Recreating the Battle of 73 Easting in a Constructive Combat Model

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ABSTRACT: *The Battle of 73 Easting was recreated using VT MÄK's VR-Forces constructive combat model. The battle was carefully recreated by representing the specific starting locations, formations, routes, combat entities, and weapons present in the battle. The model's weapon and entity parameters were modified from within the simulation tool's user interface. The method employed was similar to the retroactive predication validation method, but the objective in this work was not to determine the degree to which the model as given recreated the historical outcome; rather, the model's parameters were iteratively modified until the model's results were acceptably close to the historical outcome. By recreating a real world historical battle, the battle and its outcome are better understood, the validity of the combat model is assessed, and methods for accommodating anomalous historical outcomes are explored.*

1. Introduction

Retroactive predictive, or retrodiction, is a model validation method wherein the initial conditions of a historical event with a known outcome are recreated as closely as possible in a model and the model's results compared to the historical outcome [1]. As a validation method, retrodiction has certain methodological issues (e.g., an anomalous historical outcome may be difficult to replicate, even in a valid model), but it has a strong intuitive appeal, is relatively simple to perform, and when the comparison is made using appropriate statistical methods can be quite effective. The Battle of 73 Easting, fought in 1991 between U. S. and Iraqi armored forces, was the subject of a DARPA-sponsored recreation in the 1990s using the then-current SIMNET technology. It is arguably the best documented battle in military history and is seemingly an excellent subject for retrodiction. However, the extremely one-sided historical outcome has proven difficult to replicate in constructive combat models, which usually produce significantly more U. S. losses than actually occurred.

In this study we set out to recreate the historical outcome of 73 Easting as closely as possible in a commercial constructive combat model (VT MÄK's VR-Forces). The intent was threefold: to better understand the possible causes of the historical outcome, to determine how to accommodate potentially anomalous historical outcomes within the retrodiction methodology, and to experimentally explore the bounds of validity of the chosen combat model. After carefully recreating the battle's initial conditions in the model, a lengthy series of modifications and enhancements were made to the weapon and entity parameters available in VR-Forces as input files and tables to increase the specificity and fidelity of the model's representations of sensors, weapons, and munitions. All changes were intentionally confined to those possible via the model's user interface or within the weapons' performance data tables, i.e., no source code modifications were made. When the modifications were complete, a series of simulations of the 73 Easting battle were executed in the model and key performance measures were statistically compared, using confidence interval estimation of the mean, to the historical outcome.

Section 2 of this paper discusses the background of the event to be modeled as well as the reasons for its selection. Section 3 describes in detail the changes made to the default parameters in VR-Forces to achieve an accurate simulation. Section 4 presents the results of the study and discusses conclusions to be drawn from them.

2. Historical background

This section provides historical background on the battle of 73 Easting and its outcome.

2.1   The Battle of 73 Easting [2]

The Battle of 73 Easting was a tank battle instrumental in the victory of the Gulf War that occurred on February 26, 1991. The battle took place in featureless terrain around the Iraq-Kuwait border. With no nearby town or river to lend its name to the battle, it was named after the north-south map reference grid line, 73 kilometers east of an arbitrary origin point, near which much of the action took place.

The battle area was desert with rolling hills and desert valleys called wadi. Reduced visibility in the battle was a large factor due to morning fog and high winds creating sandstorms. Much of the combat took place within 1000 yards due to terrain and reduction of visibility.

The battle took place between the 2nd Armored Cavalry Regiment (2ACR) of the United States Army and two brigades of the Tawakalna Division of the Iraqi Republican Guard. Three 2ACR troops[1] were most heavily engaged; Iron, Eagle, and Ghost, each consisting of twelve M3 Bradley fighting vehicles and nine M1A1 Abrams main battle tanks. The Iraqi Republican Guard employed T-72 main battle tanks and BMP-1 fighting vehicles grouped in different locations along a roughly ten kilometer stretch of the desert.

The three American troops were positioned in a line running north and south progressing toward Kuwait to the east. As the troops moved forward they encountered many stationary groupings of hostile forces.

The battle began around 1600 (4:00pm) local time when Eagle troop began moving westward from near the 67 Easting. At that area, Eagle troop was encountered machine gun fire from a cluster of buildings. Eagle fired on the compound and silenced the enemy fire.

At this point Eagle troop changed formation to create a wedge with the M1A1 Abrams and the M3 Bradleys following behind protecting the flanks.

To the south of Eagle, on the right, Iron troop moved eastward and fired on the same building complex from the south side. Iron troop utilized the same formation as Eagle.

Continuing eastward, Eagle troop moved over a rising dune and after cresting the top encountered a grouping of Iraqi troops. The Iraqi troops included eight T-72s with BMP-1s behind providing support. Eagle troop fired on the Iraqi Republican Guard and destroyed the enemy troops within four minutes without any losses to the American forces.

South and further east of this encounter, Iron troop encountered a similar group of Iraqi T-72s and BMPs. Iron troop also destroyed the opposing forces with no losses.

About a mile east of Eagle's encounter with the group of eight T-72s, the troop came up against a grouping of seventeen T-72s with a line of BMPs behind [3]. The T-72s were stretched along a three mile front. Once again, the American forces destroyed the Iraqi forces with no losses.

To the north of Eagle, Ghost troop, in a line formation with the tanks in the center and Bradleys on the sides, also moved eastward through the desert. Ghost troop first encountered a grouping of T-72s and BMPs that were likely part of the large front encountered by Eagle. The

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[1] In the U. S. Army, a cavalry squadron is a battalion-sized unit and a cavalry troop is a company-sized unit.

BMPs were sitting without their engines one, reducing their heat signature in the American forces' IR sensors. Ghost troop quickly dispatched of these forces with no losses.

After facing their first conflict of the battle, Iron troop came upon a counterattack of enemy tanks moving in from the southeast. The Iraqi attack collapsed under fire from Iron. Iron then took its only casualty of the battle when one Bradley had an electrical malfunction. The Bradley maneuvered for safety and was fired upon by a TOW missile from Killer troop, having mistaken the Bradley for an Iraqi vehicle. Three soldiers were wounded in the event.

Further north, near the 73rd Easting, Ghost troop encountered a defensive line of T-72s and BMPs. The Tawakalna Division fired upon Ghost, mostly ineffectively, but did claim their only hit of the battle by destroying one M3 Bradley with 73mm fire from the BMP. Ghost troop destroyed what remained of the defensive line and held position while more tanks and fighting vehicles crested a hill, pouring into a wadi, and were soon destroyed by Ghost.

Eagle troop stopped its advance eastward near the 74th Easting. Abrams and Bradleys were pulled into a somewhat circular formation and then fired mortar fire on retreating infantry to the East.

2.2 Separation of Actions

The events of the Battle of 73 Easting can be separated into a number of actions for better analysis of the overall scenario.

The first action includes the enemy fire encountered by Eagle and Iron troops coming from a group of buildings.

The second action includes the encounters Eagle and Iron troops had with similar sized enemy groups. These encounters were with groups of eight T-72s each, backed up by BMPs.

The third action includes the battles between Iraqi groupings and Eagle and Ghost troops. Here Eagle and Ghost encountered different sections of the same defensive line formed by the Iraqi Republican Guard.

The forth action is the lengthy battle fought by Iron troop near the 73 Easting. This battle included the only loss encountered by enemy fire.

The fifth action was the ending of Eagle troops advance, and occurred around the 74th Easting. Here Eagle stopped and fired mortar rounds to the east over retreating infantry.

2.3 Selection of Actions for Recreation

For this study, actions two and three were chosen to be recreated. These two actions include all three of the

involved U. S. cavalry troops. These two actions were chosen because they could be easily modeled as compared to the other actions, and the number of losses could be easily compared to the results of a model.

Modeling action one would have needed to include the use of physical structures (buildings), adding unnecessary complication to the terrain model. Actions four and five would have required the advancing friendly entities to stop at a certain point and fire upon moving hostile entities. This is not an overly challenging requirement, but is not as simple as the requirements of actions two and three.

Actions two and three require that the three friendly troops move from one point to another, eastward, while encountering stationary groupings of hostile forces.

Losses occurred in these actions totaled all of the Iraqi Republican guard which included thirty-three T-72 tanks and thirty-six BMP-1 vehicles. No American vehicles were lost.

3. VR-Forces Modifications

VR-Forces in an entity-level combat model. It is both a functional computer-generated forces system as delivered and a simulation toolkit within which users may define new entities, weapons and damage models, entity behaviors, and scenarios. Its capabilities include entity behavior control using plans based on a scripting language and map objects such as routes and phase lines.

VR-Forces was initialized with the appropriate entities, formations, and routes to recreate the 73 Easting battle. In addition, many modifications were made to the default entity, weapon, and sensor parameters present in VR-Forces as input files and tables. The changes were made to most accurately represent the conditions and entities involved in the Battle of 73 Easting. After each set of changes the scenario was run in VR-Forces. A summarization of the changes and their effect on the results can be seen in Table 1. Details of the specific modifications follow.

3.1   M1A1 Abrams

The M1A2 version of the Abrams main battle tank is present in the default parameters of VR-Forces. Creation of the earlier M1A1 version is done by simply copying the M1A2 and editing the value that need to change.

Reload and unload times on ammunition for the 120 mm cannon in the M1A1 Abrams were lowered to be in line with reported speeds in the battle. Due to superior training, the manual loading of the 120 mm cannon in the Abrams yielded a rate of fire of once every six seconds. Accordingly, the reload and unload times were changed to three seconds each.

An infrared sensor was added to the M1A1 Abrams since they were present on the American forces in the battle. The maximum range of the IR sensor was reduced to 1000 meters due to the presence of sandstorms in the battle.

The visual sensor maximum range on the M1A1 Abrams was reduced to 1000 meters, also due to sandstorm conditions.

3.2   M3 Bradley

The M2A2 Bradley Infantry Fighting Vehicle is present in the default parameters of VR-Forces. The M3 Bradley was created by copying the M2A2 Bradley and modifying the base model.

A TOW Missile Launcher weapon system was added to the M3 Bradley entity. The Bradleys in the battle had TOW Missile launchers and used them to great effect. The number of TOW missiles on the Bradley was reduced from the default of eight to seven.

An infrared sensor was also added to the M3 Bradley. This sensor's maximum range, as well as that of the visual sensor, was reduced to 1000 meters due to sandstorm conditions.

3.3   T-72

The T-72 main battle tank is present in the default parameters of VR-Forces. Certain modifications to the default values were still needed.

The default parameters for the T-72 are largely based off of the Abrams tank. One place where this was not accurate and needed to be changed was in the speed of turret slew rate on the T-72. The turret on the Abrams can rotate at a speed of 1.6 radians per second. The turret of the T-72 however is much slower at a speed of 0.3 radians per second.

The unload and reload speeds of the T-72 were also modified to the values reported for the 125mm cannon using an autoloader. Accounts from the battle describe the motions of the T-72 turrets as dipping down after each shot, evidence of the use of the autoloader. With the autoloader the 125mm cannon is reported to be able to fire once every ten seconds. Accordingly, the unload and reload times were changed to five seconds each.

Once again, the visual sensor maximum range was reduced to 1000 meters to account for sandstorm conditions. However, no IR sensors were added to Iraqi forces as they were not present on the vehicles in the battle.

Set-up	Results	Comments
Default parameters with final entity placement and formations	Combat occurs at ranges of 2000 to 3000 meters with Red forces losing many and Blue forces losing all entities.	Inaccurate. Battle was fought at close ranges.
Ranges set to 1000 meters for all visual and infrared sensors	Combat occurs at ranges near 1000 meters with Red forces losing some and Blue forces losing all entities.	Inaccurate. Red forces were destroyed with few loses to Blue forces.
Addition of TOW Missile launcher to Bradleys	Combat occurs at 1000 meter range and Red forces lose many and Blue forces lose all entities.	Inaccurate. Red forces were destroyed with few loses to Blue forces.
Creation and addition of Sagger Missile Launcher and 73 mm Grom Gun to BMP-1	Combat occurs at 1000 meter range and Red forces lose many or all entites and Blue forces lose many or all entities.	Inaccurate. Red forces were destroyed with few loses to Blue forces.
Reduction of hit probability tables of Red forces by 50%	Combat occurs at 1000 meter range and Red forces lose all and Blue forces lose many entities.	Inaccurate. Blue have few loses.
Reduction of hit probability tables of Red forces to final values of 25% for BMP-1 and 10% for T-72	Combat occurs at 1000 meter range and Red forces lose all and Blue forces lose few or no entities.	Accurate. Red forces are destroyed and Blue forces sustain few or no loses.

Table 1. Summary of VR-Forces modifications.

3.4 BMP-1

The BMP-2 Armored Fighting Vehicle is present in the default parameters of VR-Forces. This default entity was copied and modified to create the BMP-1. Modifications were made to this entity including the creation and addition of two weapon systems, the 73mm 2A28 Grom Gun and an ATGM launcher for 9M14 Malyutka.

The 73mm 2A28 Grom Gun is the main armament of the BMP-1, and the default BMP-2s of VR-Forces have a 30mm gun as for their main weapon. The Grom gun is not in VR-Forces default weapon system definitions, so a new system was created. The system was created by copying and modifying the system definition files for the 30mm gun weapon system. Parameters changed for the Grom gun included the addition of two 73mm ammunitions, the PG-15V Heat round and the OG-15V HE-Frag round. The muzzle speed of the gun was also reduced from 1000 meters per second to 400 meters per second. Finally the hit probability tables were also edited and will be discussed in a later section.

The ATGM launcher, or Sagger Missile Launcher, was created by copying and modifying the weapon system definition files for the TOW missile launcher. Modifications made to the default configuration included reduction of the total number of missiles to four, reduction of missile travel speed from 329 meters per second to 115 meters per second, and reduction of maximum range from 3750 meters to 3000 meters.

Following modifications made to all other entities, the visual sensor range was modified for the BMP-1 to a value of 1000 meters. The BMP had no infrared sensor.

A separate entity was created called the BMP-1 Engine Off. This entity was an exact duplicate of the BMP-1 with the only exception being a reduction in the infrared heat signature range from 4000 meters to 500 meters to account for BMPs encountered in the Battle of 73 Easting that were stationary in the desert with their engines off, thereby making them more difficult to see through infrared sights.

3.5 Visibility Sensor Ranges

Visibility in the Battle of 73 Easting was a major factor in the way combat took place. Descriptions of the battle from sources present claim that conflicts would often occur at ranges as close as 1000 yards with many occurring even closer.

The reasons for these close encounters come from two major sources; terrain and environmental conditions. Rolling hills in the desert would often leave advancing troops with low visibility until the hill was crested, at which point hostile forces may be discovered on the other side at very close ranges. The environmental conditions in this area of desert included foggy mornings and, of importance in this battle, windy afternoons and evenings, the latter causing sandstorms and reducing visibility significantly.

Accurately modeling the terrain in for the battle would be difficult, as the hills in the desert change with the wind and there is no record of where each crest and valley existed. It is possible to create new terrain in VR-Forces but the difficulty in finding data for its creating in this scenario limited this possibility.

Reduction of visibility was created by decreasing the maximum range for visual and infrared sensors on all entities to follow the ranges reported for the battle. Visibility ranges vary slightly from one source to another, but a value of 1000 meters was chosen as most of the conflict took place within this range. Reducing the maximum range allowed combat to take place in close quarters as it was reported to have happened in the battle.

3.6 Correction of Hit Probability Tables

The default tables for hit probability in VR-Forces were used for the American troops. These tables were modified for use on the Iraqi Republican Guard troops. Reasons for these modifications are to account for the lack of military training and knowledge that the American forces had and the Iraqi forces did not.

The hit probability tables work to give a percentage value of the probability for hit of a given weapon system at a given range window.

Hit probability tables for the 73mm Grom Gun were originally based on those of the 30mm gun. These ranges in this table were first changed to reflect the maximum range capable of the Grom gun, reducing the maximum from 4000 meters to 2000 meters and dividing the probabilities to be valid for every 500 meter window. Initial values for the Grom gun were set as shown in Table 2.

The hit probability table for 125mm gun of the T-72 is by default based on the hit probabilities of the 120mm gun used by the Abrams. These values are shown below in Table 3.

These initial values for both the Grom gun and the 125mm gun were modified to better reflect the true weapon performance.

3.7 Reduction of Hit Probability Tables

After the preceding modifications were made the model results were still substantially in disagreement with the historical outcome; in particular, in the model runs the Iraqi forces were inflicting many more losses on the U. S. forces than actually occurred. Because the objective was to recreate the historical outcome, it was determined to further reduce the values in the Red hit probability tables. The hit probabilities of the Grom gun were changed to 25% of the original values and the probabilities of the 125mm gun to 10% of the original values. These tables with their modified values are shown below in Table 4.

3.8 Scenario Formations and Execution

American troops used two formations in the Battle of 73 Easting, a flying wedge with the Abrams tanks in the lead and the Bradleys protecting the flanks, and a line with the Abrams in the center and the Bradleys on either end. These formations were created in VR-Forces and used for the three troops in the battle. Eagle and Iron formed in the flying wedge while Ghost formed in a line.

The Iraqi forces were spread in defensive lines throughout the desert. At each point the line was created by differing numbers of T-72 tanks in the front supported by BMPs behind.

Initial Grom Gun	
Range	Hit Prob
500	0.4
1000	0.5
1500	0.4
2000	0.2

Table 2. Initial Grom 73mm gun hit probabilities.

Initial 125mm	
Range	Hit Prob
1000	0.9
2000	0.8
3000	0.75
4000	0.7

Table 3. Initial 125mm gun hit probabilities.

Modified Grom Gun		Modified 125mm	
Range	Hit Prob	Range	Hit Prob
500	0.1	1000	0.09
1000	0.125	2000	0.08
1500	0.1	3000	0.075
2000	0.05	4000	0.07

Table 4. Modified hit probabilities.

The scenario set-up in VR-Forces involved creating the American forces as the blue force, and the Iraqi Republican Guard as the red force. Initial troop placement as seen in the VR-Forces user interface is shown in Figure 1.

The red forces were split into four groups encountered throughout the battle. The first group encountered by Eagle troop consisted of eight T-72s and five BMPs. A similar group was encountered to the south-east by Iron, made up of the same number of red forces.

The largest group of red forces was encountered by Eagle and spread across a wide front. This formation included seventeen T-72s and sixteen BMPs.

The final group of red forces was in the north, encountered by Ghost. This group consisted of three T-72s and seven BMPs with engines off.
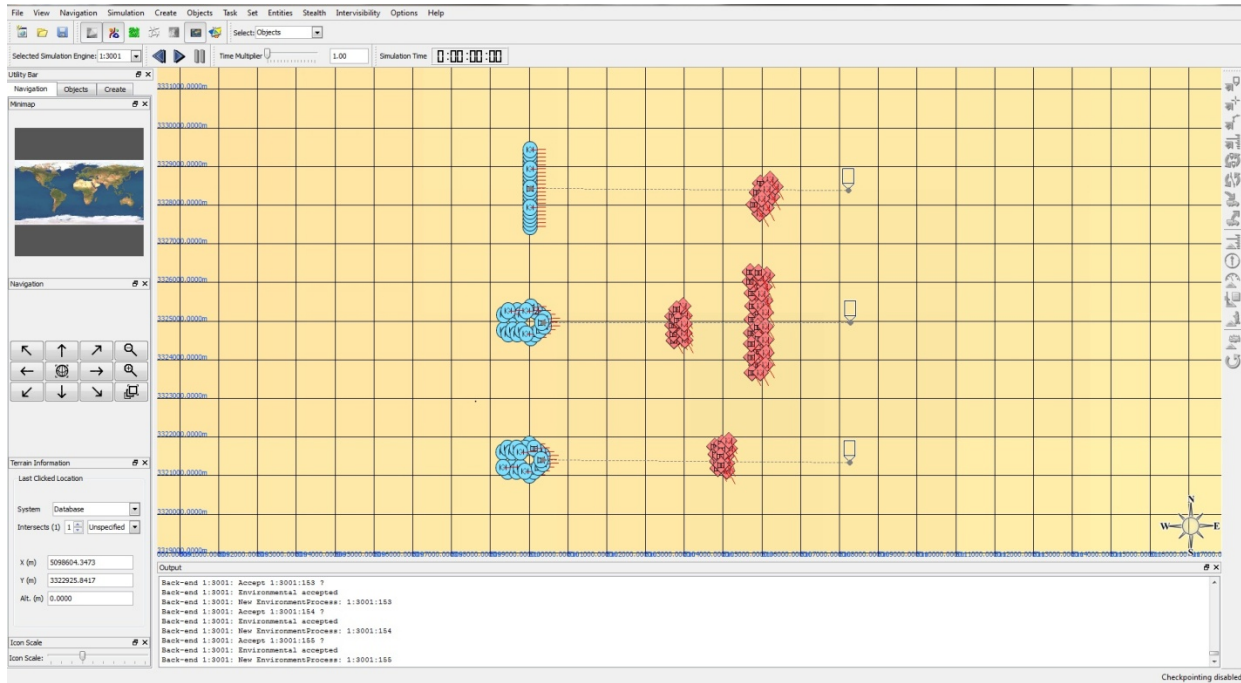
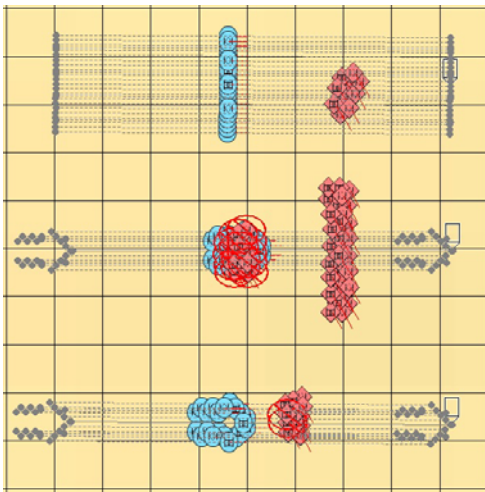*Figure 1. 73 Easting scenario starting positions, in VR-Forces.*

Figure 2. Example mid-battle conditions.

Figure 3. Example end-of-battle conditions.

The blue forces were split into the three troops involved in the battle, Ghost, Eagle, and Iron. Each of these troops numbered nine Abrams tanks and six Bradleys. Ghost, the northernmost troop, was formed in a line, while Eagle, in the center, and Iron, to the south, formed in the flying wedge formation. Each of the blue forces was given a waypoint at some distance to the east to travel toward. These waypoints were placed so that the blue forces would encounter the red forces as they moved across the desert. The initial setup of the scenario is shown in the center portion of the user interface in Figure 1.
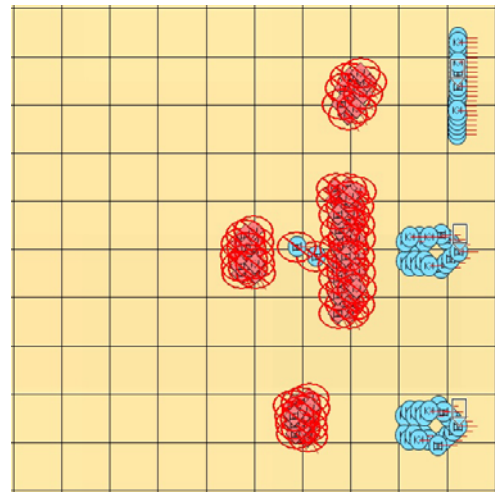
As the scenario progresses, Eagle encounters a group of red forces first, in the center of the map. Following that, Iron has a conflict with the southernmost group.

The next conflict occurs with Eagle group encountering the largest force in the center. Shortly after, Ghost troop encounters the northern group. An image from one of the runs is shown in Figure 2, where the forces have moved about halfway through their routes.

Each of the troops in the blue force then makes their way to the designated waypoint. An image of the end of one of the simulation runs can be seen in Figure 3.

4. Results and Conclusions

This section presents the results of the recreation and discusses some conclusions that can be drawn from it.

4.1 Results

The simulation was run thirty times, with data for each run collected at the end. The process of running the simulation was simply done by opening the program, loading the file, and running the simulation. The simulation was determined to have ended when all of the Blue forces groups had reached their respective ending waypoints.

After the end of each run, the number of destroyed entities of each type was totaled. As there are four different entities in the scenario, four different totals were counted. The results of these runs can be seen in Table 5.

These results can be considered to be close to the historical outcome of the battle as the entirety of the Red forces is destroyed each run and few or no losses are encountered by the Blue forces.

4.2 Conclusions

To recreate the historical results of the 73 Easting battle in VR-Forces, a series of modifications were made to VR-Forces input files and tables. (No source code modifications were made.) The modifications included:
1. Configuration of the battle starting positions, formations, and routes
2. Addition of missing entity types: M1A1 Abrams, M3 Bradley, BMP-1
3. Modification of existing entity types: T-72
4. Replication of battle visibility ranges
5. Correction of Red weapons probabilities: 73mm Grom, 125mm
6. Reduction of Red weapons probabilities: 73mm Grom, 125mm

All but the last of these modifications can be regarded as properly configuring VR-Forces to replicate the battle. The last, however, was done without any justification other than replicating the historical results. The final values of the weapons probabilities do not reflect the actual performance of the weapons modeled, but were necessary to recreate the historical result.

Subsequent to the simulation runs, one of the authors discussed the results with several VR-Forces developers. The consensus was that the historical results were due to the poor motivation, training, and leadership of the Iraqi troops at the historical battle; the Iraqi troops did not use their weapons up to their nominal performance, as reflected in the hit probability tables.

Run	Abrams	Bradley	T-72	BMP-1
1	0	0	36	33
2	1	0	36	33
3	0	0	36	33
4	0	0	36	33
5	2	0	36	33
6	2	0	36	33
7	2	0	36	33
8	0	0	36	33
9	4	0	36	33
10	1	0	36	33
11	1	0	36	33
12	1	0	36	33
13	1	0	36	33
14	2	0	36	33
15	2	0	36	33
16	1	0	36	33
17	2	0	36	33
18	0	0	36	33
19	1	0	36	33
20	2	0	36	33
21	0	0	36	33
22	2	0	36	33
23	2	0	36	33
24	1	0	36	33
25	0	0	36	33
26	0	0	36	33
27	2	0	36	33
28	1	0	36	33
29	1	0	36	33
30	2	0	36	33

Table 5. Results of 30 simulation runs.

Some constructive combat models include an "effectiveness" parameter which is intended to reflect the quality of the troops involved. The effectiveness parameter affects the various actions the troops perform, including weapons hit probabilities. VR-Forces lacks an effectiveness parameter, which the VR-Forces developers recognized as a shortcoming. The explicit reduction of the Red hit probabilities needed to achieve the historical outcome is understood as a means of implementing the equivalent of the effectiveness parameter.

Retroactive prediction, or retrodiction, of historical events using a model is generally seen as a powerful validation method [4] [5]. In retrodiction, the normal procedure is to execute the model "as is", or at least only with modifications that can be justified on the basis of model accuracy, and measure the differences between the model results and the historical results. In this work, the goal was to recreate the historical results as closely as possible, and to do so the model modifications went beyond those that could be justified based on model accuracy. In doing so, however, a possible shortcoming in the model was identified. This demonstrates a possible utility of such recreations.

Finally, a possibility that should be considered in both retrodiction and recreation is that the historical result is itself could have been anomalous, i.e., it may have been an unusual or improbable event that would not necessarily recur. For example, the one-sided outcome of the 73 Easting might have been inevitable given the U. S. superiority in both equipment and troops, or it may have been unusual in the sense that 30 repeats of the actual battle (not an experiment anyone would like to conduct) would include with the same one-sided outcome. The fact that anomalous low probability outcomes can occur in reality can make a retrodiction or recreation of an historical event frustratingly problematic.

5. References

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6. Authors' Biographies

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