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VBS3 as an Analytical Tool – Potentialities, Feasibilities and Limitations

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ABSTRACT

The Bundeswehr Office for Defense Planning tasked two teams, students in Bachelor/Master programs at the two universities of the German Armed Forces and their academic advisors to investigate the capability and usability of the NATO wide for training purposes used software Virtual Battlespace 3 (VBS3) for real world scenario analysis. For doing so, the student teams chose different perspectives on the software. Every student of the university in Hamburg generated during a one-trimester course on "Computer-based conflict analysis" one scenario each. The task hereby was to test the physical and technical properties of weapons, buildings, and vehicles, as well as the behavior of computer-simulated living entities (friendly and hostile forces, civilians, animals). By contrast, the students of the university in Munich developed during a two-trimester study project a constructive approach to explore analysis capability, usability and realism of the software. For doing so they took a closer look on the software's models of weapons, vehicles and soldiers and developed testbeds for series of experiments in each of these three scopes to identify scenarios and analysis tasks for which VBS could be used by the Bundeswehr Office for Defense Planning. Aim of both teams was to understand the software's ability powers on the one hand, but also the limitations to realism and analysis capacity on the other hand. The simulated results are compared with the expected behavior of their counterparts in the real-world. From this, conclusions on the usefulness of VBS3 for training soldiers, for ex-ante planning missions, and their ex-post analysis are drawn. The results of this study are of interest for military analysis as well as for simulation and training in the armed forces.

Introduction and Motivation

The two Universities of the Armed Forces, the Helmut-Schmidt-Universität (HSU) and the Universität der Bundeswehr München (UniBwM) were tasked to find ways to assess the potential of the simulation software Virtual Battlespace 3 (VBS3) as an analytic tool for the Bundeswehr Office for Defense

Planning. The Bundeswehr Office for Defense Planning described that realism, analysis capacity and usability of the software is of interest. Two teams of students together with their academic advisors took up this challenge and developed specific analysis perspectives and addressed the challenge in different ways. This paper presents this study, its analysis perspectives and the results.

The initial initiative for such course and project came about two years ago from the Bundeswehr Office for Defense Planning of the German Armed Forces. Various software products are already in use. The development of a new software system, specially tailored to the needs of the Office is very costly and takes a lot of time. Hence one is willing to buy products from the market, off the shelf, which are readily available and assumed to be reliable, since they are already in use in other armed forces around the world.

According to the website of the vendor Bohemia Interactive: "Virtual Battlespace 3 (VBS3) is a flexible simulation training solution for scenario training, mission rehearsal and more." VBS2 (the predecessor) is already in use at various places in the German Armed Forces, mainly for educational and training purposes. It is also used by many other armies around the globe, for instance, the British, see Curry et al. [4]. Here, the artificial intelligence is not needed, since all human entities in the simulation are controlled by real human players, which are connected by a network of computers. Still, the physical and technical properties of the systems and the interaction of the players (and their avatars) with the environment are an important factor in the realism and thus usability of such simulation. VBS3 offers a state-of-the-art visualization of the virtual environment, and requires a decent hardware equipment in order to compute new image frames at a sufficiently high rate.

However, it is unknown how these systems work "under the hood", because not every behavior is openly specified. Thus, some amount of reverse engineering is required in order to understand if physical and technical properties of systems (actors and sensors) are accurately represented with such simulation environment. These systems are also able to incorporate living entities, which can be own, neutral, or hostile forces, and civilians (and even animals). If they are controlled not by human players, but by the computer, one speaks of "artificial intelligence" in their control. The immediate question arises if their behavior is realistic, that is, if it is more on the "intelligent" or more on the "artificial" side. First attempts to use the software VBS3 and the tutorials and scenarios that come with this software as well as the reports at conferences suggest that there are some "artificial" phenomena unwanted both in analysis and training applications of the software. The questions arise whether it is possible to identify scenarios and analysis methods for which this inspiring and potentially useful software product can be used in analysis as well for training purposes and whether use cases and methods can be identified such that that users are aware of limitations or even caveats in their scenarios in both analysis and training.

The paper at hand discusses the perspectives of the two teams, the scenarios and methods they identified as potentially for the Bundeswehr Office for Defense Planning, the scenarios they built and analyzed as well as the results of the analysis. Both student teams employ for their studies only the commercially available version of VBS3 and open source data.

The paper is organized as follows. It presents the two different settings at UniBwM and HSU in the second section, followed first by the results of HSU in the third section and followed with the results of the UniBwM in the fourth section.

The General Setting

Two teams of students took up the task and this section briefly describes the background of the students and the project at the two Universities of the German armed forces in Munich and Hamburg. The teams received an introduction to the Office for Defense Planning with its organization, its tasks and its main processes and insights into various examples of analysis task and tools.

The General Setting at the HSU

During the Spring Term 2016 (April-June) the course "Computer-based conflict analysis" took place at the Helmut Schmidt University. It was part of the interdisciplinary studies, which every student has to undertake as part of his curriculum. Ten undergraduate students signed up, of which three were female and seven male, and eight were students of business economics ("Betriebswirtschaftslehre") and two of macroeconomics ("Volkswirtschaftlehre"). Moreover, one was from the Navy, one from the Air Force, and eight from the Army. The professorship of Applied Mathematics has a history in offering similar courses, see Fügenschuh and Müllenstedt [1] and Fügenschuh and Scholz [2].

The software VBS3 was used in this course. Each participating student used an individual installation of the program for testing purposes. It was the first task for each student to develop an idea for a scenario that he wants to set up in VBS3 and analyze its properties and system's behavior. In the end, ten very different results were presented at a final rehearsal during a day-long meeting at the Bundeswehr Office for Defense Planning in July 2016. In the following, we present each of these scenarios in detail. The respective student who carried out the research is named in each subsection. We gathered the scenarios in two groups. In the first group are scenarios that are more technically oriented, that is, they focus on single technical or physical properties of systems (weapons or vehicles).

The General Setting at the Universität der Bundeswehr München

Five students of the Bachelor programme Information Systems (Wirtschaftsinformatik) at the UniBwM and three academic supervisors formed the team at the Universität der Bundeswehr München. The analysis was done as a study project as part of the B.Sc. program Information Systems in the second year of the programme. This team build on the experiences with a course and joint project with the Bundeswehr Office for Defense Planning in the previous year.

The students in this course had different backgrounds as officers in the German armed forces and different professional careers prior to the studies at UniBwM. Students were encouraged to draw from their individual professional experiences to develop individual perspectives and questions in their study. They were encouraged to look for scenarios and analysis methods in which the VBS3 software could be useful for the Bundeswehr Office for Defense Planning. "Appreciative" and "Constructive in the sense of design science" as well as "Productive Use of an Off the Shelf Product" are the guidelines given to the students. The students were encouraged to take the perspective of a young officer – with an education at the University. What would a young officer do to build a faithful simulation with VBS3? The team discussed that reengineering the code would not be an option and thought of a constructive way to deal with the software.

The Results of HSU

Analysis of Terrain, Weapons, and Vehicles

VBS3 comes with an internal editor, with which it is possible to place entities such as humans, animals, vehicles, weapons, ammunition, or buildings onto the terrain's surface, and also to modify the terrain itself by digging holes, raising hills, or laying out streets. For more complex issues there are external editors for the same purpose, which come with a more user-friendly interface. Finally, there are third-party editors, which were not available and are thus not part of this analysis.

Modelling a Real-World City

Eckernförde is a harbour city of 22.000 inhabitants in the state of Schleswig-Holstein, located at the Baltic

Sea. It is the base of the German submarine squadron. **Konstantin Klein** chose the task to develop an accurate representation of this city and its surrounding coastline within VBS3. This means the proper selection of buildings, street infrastructure, and also to place civilians into the city to simulate a lively environment.

For tasks like this, VBS3 comes with a built-in scenario editor, which turned out to be quite intuitive and easy to use by operating with a computer mouse and selecting items from a database. Results from this are directly visible on the screen. On the downside, it is not possible to create an entirely new terrain. As a basis, one has to select one of a few existing terrains and start modifying it from there on. The options how to modify this existing pre-defined terrain are rather limited and it is thus difficult to perform huge terra-forming operations.

Visitor4 is a separate piece of software within the VBS3 package. It allows a detailed manipulation of the terrain, and is fully compatible with VBS3. It is described in detail in a user manual, but there are no tutorials to guide a new user. It is much more complex to use, compared to the built-in editor, and it requires additional software. It takes much more time to become acquainted with this program.

Due to the time restrictions in this course, the student was in the end able to understand how in principle the task could be achieved, but was not able to create a detailed representation of the city Eckernförde.

Screenshots from the terrain editor Visitor4.

Tanks

The ultimative goal of **Jeanette Diesing** was to analyze the behavior and usability of tanks. VBS3 comes with some built-in maps, and from there, the “Eastern Europe” map was selected, since it offers an suitable terrain for tank operations. A tank battle was to be simulated, where the own forces consists of a mixture of

Bradley and Leopard 2A4 tanks, and the enemy forces were a transport tank (BTR), a scout tank (BRDM), and an armored tracked vehicle (BMP). The own forces are tactically moving through the terrain and once the enemy forces were discovered, the battle starts.

To begin with, it was analyzed how well each single tank is represented in the simulation. For this, the tank was placed on different soil conditions (streets, smaller roads and open terrain) with different slopes. It turned out that the VBS3 physical engine takes properties of the soil into account when simulating the movement of the vehicle. Deviations from published technical data were within an interval of 5 km/h.

Next, the behavior of a tank when colliding with other objects was simulated. It turns out that trees are not obstacles and can be driven through. Camouflage nets on rods also crash when ran over by a tank. So far, the tank-obstacle-interaction was rather realistic. However, a tank also drives through rolls of S-twist, which is not realistic, since tanks usually have to avoid them, because they can easily get stuck in the chains, and stop the tank. Tents behave like solid buildings and also stop the tank from driving through them. A tank does not drive over a car, but pushes the car in front of it. Concrete obstacles even less than 1 m in height can stop a tank, it does not run over them.

Tanks carry simulated soldiers. On the enemy side, the soldiers leave the tank when it is under attack. Own soldiers leave the tank when (manually) ordered to do so, but it was not possible to order them to go into the tank again. Instead, they follow their tank on foot.

A tank has a simulated optical device (an infrared camera, IRC), and for this, the following observations were made: If a tank has the same temperature as the surrounding environment, it is invisible on the IRC. After moving the tank around, the motor and the exhaust pipe are shining brightly. After firing, the muzzle becomes visible. Single soldiers can also been seen. Furthermore, the IRC can see through smoke, which is an important property during a battle. Summing up, the IRC is simulated properly within VBS3.

Tactical behavior of a tank platoon.

The Bradley tank is endowed with a MK Bushmaster 25 mm. After a single simulated shot, there was already a large amount of smoke that fogged up the optics for several seconds, and thus turns out to be a bottleneck during the fight. Re-loading the gun was instantaneous, which is also not realistic. Furthermore, the weapon cannot be operated from the seat of the tank commander, also not in line with the real-world properties of the tank. Furthermore, the Bradley carries TOWs (guided missiles). When a TOW is in flight, the tank is not able to move. It is arguable whether this feature is realistic; in urgent situations it might be necessary to sacrifice the TOW in flight in order to survive. The re-loading does not consume time, and there is no visible smoke when a TOW is fired from an enemy tank.

The Leopard 2A4 tank is endowed with a 120 mm cannon. The smoke after a single shot is depicted in a realistic way. Re-loading takes 4-5 sec., which is also lifelike. The machine gun, however, does not show scattering effects (it shoots on a single point) and the muzzle flash is poorly visible. It is not possible to do damage to the vehicle when shooting with the MG on it.

Unmanned Aerial Vehicles

VBS3 offers a variety of virtual airplanes, helicopters, and unmanned aerial vehicles (UAVs) .The latter were tested by **Lucas Pätzold**. In order to execute a UAV mission, one has to set up the following four entities in the mission editor: a ground control unit, a UAV, a player unit, and a control link. After that, the

UAV is ready for take off. The UAV starts and lands autonomously, after it is ordered to do so. When airborne and with no further orders given, it flies in circles.

Flying a UAV.

Most of the UAVs in the simulation fly in a very stable manner and react promptly to new commands, for example, the MQ 1 Predator or the MQ 9 Reaper. Other UAVs show various kinds of problems, for example, the Luna X2000 becomes uncontrollable when reaching a certain altitude (still below the vendor's specifications), the ASN 209 is not able to fly, and the maximum velocity of an IAI Heron is 100 km/h. After giving the "Land" command (within the range of an airfield), most UAVs land without problems, only the Luna X2000 does not show a reaction on this. The artificial intelligence tries to avoid obstacles in the terrain.

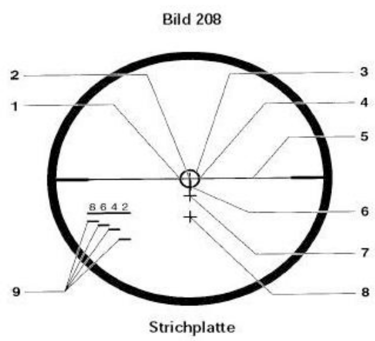
The UAVs can be damaged, and the damage is realistic. The UAV takes damage when hit or colliding with another object. When the damage is too severe, the UAV cannot be used any longer, and the signal is lost. The damage occurs on that particular part of the UAV, where it took the hit. The amount of fuel is shown, but there is no reaction when fuel runs out, the UAV simply continues flying.

As a conclusion, most aspects of UAV missions can be simulated in VBS3, but only the UAVs Honeywell RQ 16, MQ 9 Reaper and MQ 1 Predator offer a bug-free simulation. The optical devices offer a large zoom range, but only in normal and night-vision mode (infrared is missing). A simulation of the ASN 209, Luna X2000 and IAI Heron was not recommended by the student.

Weapons and Reactions of Others to Their Deployment

On a virtual shooting range, **Sabrina Güllich** made observations of the behavior of firearms, where she focused on the G36, MG3, and SIG-Sauer P225. Targets were placed with the editor in various distances from the marksman. After a few rounds of shooting, the following immediate observations were made: The range of the firearms is lifelike. There is no difference in aiming when the shooter is exhausted. However, when lying the accuracy is higher compared to a marksman who is standing. The weather has no influence on the targeting precision. The bullet hole is not displayed on most targets, so it's hard to see where exactly the bullet has hit. The bullet never goes through a target, so it is not possible to hit a second target with the same bullet.

For the G36 in particular, it is not possible to partially load a gun. The MG3 cannot be set up on the bipod. The anti-aircraft sight is always open. It is not possible to change the muzzle. There is a visible spreading when firing. The SIG-Sauer P225 automatically locks the breechblock after the last bullet has been fired. A movement of the catch lever is visible.



The optics of a G36 rifle (left), schematic plot (right).

How do friendly and enemy forces react to fire? When firing on own forces, injuries are visible. Death occurs only after several hits by loss of blood. There is no social behavior visible: the casualty does not complain or fire back, and other comrades do not conduct first-aid measures. Civilians do not show reactions when a firearm is shot next to them. Animals also show no reactions to the noise of firearms. Most of the time there is also no reaction when being shot, also no injuries are visible. For enemy forces, the reaction can be controlled by settings in certain menus. They may fire back always, or only when being shot first.

Vehicles and Convoys

The VBS3 database offers a number of vehicles from the armed forces of various nations. **Enrico Barth** put his focus on some vehicles used by the German Bundeswehr: the Wolf GD, Wolf GD San, Fennek, GTK Boxer San, and Scania P124-PLS. He compared the technical properties of the simulated vehicles with those of their real-world counterparts. In virtual driving experiments the maximum speed and acceleration properties were compared to the real-world behavior. It turned out that some vehicles were actually represented quite accurately, whereas others deviate significantly from their real-world counterparts. For example, the (real) Wolf GD has a switch to change between two-wheel- and four-wheel-drive, whereas the virtual Wolf GD does not offer this feature. The virtual vehicles react on the terrain (slope and surface) and have according to the soil a different maximum speed and acceleration. Using the keyboard to drive such vehicle turned out to be quite challenging or rather impossible. At higher speed some vehicles often leave the road or roll over (even at 20 km/h), which they would not do in reality.

In a further experiment, the wheels of a vehicle were shot. If a single tire is flattened, then the vehicle's movement is biased towards the direction of this tire. If three or more tires are flat, then the maximum velocity is reduced to 11 km/h. This seems to be a reasonable assumption. On the negative side, however, damages to a vehicle are not visualized and have no influence to its driving performance. When the vehicle is lying on the side, and the soldiers are jumping off from it, they got killed for an unknown reason.

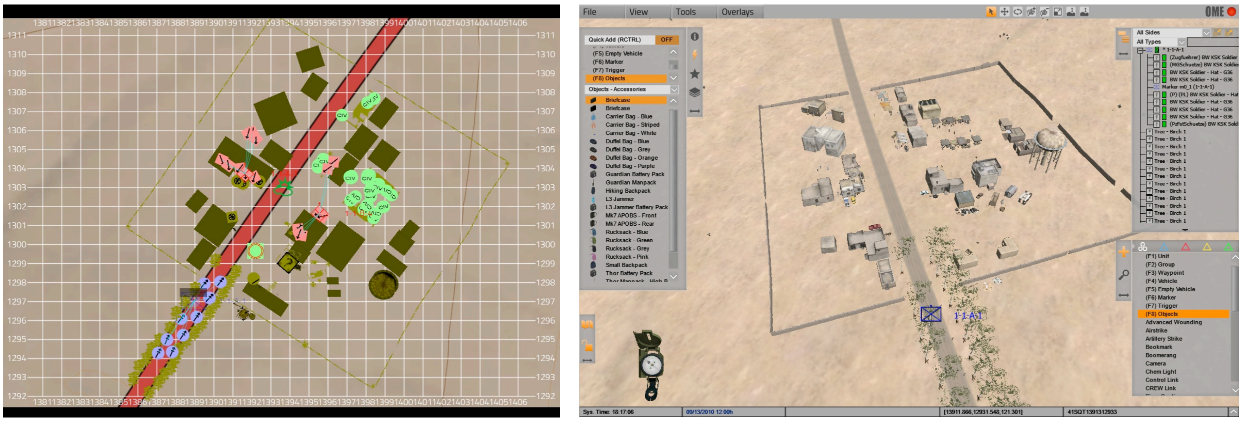
Vehicles can be grouped to convoys, where one vehicle is chosen as the leading one. By creating a list of waypoints one can send the convoy on a mission. It was observed that convoys consisting of a homogeneous fleet of vehicles are behaving as expected. They keep their assigned speed and distances. However, for an inhomogeneous fleet of vehicles, various problems occurred. The distances were not obeyed by the vehicles. Some stopped without any known reason. They also changed ordering during the drive. This makes the simulation useless for such kind of missions.

Setting up Complex Missions

Alexander Mergel and **Felix Bender** created a scenario that consists of a small village in the countryside of some desert state. A small group of soldiers marches into that village and gets under fire from insurgents that hide in houses and on rooftops. Furthermore, there are neutral civilians on the market place of the village which are in the middle of the fighting.

The behavior of the persons should change depending on the actions that the player conducts, which requires the use of VBS3's trigger feature. A trigger is activated when a certain user-defined criterion is met, for example, if the player soldier reaches a certain waypoint. The trigger then changes the behavior of some computer simulated entity, for instance, a neutral person suddenly is hostile to the player's group of soldiers and tries to attack them. If the human player who interacts with the simulated environment is confronted with such sudden change in the behavior of the other simulated persons, he might think that there is some kind of intelligence in charge of it. When going through the simulation a couple of times, it is more likely that the human player discovers what causes these kind of changes. This can be shaded to a certain extend by making the activation of a trigger depending on more complex evaluations than just the reaching of a certain location, or by adding some kind of randomness to the activation (the trigger then only executes with a certain probability). If a trigger is evoked by passing a certain waypoint, then this might cause problems in the situation, for example, if the player does not run over the waypoint, the trigger is never executed. Or, if the player takes a short-cut, the trigger is executed too early, which also might lead to unintended consequences.

Furthermore, a trigger can be controlled by another trigger. This is a useful feature in case the first trigger would be executed several times (but should do so only once). Then it can be stopped by a second trigger that deletes the first one.



A desert village, map view (left) and 3D view (right).

When executing the whole scenarios, some flaws in VBS3 showed up. For example, the hostile forces never fired from inside a building through the window, which clearly limits the usefulness of such simulation. However, when carefully and manually filtering those simulation runs that showed a too artificial and unnatural behavior of the soldiers, the remaining ones are worth being considered for a further analysis. This analysis was carried out by Felix Bender (see below).

Maritime Missions

VBS3's maritime capabilities were challenged by **Lisa Hoffmann**. Based on the Porto map that combines land and large open sea areas, she build up a scenario that could happen every day in the Mediterranean Sea: human trafficking on board of small non-oceangoing boats (for this, a „Dhow" type boat from the VBS3 data base was chosen). During the ongoing mission EUNAVOR MED – Operation Sophia, several frigates are patroulling the Mediterranean to detect such boats, and to rescue the people on board, mostly refugees from destabilized countries.

It turned out to be rather to place refugees no board of ships. These people do not behave „refugee-like", they show very little motivation to move on board of the rescuing ship. When placed in the water, a person starts swimming. Effects of fatigue or not simulated for swimmers, he could swimm forever. The water temperature also does not effect a swimming person. Even in ice-cold water, he is able to swim without time limit. Only when diving, the swimmer dies after 50 seconds under water.

It was not possible to directly simulate the boarding of refugees from the Dhow to the frigate. In order to approximate the boarding, triggers were used. A trigger is a programmable feature that is executed when a certain criterion is met, and which changes other parts of the simulation. Here, the trigger is executed when the frigate is entering a certain radius around the Dhow, and upon execution, the refugees are "teleported" on board of the frigate, which is the representation of a boarding procedure within the simulation. As conclusion, such complex maritime mission turned out to be difficult to simulate within VBS3.

A Dhow with refugees approaching a frigate.

Analysis of the Artificial Intelligence

The scenarios described in the previous section usually highlighted a single technical or physical effect. In this section we describe more complex scenarios where first the editor was used to prepare a terrain, place some entities in it, and then simulate the behavior of the these entities.

Fighting in a Village

Based the above described desert village scenario, **Felix Bender** took a closer look to the actual course of a scenario. A group of ten soldiers (one leader and nine soldiers) are marching into the village. Each soldier is equipped with a G36 and an M9, three soldiers carry a bazooka (Panzerfaust 3), a garnet pistol, and a machine gun MG3. The enemy forces use AK-47 and one has an RPG rocket launcher. These fighters were placed in the streets, into buildings and on rooftops. The group is marching into the village and is soon attacked by their enemies. This situation was simulated 50 times. The following questions are of interest: Which group wins/loses most of the time? Was the movement of both groups coordinated or uncoordinated? How many losses occurred on both sides? Did the civilians (on the market place) suffer losses?

When the outcome of a scenario run could not be determined after five minutes, it was terminated. On average, five (of ten) of the own soldiers died, and thirteen (of 15) enemies were killed. The own group won in 58% of all cases, the enemies in 16%, despite the fact that they had five men more at the beginning. In the remaining 26% of all runs, no winner was determined after five minutes. In general one can say that the enemy's losses are highest, when the soldiers do not coordinate their efforts, but run around on the battlefield almost randomly. A similar observation is true for the own forces. In most cases, the artificial intelligence control worked properly and lifelike. However, one cannot rely on it, all scenarios have to be manually observed, before conclusions are drawn from their outcomes.

Battles of Encirclement and Annihilation

In the VBS3 manual it is described that soldiers can surrender when they are in desperate and hopeless situations. In order to simulate such cases, **André Rahe** created an environment where escaping is not an option. From the available maps he took one with a large building with an atrium. The outer walls were further fortified by the VBS3 terrain editor so that all exits are locked, and the atrium was filled up with military equipment, such as different factions (including civilians), vehicles, or helicopters.

A battle in a closed fighting arena.

After having set the stage, the simulation began. It turned out that there were no surrenders or prisoners. All enemy forces were eradicated, and also a different number of own forced were killed. The latter number largely depends on the way the artificial intelligence was able to control the enemy forces. The more tactical and coordinated they operated, the more casualties they could generate.

Fighting One on One and One on Many

While setting up his scenario, **Jan Rodewald** discovered a remarkable effect. The area was surrounded by a high and non-permeable wall. Right besides this wall he placed a gasoline station with a small attached building. Now it was possible for soldiers to leave the area through the wall by entering the attached building. Also thickening the wall did not prevent the soldiers from doing so. Only moving the building away from the wall finally helped. The lesson learnt from this is: Never trust what you see on the screen. The logical representation in the computer's memory can still be very different from this.

After having solved this and other similar problems, the scenario was ready to be tested. A single soldier behind a pile of sand bags should aim at a number of attacking terrorists. The number of attackers varied, and the behavior of both groups was to be observed. For each fixed number, the scenario was executed a couple of times. As a result, the single soldier being attacked never surrendered, no matter how many attackers were coming. He also did not try to retreat or escape. At a certain number of attackers, he had no chance and his loss rate converged to 100%. This is supported by that fact that the artificial intelligence seems to be is confused by a large number of attackers, and often changes the target for aiming, and forgets to shoot.

Two soldiers seeking coverage.

It was also tested how armored vehicles react when being shot. It turned out that the artificial intelligence always leads its units into an attack, even if a heavily armored vehicle cannot be damaged with a too small gun (AK-74 on Leopard 2, for instance).On the positive side one has to acknowledge that the artificial intelligence tries to flank opponents. The larger a group of soldiers is, the more aggressive they push forward.

On the positive side one has to acknowledge that the artificial intelligence tries to flank opponents. The larger a group of soldiers is, the more aggressive they push forward.

Conclusions

VBS3 was analyzed during a one-trimester course by a group of ten undergraduate students. They came with various computer skills. Some of them are familiar with first-person-shooter games for many years, whereas others rarely play computer games at all. In this respect, our group of students is representative for the current generation of young officers. The formal amount of time to be spent with this course (in classroom and self-studies) was 150 hours, and in the end, this turned out to be a reasonable estimation on average (although some students put much more time into the coursework). All students, even those being sceptical about the topic at first, where motivated and even enthusiastic at the end. Some asked, if they could do this course again. So, learning with and from simulations is a motivating topic.

The students took a very critical look at the software. The above descriptions are the summary of more detailed reports written by the respective student, and being about 6-10 pages long each. They will be published in the forthcoming report of Fügenschuh and Vierhaus [3]. The students are military personnel and have different degrees of training. Some were in the armed forces for several years already, others had one year of basic training before they came to the university. Based on their military experience and common sense, they tried reconcile the simulated results with their previous experiences. In some cases, their judgement is over-critical, but in most of the cases, they discovered serious flaws of VBS3, in particular with respect to the artificial intelligence, but also with respect to certain technical and physical properties. However, they all acknowledged that VBS3 has, despite its flaws, the potential of being a useful tool for the education and training of single soldiers and small groups on various missions.

It is also possible to use VBS3 for simulating missions as an ex post analysis by scripting the behavior of all entities being involved and then to study the dynamics from different perspectives and camera angles. By doing so, the scenario becomes imaginable, and can be studied from the point of view of different participants to study the action of each person involved.

It is tempting to use VBS3 as a tool for strategic planning by letting the simulation run against itself and vary the input parameters in each run. For example, the number of forces, the weapon mix, or the attack/defending strategy is modified. After each run it is reported how many losses each side suffered and if the mission goal was accomplished. After many thousand or ten thousands of runs, one could get a clear idea of what works and what not, hence an optimal deployment of forces could be deduced from such a big data approach. Based on the experience of the students, one has to be careful with such an approach with the current version of VBS3. The artificial intelligence turned out to be more artificial than intelligent, which led to unexpected, unlogic, and unreasonable behavior of the forces (that is, a behavior you would never see from real people, no matter how stupid or fanatic they could ever be). In a big data approach, these scenarios are not assessed in detail due to a lack of time, only the outcome is stored in the database. Hence one relies on a simulation that reflects the outcome in the real-world, in order not to get misleading results in the end. When VBS3 is used in such a data generation loop, the results are highly questionable, as was shown by the students in their experiments with the AI. At the present stage of the software one has to put a human-in-the-loop and manually observe and assess each single simulation run whether the entities show a sensible behavior or not, and only those that are positively marked are allowed to enter the database with their results. This for sure reduces the number of simulation runs by two to three orders of magnitude (factor 100-1000) compared to a standalone simulation, which VBS3 is currently not capable of.

The Results of the Team of the UniBwM

The discipline of Information Systems is – among other topics – about the productive use of technology in organizations [5]. The perspective of the team follows this Information System paradigm and to identify ways to use the software VBS3 in a productive way for the Bundeswehr Office for Defense Planning´s tasks and contexts.

As their first steps with the VBS3 software, students looked at tutorials and available scenarios and were – as their academic supervisors – inspired by the power of the simulation with its graphics, the multitude of available weapon systems and the artificial intelligence. However, the work-arounds or phenomena of the artificial intelligence seemed to make the software usable for the tasks of the Bundeswehr Office for Defense Planning. The Bundeswehr Office for Defense Planning provided insights in tasks, as well as in the core processes of concept development and experimentation allowing students to understand the requirements for an analysis tool. In various iterations and discussions, the team of UniBwM shaped its perspective. The team refined the task of the Bundeswehr Office for Defense Planning as follows – a young officer should be able to use VBS3 for typical analysis tasks. So analyzing code or programming work-arounds would not be a feasible approach.

The team developed testbeds with ways to demonstrate feasibility and realism for use cases. The students chose soldiers, vehicles and weapons as the three domains for which they wanted to develop testbeds. Subsequently, we describe motivation and experiences with all the three testbeds. Overall the team refunded their perspective to be appreciative and constructive – the aim is to find ways to make productive use of the VBS3 software as analysis tool.

Soldiers Study

Christine Dreilich took a closer look at soldiers in VBS3 and their physical capabilities regarding stamina under the influences of weather, terrain, weapon carry mode an equipment weight. Therefore, the student used a self-made, standardized, 100-meter long running track, to ensure, that the experiments are equal and only the testing parameters change.

100-meter running track, weather: snow.

The utilized parameters consisted of different terrain (street, countryside, snow) and weather conditions (fog, rain and snow), but also a variety of equipment-weight and weapons. After several test runs, the result was, that neither the weather condition and terrain, nor the different loadout had a significant impact on the soldier's movement or exhaustion. There was no difference between a soldier equipped with 80 kilogram of weight and a soldier equipped with 20 kilogram of weight.

The only exception is 1,50-meter high snow, whereby the soldiers speed is much slower.

Vehicles Study

A scenario for military simulation includes, besides soldiers and weapons, also vehicles to create a realistic setting. VBS3 offers a wide range of military and civil vehicles, which can be simply added and controlled during the creation of scenarios. **Florian Spanier** was putting his focus on vehicle's movement and speed and if there are any influences to these parameters from outside, similar to the soldiers' study. In order to get an overview of those dependences, **Florian Spanier** used different vehicle types (vehicles with small and big tires, as well as tracked vehicles) and different weather and terrain conditions.

Different vehicle types, weather: fog.

Different vehicle types, terrain: 1.50m snow.

The result of this study is, that weather conditions do not have any influence on vehicles' movement. The only exception is, like in the soldiers' study before, 1,50-meter high snow. One more remarkable observation is, that there are no groove tracks on wet terrain modelled.

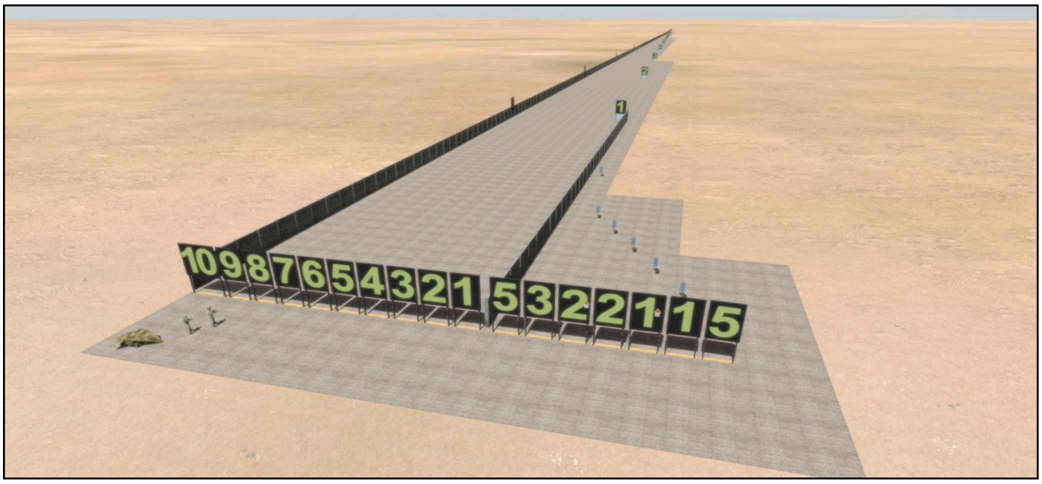
The maximum speed of tyre vehicles decreases from street to lawn/gravel to sand. The maximum speed of tracked vehicle, however is not effected by terrain.

Weapons Study

For a constructive, military simulation, like VBS3, the accurate representation of weapons and ballistics is essential. Therefore, **Timo Löffler** and **Stefan Fleischmann** chose weapons and ballistics as their subject for the study and took a closer look at how these systems are implemented in VBS3. The students wanted to figure out if the software´s models of ballistics and projectile trajectory are conforming to their expectations and if there is any influence of weather to projectiles. Furthermore, they examined the model of the H&K G36, especially the correctness of the reflector and telescopic sight.

In order to test the implemented models, the two students developed a testbed in form of a shooting range. This shooting range consists of two parts: one with close range targets from 5 to 50-meter and one with targets in higher distances from 100 to 1000-meters.

With this testbed, the students were able to perform their experiments and validate the observed results. The ballistic and especially the projectile trajectory, observed with the After Action Review (AAR), confirmed the expectations of the students. The weather, however, has no influence on the projectile trajectory. In order to analyze the sights of the G36, the students used their military knowledge. For the test of the telescopic sight, they used – as in their basic training taught – the points of aim for 200, 400, 600 and 800-meters. The result was, that the 200-meter mark is correct but the model of the telescopic sight is imperfect, particularly the marks for 400, 600 and 800-meters. So the projectiles, which should be on target when the 400-meter mark is used on a target in 400-meters distance, will fly over the target. The reflector sight works realistically for the combat range up to 200-meters.



Shooting range.

Conclusions and Discussion of the UniBwM Results

Five students from the Universität der Bundeswehr München were tasked to take a look at the software VBS3 to find out if it is possible to use it for analytical purposes. In three different studies (soldiers, vehicles and weapons) the results of the examined systems distinguished in maturity and their conformation to reality. The simulation showed a very high level of detail and various implemented vehicles, weapons and gadgets. To test those systems, the students not only used their creativity to solve problems or find work-arounds, they also used their expertise as officers and officer candidates and their military background. They also utilized their knowledge, gained through playing computer games like Aram 3 from Bohemia Interactive, which is very similar but not identical to VBS3.

Christine Dreilich found out that the overall movement and mobility of a soldier is in fact not affected by the weight he carries or the environmental conditions. However, the model of soldiers in VBS3 is detailed enough to use it for an analytical purpose on simple scenarios.

For vehicles, Florian Spanier observed that there is a wide range of usable vehicles out of various armed forces. Environmental conditions do not always have an influence to the speed or mobility of vehicles, but the overall model is suitable for the examined task.

The ballistic model of a projectiles trajectory complied entirely to Time Löffler's and Stefan Fleischmann´s expectations. Furthermore, the students approved the model of the G36 for very correct, even if the telescopic sight is not working as anticipated. Their overall conclusion is, that VBS3 is very well utilizable for analytical purposes.

The appreciated and constructive result of the team´s study project is, that in parts and depending of the scenario, VBS3 is capable of being used as a tool for analytical simulation purposes. VBS3 is indeed no software for constructive simulation, but has a very high level of detail, which empowers customers like the Bundeswehr Office for Defense Planning to use it as an analytical tool.

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References

[1] Armin Fügenschuh and Daniel Müllenstedt (2015), Rechnergestützte Konfliktanalyse am Beispiel von Command: Modern Air/Naval Operations, Technical Report (in German), Applied Mathematics and Optimization Series AMOS#36, Helmut Schmidt University/University of the Federal Armed Forces Hamburg, Germany.

[2] Armin Fügenschuh and Frederik Scholz (2016), Bewaffnete Konflikte: Geschichte, Dynamik, Simulation und Analyse, Technical Report (in German), Applied Mathematics and Optimization Series AMOS#43, Helmut Schmidt University/University of the Federal Armed Forces Hamburg, Germany.

[3] Armin Fügenschuh and Ingmar Vierhaus (2016), Rechnergestützte Konfliktanalyse am Beispiel von Virtual Battlespace 3, Technical Report (in German), Applied Mathematics and Optimization Series AMOS#47, Helmut Schmidt University/University of the Federal Armed Forces Hamburg, Germany.

[4] John Curry, Tim Price, and Phil Sabin (2016), Commercial-Off-the-Shelf-Technology in UK Military Training, Simulation&Gaming, Vol. 47(1), 7-30.

[5] Hubert Österle, Jörg Becker, Ulrich Frank, Thomas Hess, Dimitris Karagiannis, Helmut Krcmar, Peter Loos, Peter Mertens, Andreas Oberweis, and Elmar J Sinz: Memorandum zur gestaltungsorientierten Wirtschaftsinformatik. In: Zeitschrift für betriebswirtschaftliche Forschung, Jg.62 (2010), Nr. 6, S. 664–672 – Available at http://www.alexandria.unisg.ch/Publikationen/Zitation/Hubert_Oesterle/213772 Hubert