonging to them; interest groups include religions, political parties, tribes, ethnic groups, etc. Each people object could belong to multiple interest groups through liaisons that are characterized by an intensity level, as well as each interest group is connected with other ones through links determining type of attitude and intensity through fuzzy membership functions. The people objects and interest groups adopt fuzzy logic based on Fuzzy Allocation Matrices that determine their reactions and the application of specific ROE (Rules of Engagements). Entities, units and people objects are characterized by aggressiveness, stress, fatigue, fear levels evolving based on specific functions considering both their status, activities and perception of events (Bruzzone & Massei 2010). In order to initialize the population it is applied Monte Carlo simulation in consistency with general statistics of the geo political area at the beginning of the simulation. The model should support also estimation of impact of critical events such as famines, floods and epidemics, civil wars due to ethnic and religious fragmentation with the emergence of new states to secede from existing areas as happened in Katanga (Abi Saab 1978). Such stochastic elements are defined based on probability distribution influenced by simulation variable (Bruzzone 2013).

4 MIGRATION FLOWS & DATA FOR A REALISTIC CASE STUDY: NIGERIA

The current experiences and the expectations about future migration flows have been extensively analyzed both at international level and Nationally based on latest developments (Bjarnesen 2015; Citterio 2016; Lanni 2016). Hereafter, it is proposed a realistic case study of current migration flows to Europe based on current situation, subjected to be regulated by the recent agreement between European Union and Africa's countries, Migration Compact (EC 2016). From this perspective, a special attention is paid to African Western Routes involving Nigeria, the Africa's most populous country.

The data described below are the base that will be used to create the scenario for simulation; indeed these data set are based on public domain sources available from Institutions, Project and Organization (UNHCR 2015b; ACLED 2016a, 2016b; IOM 2016a, 2016b, 2016c, 2016d, 2016e; Sabbati 2015, UNICEF 2016).

4.1 Nigeria Population

Nigeria is the 9th most populous country in the world with an estimated population of 150 million of people. The country has been undergoing explosive population growth and has one of the highest growth and fertility rates in the world; current estimations are corresponding to 182 million inhabitants in 2015 and 399 million forecasts for 2050 (DESA 2015b). Indeed United Nations Population Division estimates Nigeria will add more people to the world's population by 2050.

4.2 Nigeria Economic Situation

Nigeria is one of the fastest growing economies in the world. Petroleum and oil resources play a large role in the Nigerian economy. The country is the 6th largest producer of petroleum in the world; it is the 8th largest exporter and has the 10th largest proven reserves of it; moreover occurrences of uranium have been discovered in North-eastern states of Bauchi, Adamawa and Taraba; as well as in Plateau, Kano and Cross River States and the government is concluding plans to resuscitate its moribund cocoa factories at Idanre suitable for chocolate with huge potentials for the production capacity.

4.3 Social Situation

Nigeria possesses a huge inequality in terms of wealth and poverty among population (UNICEF 2016). Indeed while the Country has vast oil wealth, the large majority of Nigerians is poor: 71% of the

population living bad on incomes less than one dollar a day and 92% on less than two dollars a day. The local life expectancy remains petty low and decreased from 47 years in 1990 to 44 years in 2005.

4.4 Political Situation

Along the last years Nigeria experienced military dictatorship, corruption, political instability and poor governance; these reasons affected the Country development leading to very low investments in infrastructures and basic services that are totally inadequate respect the population needs. Corruption is very diffused and represents one the principal challenges in Nigeria.

4.5 Population and Collective Security

Along the last months and years several thousand people have died in attacks led by insurgent and rebel organization, especially composed by Islamic State-aligned Boko Haram (BBC 2016). Indeed the group has separatist aspirations that have further growth recently; they final goal is the establishment of a "State" where to impose Islamic law. It caused thousands of Christians to move away. According to the "Armed Conflict Location and Event Data Project" between 1997 and the end of 2015 in Nigeria there have been 50,157 violent deaths (e.g.car bombings, armed clashes, etc.).

4.6 Nigeria Migration and Human Traffic

The major host of people moving from Nigeria is Italy, where many of the migrants arrive trough the South Sea Border. An important aspect of the mass migration is the exploitation by several criminal organizations of human trafficking, which is by far a contemporary form of slavery and above all an affront to Human Dignity.

4.7 Migrations & Asylum in Nigeria Case

Despite the growing figures of migration from Nigeria, the recognition rates for asylum and protection are pretty low: less than 5% of Nigerian immigrants get refugee status in Europe and overall about 25% get protection in the various forms provided for by national law.

4.8 Scenarios for Decision Makers on Migration Flows

It is evident that Nigeria represents a big challenge (Frouws et al. 2016) However, the demographics presented above confirms that this phenomena have a big inertia and should be not just attributed to temporary crisis situation; in case of Nigeria and other areas, the crisis situations results, unfortunately, almost endemic and persistent. This last consideration confirms the necessity to plan actions devoted to address and solve these issues concurrently with management of migration flows, as intended by Migration Compact. Moreover, European Countries should also consider the different positions, plans and foreign policy objectives of other major players in the African Continent, such as China, United States of America and Russia. Finally, it could be worth to consider solutions for Africa based on something similar to *Marshall Plan,* in the similitude of what they did the USA at the end of World War II (Muller, 2016).

5 NIGERIA CASE STUDY AND VV&A

This research is currently based on reorganizing the previous models and to develop new conceptual representation to reproduce the population dynamics, therefore some preliminary model about flows change due to stochastic factors has been introduced; in this case discrete event Monte Carlo simulation was applied and it was carried out a measure of the experimental error due to the pure influence of stochastic factors also in order to apply ANOVA (Analysis of Variance) to the simulator (Donohue 1994); the graph proposed in figure 5 confirms the stability of the simulator and the acceptable confidence model of the preliminary version of the simulator DIES IRAE SOCKS in reproducing the migration flows. In the figure proposed the average monthly flow to Europe since the starting year has been calculated for over 9

years; it is important to state that the predictive capability of the simulator is obviously limited respect complex target functions (e.g. social key performance indexes), therefore it is evident that migration flow quantities could be properly estimated over long periods.

6 CONCLUSIONS

This paper proposes the development of simulation models of migration flows based on Human Factors and Intelligent Agents; the obtained results encouraged the authors to continue their efforts to acquire further data, in order to finalize the definition of the conceptual models related to case of recent Migration Compact between Europe and African States. This research represents a first step in order to create a scenario, data set and models to conduct this experimentation; the connection with SMEs allowed to finalize potential actions and policies to be simulated, therefore the real experimentation will be carried in future development of this project in order to provide guidelines and support to decision makers.

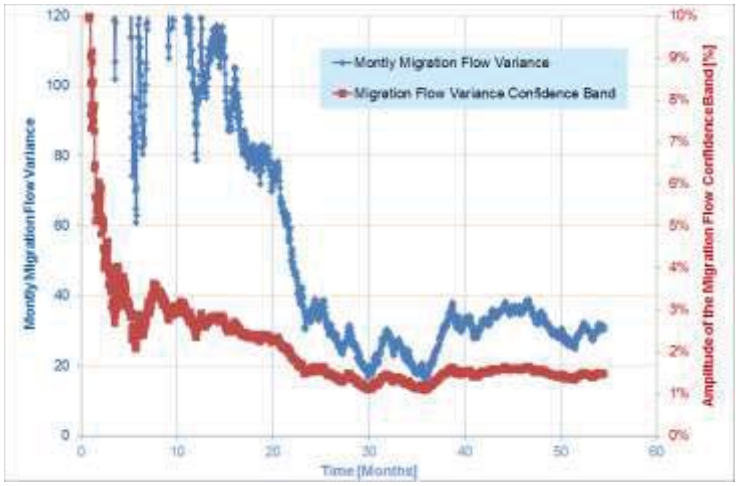

Figure 5: ANOVA applied to Average Migration Flow

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