

Identification of Critical Factor Sets for Close range Engagements in Urban Operations

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The dynamic and asymmetric environment of today's battlefield and the proliferation of technologically advanced equipment at the soldier level have increased the need for more accurate and higher-fidelity modeling of the individual soldier in combat. Traditionally, the focus of the combat modeling community has been on large-scale battlefield platforms and unit-level analyses. Consequently, the representation of the individual soldier on the battlefield has not kept pace with other representations. These Infantry soldier models require unprecedented fidelity in terms of the Infantry soldier entity, his behavioral and decision processes, and his environment. In order to enable the modeling community to more accurately represent the individual soldier in combat simulations in a timely and cost-effective manner, it has become important to first identify and develop the critical factors and functions that have the greatest impacts on soldier lethality, survivability, and combat effectiveness in close range (0-50m), team sized engagements. We used the Systems Decision Process (SDP) to identify these critical factors and recommend to our client the order in which they should be addressed by the modeling community. Our application of standard systems engineering tools led to a unique characterization of the factors considered most critical for the accurate representation of individual soldiers in close range engagements. The result will be an ordered set of factors that will help to focus the efforts of the modeling community and ensure the more timely and cost effective integration of soldier behavioral and decision-making aspects into combat simulations. Our paper will discuss the problem background and methodology we applied to find critical factors that will enhance the modeling and accurate representation of the individual soldier in a close combat situation.

I. INTRODUCTION

BECAUSE of the current operational environment experienced by U.S. Army soldiers and the advancement of future Army systems in support of these soldiers, many venues within the Army have developed an increased demand for models that represent individual soldier actions. Among the acquisition community, PEO Soldier, "the US Army's material developer for nearly every

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item or equipment carried or worn by the infantry soldier," has a large stake in getting equipment to soldiers in a timely and efficient manner. (Boylan-Tollefson, 2004) Through modeling and simulation, it is possible to guarantee this before these large sums of money are spent. Current models generally have high resolution and fidelity, but fail to capture or accurately represent human behaviors of soldiers. (Boylan-Tollefson, 2004) The community does not know which factors impact a soldier when faced with a short range engagement. The objective of this project is the determination of those factors that contribute to a soldier's lethality, survivability, and combat effectiveness in a short-range engagement on a modern battlefield.

Determining which factors contributed most to enhancing soldier performance is a big project. Adopting the United States Military Academy's Systems Decision Process provided the backbone for this project. The SDP can be applied to any system in any phase of its lifecycle. Specifically, the SDP starts with the current system and ends with the desired end state, focuses on the needs an objectives of stakeholders and decision makers, has four steps (problem definition, solution design, decision making, and solution implementation), and specifically considers the system's environment and how the environment will effect system use (DSE: Reader (Systems Design Process): 6-7).

The assumptions that we developed from our constraints and limitations help us to frame our problem and move on to the modeling phases. These assumptions fall into three basic categories. These categories are data collection, generalizing soldiers, and conducting combat operations. Data collection required that a large number of surveys be sent out. Interpreting this data required that we assume we had a statistically significant number of responses and that the information was accurate and truthful. Generalizing soldiers takes the form of assuming that the same factors affect all soldiers regardless of MOS/branch and individual soldiers and teams equally. When modeling combat operations requires assumptions that all communications are monitored continuously and will be a dialogue between the two parties, that the enemy has element of surprise, and that the mission objective and engagement are separate entities. Beyond the assumptions about creating models, it was assumed that output from models is sufficient to conduct statistically significant analysis and that a lack of technological experience will not prohibit modeling efforts by the team.

II. PROBLEM DEFINITION

The Problem Definition phase of the SDP consists of Stakeholder Analysis, Value Modeling, and Functional Analysis. Stakeholder Analysis is the process of the

Stakeholders providing our project team information on the given problem in order to put the problem in context and develop the problem statement. Stakeholder Analysis is important because it keeps the capstone work team's and the client's goals in-line and on track with one another. Value Modeling involves determining the system objectives, performance measures, weights associated with the different value measures from the Stakeholder or senior client. The Value Modeling phase is important because it tells how important different aspects of a problem are to the client and ensure the accuracy and validity of the product received by the client. The complexity of the human body and mind has astounded some of the greatest minds of all time, so in turn, because our problem involves humans, especially in stressful situations, it is extremely complex, which is one aspect we will strive to limit throughout the process. The impact of a successful project and product is knowledge that will likely help the M&S community to more accurately model soldiers in close range combat environments which could find further purpose in developing training and equipment that could one day be fielded.

A. Initial Problem Statement

The initial problem that we are addressing is identifying the critical factors necessary to model close range, quick reaction, and combat engagements. While the need to accomplish such modeling has been identified the development and identification of these factors has not. It is our goal to develop a model that will accomplish this.

B. Stakeholder Analysis

Our client is the TRADOC Analysis Center, co-located with the Naval Postgraduate School in Monterey California (TRAC – Monterey). The primitive need from the TRAC-Monterey perspective is determination of which critical factors affect soldiers in close range engagements. The user for our research will be the Army modeling community that oversees the development of combat simulations. Research on how soldiers fight and act when they come under fire is scarce and the modeling community seeks a more accurate representation of human behavior. These critical factors for modeling soldiers is of utmost importance in the Global War on Terror because of the need to rapidly field equipment to soldiers deployed abroad. This research is vital to cutting out costly and time consuming steps in the development of equipment and ideas for the soldiers to implement and fight more effectively.

When developing our Stakeholder Analysis, we utilized two methods: surveys and review of literature. Stakeholder Analysis began by reviewing literature. MAJ Boylan's prior experience and technical reports with soldier factor modeling provided a large portion for this information. Information from these technical reports and documentation was broken out into three areas: a summary, derived factors, and derived functions. Most beneficial were (Tollefson and Boylan, 2004) and (Schamburg, 2005) technical reports. These documents provided some directly relevant information

including systems decompositions and functional hierarchies. The Schamburg technical report provided a basis for our value modeling. Using his work as a basis for our own, we modified the decision making process and his critical factor value modeling.

Stakeholder	Stakeholder Name	Needs	Desires
Chief Decision Maker	MAJ ALT	Important Factors in a close range engagement	Research backed up by modeling
Client	TRAC Monterey	Important Factors in a close range engagement	Research backed up by modeling
User	Modeling Community	More information on soldier factors	Research backed up by modeling
Other	American Soldier	New equipment, well designed for use in combat situations	Rapidly fielded, well designed equipment

Table 1: Description of Stakeholders Needs Analysis

Surveys comprised the largest part of our Stakeholder Analysis because they allowed us to get a close look at how soldiers in combat react to situations and effectively respond. These surveys sought to target information about what made soldiers lethal, survivable, and combat effective. Designing the surveys was an incremental process. Originally, we designed our surveys for three groups: soldiers, law enforcement, and experts from the modeling community. Great lengths were taken to avoid systems engineering specific language that might confuse or turn respondents away. The questions from these surveys were specific, but failed on some accounts to tackle exactly what we desired to learn from those surveyed. In fact, one of the respondents took the time to critique the survey and suggested using a scenario to frame our questions and also to have a better picture of what we wanted to learn from the surveys. Questions also arose about the merits of using law enforcement and modeling experts, when soldier feedback was what was really needed.

From this rough beginning, a new survey was designed just for combat veterans and sent out primarily to soldiers with combat experience, actually engaging and being engaged by the enemy. The survey begins with describing the problem, the purpose, and then giving a scenario that is hopefully familiar to those answering the survey. The scenario used to frame the later questions follows:

“You are a part of a platoon or squad-sized dismounted presence patrol in an urban environment in Iraq. While patrolling, your element is engaged from close range (0-50 meters) with small arms and limited RPG fire.”

Though elementary, the scenario provides context for the questions that follow. These questions sought to get at the order of actions taken and to get time estimates, what improves survivability, lethality, and combat effectiveness, and how these actions are applied on a team or squad level. The final step question sought to get a deeper look by asking what sorts of skills they would recommend for training. This

survey was sent out to all deployed, prior service soldiers, officers in the Department of Military Instruction, and to the officer pool in general for feedback.

Results from this survey were more focused and comprehensive than the previous survey set with some similar answers appearing in many varied contexts. Across the board, returning fire and seeking cover were the dominant results. They appeared as the top two most common results in three of our eight questions. Also important was communication, which emerged as a, not surprisingly, important aspect of lethality. The important takeaway from these surveys was level of agreement on the results and also the common sense nature of the results. Nothing in the survey results was very surprising, but the consistency of response gave us a definite direction to pursue the different aspects of lethality, survivability, and combat effectiveness.

Overall, the Stakeholder Analysis has painted a clear picture of the direction that this project needs to take for success. A variety of useful tools, like value modeling resources, functions, and factors all came out of our literature review, while the surveys provided timely context and specificity for them. The surveys also backed up many of the takeaways from the Literature Review providing the foundation for the drive ahead.

C. Functional Analysis

The functional analysis allows us to develop a better understanding of the system and the functions it is intended/expected to perform. In this case, the system consists of the individual soldier and decomposition of each soldier's function under study. In our scenario, and directly related to how we plan to model and simulate the scenario, we made three sub-functions for how we feel the soldier reacts in a close combat engagement: assess, decide, and act.

These are the three functions that occur every time the soldier is faced with a close combat encounter and how we plan to focus our further efforts to improve modeling efforts. Then in the decomposition stage, we break the three functions down even further to give a more detailed analysis of what each functions consists of. With the three main functions of decide, assess, and act along with the decomposition of each, we find the functional hierarchy. The complete hierarchy allows us to look at the entire system, individual soldier, then, at once we can understand the complexity of the thought process of a soldier faced with combat decisions and his ability to assess, decide and react in almost a simultaneous fashion. However, we made prior assumptions that each function occurs independently and not simultaneously.

The functional analysis stage also consists of functional flow. In the functional flow, we made an effort to model the thought process of the soldier and applied the method of entity diagrams to better this process. The entity diagrams make it easier to lay the process out in a step-by-step manner and prevented us from looking at the actions of the soldier

occurring at once, even though we understand the entire process occurs within seconds of encountering the enemy.

Functional analysis encapsulates our previous steps and allows us to narrow our scope on the difficulties in modeling the soldier. Before being able to decompose this system, we had to review past projects to understand what previous efforts encompassed and talk to the stakeholders to determine their needs in this project. An important note to make; we discovered in our review of literature that in the 2004 Boylan-Tollefson Technical report, the authors created a functional hierarchy which coincided with the direction we wanted to take our hierarchy. Designed for a different purpose, it fit properly and for efficiency purposes we made subtle revisions and used it for a guide in our model.

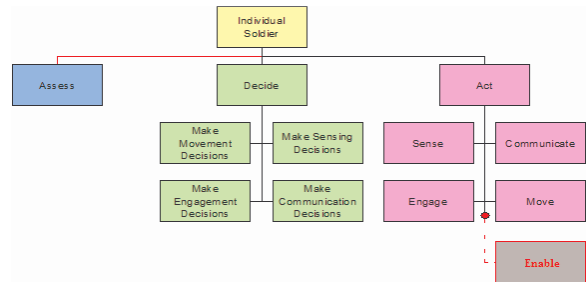


Figure 1: Functional Hierarchy – Representing Adjustments from Boylan Tollefson Hierarchy

D. Functional Decomposition

The Functional Decomposition allows the capstone to further understand every component that makes up each function. By decomposing each of the functions we can better understand the thoughts of the soldier and the complexity of the close range engagement scenario. As stated, we decided to model the soldier using three functions: decide, assess, and act. With these three functions we further decomposed the sub-functions of each main function and tried to go into further detail than in the Boylan-Tollefson report. The authors of the report created “cut-line” or a place to end decomposition and we decided to make an effort and expand our efforts from this line.

This is very apparent in the function of assess. We not only expanded the decomposition, but tailored the sub-functions in a way to better align with the given scenario of a close range engagement. In this further decomposition, we tried to encompass how the soldier will perform certain assessments before leaving the FOB (i.e. assessing mission, friendly, or enemy) and the other assessments will be continually done throughout the progression of the mission.

We also eliminated the enable function from our hierarchy. We felt this function did not directly apply to our scenario and would only further complex the modeling efforts to be performed. Through the elimination of this function we created a more simplistic and accurate portrayal of the close range engagement and created a hierarchy to serve our purpose.

While looking at the functional hierarchy, one can see the “total” system under study and its complexity in each realm of the scenario. We felt the scenario of a close range

engagement could be encompassed through three main soldier functions: decide, assess, and act. In the hierarchy these functions are apparent as well as the decomposition of each. The hierarchy helps piece together the entire system and we can move away from a simultaneous occurrence of events, to a more independent event that happens in a particular order.

E. Functional Flow

The primary purpose of the functional flow diagram is to “provide a better understanding of the relationships of the functions and tools to support requirements identification (Parnell, et al., 2006, 221).” To prevent looking at assessments, decisions, and actions in a simultaneous manner, the functional flow diagram lays the events out in a more sequential fashion. Given this, we used entity diagrams to present a more accurate portrayal of the close range engagement. Refer to Figure 2.

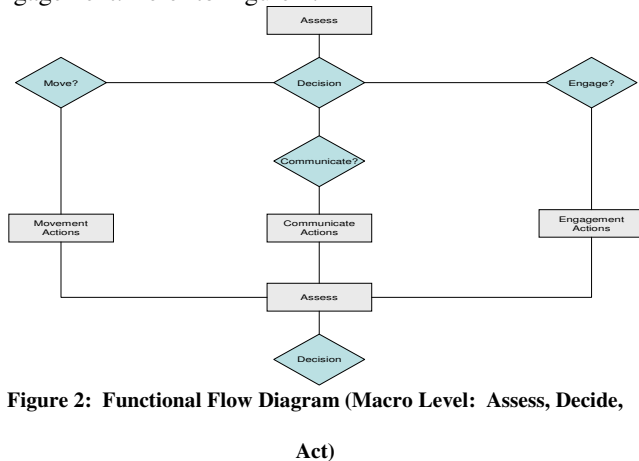


Figure 2: Functional Flow Diagram (Macro Level: Assess, Decide, Act)

As Figure 2 shows, we begin this scenario with an initial assessment of the situation the soldier is in (at FOB assessing mission or in the actual engagement). Based on the assessment the soldier then transitions to a decision: engage, communicate, or move. Pursuant to the decision, the necessary actions take place. Upon completing the actions, the soldier then continues to make further assessments. Our objective was to model this process as being a continual situational assessment followed by the necessary decisions and actions.

Figure 3 describes the Assess process in detail. To examine this process, we further examined what exactly is occurring in the cerebral component of the soldier. It is important to decompose these second-nature processes. We represented this mental thought process meticulously in order to more accurately model individual soldier’s actions. Consequently, we discovered in the assess stage, the soldier is taking in many different aspects of the environment and making several decisions, which then lead to an engage, communicate, or movement action. These findings reveal the complexity of the problem and what exactly the thought process of the soldier encompasses. In Figure 3, the assess

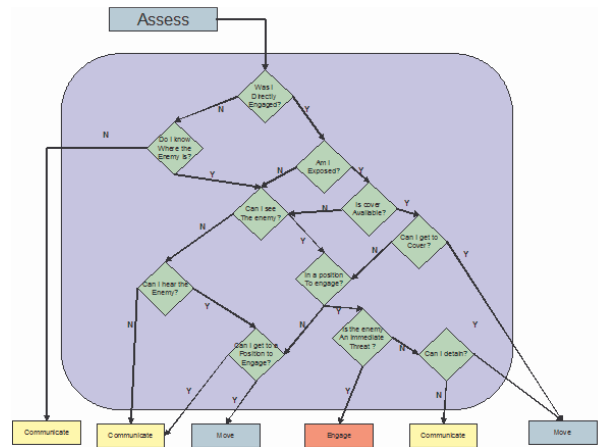


Figure 3: Entity Flow Diagram (Micro Level: Assess)

stage is thoroughly examined, while the group tried to capture the several decisions made throughout the assessing process and how it eventually leads to a particular action.

F. Revised Problem Statement

Before entering the value-modeling phase, we have determined our revised problem statement to be:

“Determine the critical factors to maximize combat effectiveness in terms of lethality, survivability, time to complete mission, and mission completion during close range engagements in urban operations.”

Using this revised problem statement, we can focus our modeling efforts and continue to narrow the scope of this project to best model the soldier and the critical factors that contribute to his success.

G. Value Modeling

Our value modeling efforts focused on developing a qualitative model to evaluate the functions of our system. This included the development of a value hierarchy that reflects the client’s values and objectives. The four primary components of the hierarchy are lethality, survivability, combat effectiveness, and time to model. To measure the quality of the alternatives, we developed objectives that are assigned value measures to assess the degree to which an alternative achieves each objective.

H. Value Hierarchy

In order to capture the stakeholder’s values regarding the fundamental objective and its’ key elements, it was necessary to develop a qualitative model. With this, we created a value hierarchy with an overarching fundamental objective with four second-level essential elements on which we will focus our analysis. These second-level functions each have objectives with values measures that allow us to quantify the effectiveness of our model in regard to our revised problem statement.



Figure 4: Value Hierarchy

The fundamental objective encompasses the scope of our project and the purpose of the capstone team. Our main stakeholder, TRAC-Monterey, wanted us to develop our model using LTC Schamburg’s efforts as a foundation on which to build the value hierarchy. Using the Schamburg Technical Report, we created the value hierarchy below.

III. SOLUTION DESIGN

A. Alternative Generation

Solution design requires idea generation, which stimulates alternative generation, and solution enhancement (Systems Decision Making in Systems Engineering and Management, Fall, 2006). As discussed in the Stakeholder Analysis, we contacted individuals with combat experience and issued a survey with various questions in order to determine the most important alternatives or factors. Eight factors were identified as critical to soldier performance: seeking cover, returning fire, speed, maneuver, accurate fire, mass fires, communication, and assessing. For the purpose of modeling, we treated each factor as an alternative.

B. Modeling and Analysis

Simulation will provide the clear insight and quantitative backing to decide which alternative offers the greatest combat effectiveness. MANA and PYTHAGORAS, agent based models where the behavior of each entity is determined by selecting values for a range of particular attributes, are the software packages that will provide insight into a soldier’s combat effectiveness. We selected agent based models because “agent based models consist of dynamically interacting rule based agents. The systems within which they interact can therefore create complexity like that which we see in the real world” (Agent Based Models, http://en.wikipedia.org/wiki/Agent_based_model, accessed 13 April 2007).

Factor	MANA Equivalent(s)
Seek Cover	Cover, # of hits to Kill, Personal Concealment rate per turn
Accurate Fire	Hit rate per discharge
Base of Fire	Targets unknowns pause
Mass Fires	Squad Contact persistence
Maneuver	Friendly/uninjured friendly
Reflexive Fire	max targets/step
Speed	Movement Speed/next waypoint
Communication	Intra Squad Comms Delay
Assess	Classification Rate/Detection Range

Table 2. Factors in MANA Implementation Method

C. Approach

Neither of these software packages provides direct parallels between the factors from alternatives generated in the alternative generation phase of the SDP. Therefore, we sought to model the alternatives with similar factors in the software package. For example, “Accurate Fire” became “Hit rate per discharge.” “Hit rate per discharge” is the number of hits scored divided by the number of rounds fired. An accurate shooter would tend towards 100%, while a poor shooter would tend towards 10-20%. See Table 2 for the implementation of alternatives in MANA.

D. Model Development

With the groundwork for implementing the alternatives in simulation laid, we turned our attention to developing the scenario our simulation should test and how we would determine the attributes of friendly and enemy forces. Using scenarios developed for training in real world urban environments as a foundation, we altered the scenario to reflect the requirements of our stakeholders. They desired that we consider close range urban environments between team or squad sized elements (4-9 soldiers). Our scenario takes place on a simulation of Baghdad streets and involves a friendly Fire Team (comprised of four soldiers) and five insurgents. We selected this scenario based on guidance from the defined scope of our project, a small unit engagement, and from further guidance from our decision maker. A Fire Team is among the smallest units in the army capable of individual action and provided a close look at small unit engagement.

The basic parameters of our scenario established, we looked to ensure that the soldier attributes reflected real world data and were traceable. We drew heavily on data from the Soldier Battle Lab at Fort Benning (Gerald L. Beckwith, SAIC Contractor: Experimentation Division, SBL, ACTD) to define soldier accuracy, movement speeds, classification ranges, etc. This process made sure that our model was verified against real world situations and that our data might actually reflect actions taken by soldiers in combat.

Basic validation has taken the form of making sure that our soldiers and insurgents conduct a relatively realistic fire fight

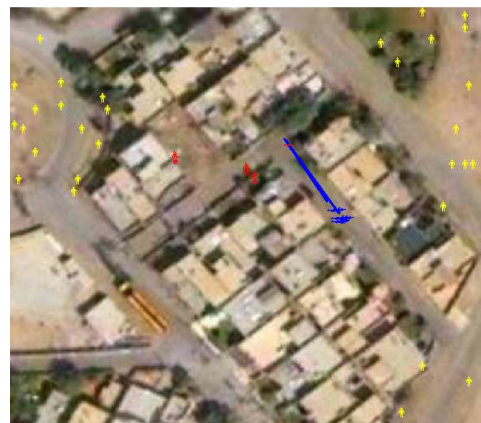


Figure 5: Screenshot of Scenario from MANA

and take casualties in proportion to the real world results of close range engagements. Currently, we have not done large batches of tests, but the manual, limited tests provide good indicators.

E. Outputs of Interest

Outputs of interest were determined by looking at the possible outputs for each model and determining which would provide valuable feedback for run comparison. For Pythagoras, the outputs of interest include number of friendly soldiers remaining at the end, percent of mission complete, range at which friendly soldiers detect the enemy, ammunition expenditure, number of enemy alive at the end of the mission, the shot to kill ratio by friendly forces, and the average enemy health at the end of the mission. MANA has the same outputs, except MANA does not collect information about health so this output is not considered.

Broadly, the outputs fall into survivability, lethality, mission completion, and combat effectiveness groups. Within each group, the outputs are weighted so that each group has an average score. Each group also has weights so that a weighted score can be determined for comparison of the raw data.

F. Raw Data Functions

Because we desire to capture insight into the survivability, lethality, and combat effectiveness characteristics that cannot be precisely modeled, we took outputs of interest and combined them so they reflected these characteristics. For example, combat effectiveness is a combination of detection range, ammunition expenditure, and number of enemy alive. A weighted average of value scores provides a score for each characteristic, that are then averaged to provide a score for each alternative.

Each output of interest is scored according to a value function that seeks to adjust scores based on the relative value of a particular range of outputs over another range of

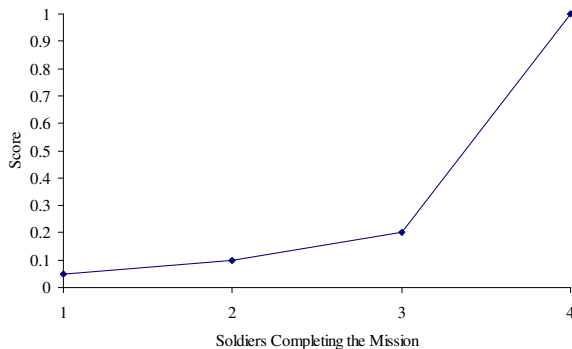


Figure 6. Raw Data Function for Soldiers Completing the Mission

outputs. For example, scoring the number of friendly soldiers left is not a linear curve, but is modeled as shown in Figure 6. In Figure 6, you can see that the value of completing the mission with all four soldiers in the team is much greater than returning with three or less. This reflects the high value of life in the United States Army in addition to

the loss of team effectiveness that accompanies the loss of soldier in a team, especially a close teammate.

IV. CONTRIBUTIONS TO WORK

Work done on this paper provides valuable insight for the military modeling community into the critical factors needed to give models greater fidelity. The currently available soldier models are more focused on longer range engagements in open areas. The realities of the Global War on Terrorism, and the close range urban engagements that accompany it, need better models so that better equipment may be better fielded faster so soldiers on the ground can be confident they have the best tools available to do their jobs.

V. CURRENT STATUS AND FUTURE WORK

Currently, this paper stands on the verge of collecting and processing data. The rough design of experiments is to evaluate the effect of each factor through a process like sensitivity analysis where each factor is varied over a range of percentages to determine which has the greatest effect on close range urban engagements.

Once all data is collected, the raw data will be scored and interpreted in conjunction with the time to complete modeling that factor and the cost of modeling that factor. Completing the scoring of each alternative will almost totally complete the project, as implementation was explicitly not our concern in the initial project statement.

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