Optimisation of Professional Wargaming with Board and Tabletop Wargames which really are Qualitative Agent-based Models

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USI Occasional Paper

Introduction

Wargames can be grouped into reductionist or aggregative models, where reductive models break combat down to encounters and duels between small forces, adjudicate, and aggregate their results, while aggregative ones first aggregate forces and adjudicate results, and distribute them.[1] The models are predicated on a causality, although no causality has ever been empirically established between inputs (strength, logistics) and outputs (casualties, distance moved).[2]

At the heart of most models is the Lanchester family of equations which is based on determined relations between forces and progress. In reality, military forces are inhomogeneous, unpredictable, social, and boundedly rational, marking combat with complex and endless feedback loops that show little linearity or causality. Geometries of naval combat (torpedo path, or effect of eddies on submarine hull) can be modelled accurately, but no determined accurate model of fleet action, with human crews in varying states of morale distress operating in a turbulent sea, can be created. Causality-based mathematical models do not survive the fog of war[3]; and Lanchester equations are upheld neither by sea, air[4], or land[5] combat. Consequently, all claims to statistical, empirical verification must be treated with suspicion, as the data they are based on is amorphous and incomplete, and cannot be represented quantitatively without arbitrary manipulation.

Also, these models concentrate only on outputs and cannot deal with outcomes, such as effect on morale, or triggered public outrage.[6] Nor can they depict synergy; effect of a minefield covered by machinegun is not the total of casualties inflicted by minefield and the machinegun but forced change in tactics. Far from being empirical, mathematical models, including ones based on 'historical experience' like the Quantitative Judgment Model (see later), are really based on rationalising in afterthought.[7] Thus, the first part of the aphorism attributed to George Box, that 'all models are wrong'.[8]

Warfare as a Complex Adaptive System

Searching for better representation of warfare takes one to systems theory. Applied to military problems by Israeli Brigadier-General Naveh in his 1997 PhD thesis[9] on history of operational art, 'General Systems Theory', originally proposed in the 1950s, is better suited to ill-structured, non-linear systems which it sees as not a mere sum of parts, and tries to understand interaction between parts.[10] Studies progressed through 'Complexity and Chaos' theories, which saw systems as non-linear, with feedback loops and anticipatory behaviour, their focus on roles of mass, friction, and the fractal nature of war[11] rendering them suitable for understanding conflict. While chaos theory focused on low-dimensional deterministic systems with fixed transformation rules using continuous mathematics, complex systems, in contrast, focus on high-dimensional non-deterministic systems with discrete, discontinuous, and adaptive rules.[12]

> **In reality, military forces are inhomogeneous, unpredictable, social, and boundedly rational, marking combat with complex and endless feedback loops that show little linearity or causality.**

The American meteorologist Garnet William presented weather as a system of many similar but independent agents dynamically trying to adjust to other agents as per simple rules, causing the system to spontaneously self-organise.[13] Such observations led to emergence of Complex Adaptive Systems (CAS), whose characteristics include evolution, aggregate behaviour, and anticipatory behaviour.[14] The satisficing rather than optimising behaviour of the components of a CAS has military relevance[15], because this is how military elements behave, triggered by local stimuli, grabbing expedients affected by fear, exuberance, or resilience. They also meet the other characteristic features. A Tank-Hunting Team operating ahead of the defences might convert into a stay-behind party with new tasks once the enemy attack begins. Despite composition remaining the same, its behaviour is now evolved.

Behaviour of complex systems is not a simple summation of behaviour of parts but aggregates upwards. Actions of a platoon attacking a section post (following the 3:1 rule), cannot simply be 'lashed up' upwards for a division attacking a brigade sector (3:1 again). It would be ridiculous to say that since one fourth of the platoon was killed or injured in the battle, one fourth of the division, i.e., two of its nine battalions and one of its four artillery regiments, would also get written off! Despite the exclamation, this is what most equation-based models do (in addition to enforcing a homogeneity on the forces). Some models do try weighting distribution of casualties towards units in contact, but it ignores behavioural aspects. Also, tactical actions are based on anticipation, making forces adopt drills and tactics. An advancing column deploys forces to protect its flank, if enemy is anticipated. Even if flank protection was absent (say, having lost its way), the enemy, anticipating flank protection, might still not attack. Here, an entire set of tactical choices is dictated by anticipation, with no physical movement. Effect of anticipation can be disproportionately more than anticipated; a small British recce force triggered a German withdrawal

across the Marne in the First World War as it was interpreted as a general advance. Anticipatory behaviour causes major non-linearity in warfare.[16]

Complex systems are extremely sensitive to initial conditions, and their endless feedback loops are impossible to define with equations. This is because the satisficing behaviour of components edge the system towards local equilibriums[17] and emergent behaviour.[18] While mathematics of movement, orientation, speeds, or hit probabilities suit micro-level behaviour, both reductionist and aggregative approaches suppress the characteristics of CAS, especially behaviour of components, glossing over the nature of battle. This is why there are so many variants of the Lanchester Equations, each less satisfactory than the other.

Modelling Complex Adaptive Systems with Agent-based Modelling (ABM)

Several approaches to model complex environments of boundedly rational components have been attempted, such as cellular automata, classification trees, and ABM. This paper deals with the last of these.

What is ABM? Evolved out of John von Neumann's cellular automata pioneered in the 1950s, ABM has been used for understanding complex systems in business, technology, and social sciences.[19] It represents components, such as stock market investors, migrating guns, or COVID vectors, as agents of varying sizes, which interact through a rule-based structure.[20] Agents, which can be individuals, households, infantry companies, formation headquarters, countries and governments, are unique in not only physical but also behavioural characteristics such as morale, leadership, training, ethnicity (the so-called 'ilities'[21]) which are difficult to model by other methods. This is explained as under:

> **Effect of anticipation can be disproportionately more than anticipated; a small British recce force triggered a German withdrawal across the Marne in the First World War as it was interpreted as a general advance.**

- Usually agents are live, but could also be inanimate, such as roads, weather, river, public opinion or television rating point. Their characteristics are:

  ¤ Active, i.e., able to perform actions, not always physical, that affect the environment.

  ¤ Social, able to cooperate with and also coerce one another.

  ¤ Not omniscient but perceptive and able to process information, infer, and anticipate intent of other agents.

  ¤ Autonomous, i.e., act in not pre-scripted manner but use internal logic to determine action.

  ¤ Goal-oriented, and able to select courses towards them but act not as optimisers but satisficers.

  ¤ Capable of irrationality due to fatigue, anxiety, confusion, conflicting priorities, and imperfect information.

> **Their stochastic nature, ability to mimic real-life behaviour, and create unforeseen higher order effects give ABMs greater explanatory and exploratory power to render complex adaptive systems.**

Thus, each agent can behave differently in each situation.

¤ Instantiated; factors define state of an agent at any time and can change during the simulation.

¤ As unpredictability of agent behaviour causes endless paths from any point, the overall effect of their actions is not their sum, but aggregate behaviour. This non-linearity is a major leap from causality-based approaches which translate action of a single agent to actions of many individuals. Their stochastic nature, ability to mimic real-life behaviour, and create unforeseen higher order effects[22] give ABMs greater explanatory and exploratory power[23] to render complex adaptive systems.

¤ Ability of ABMs to embrace rather than ignore complexity is illustrated below, using a sequence reminiscent of Swinton's coming-of-age novella, Defence of Duffer's Drift.
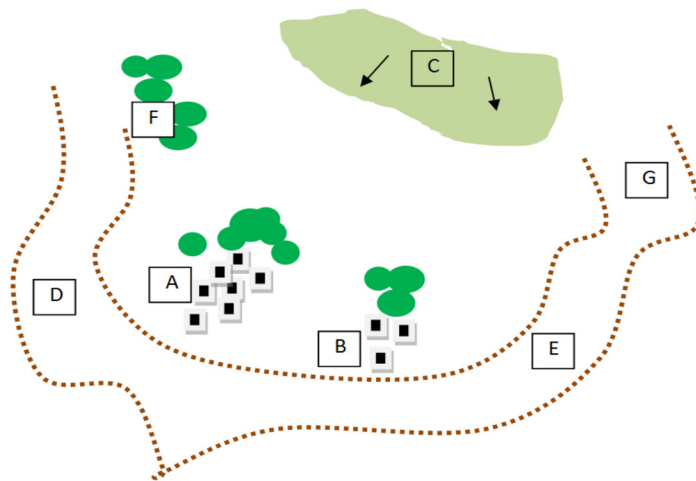
Figure 1: An Agent-based Representation of a Simple Tactical Situation

- In the diagram at Figure 1, a section of 10 agents (soldiers) in cover behind two clumps of trees at A and B are programmed to capture the Hill C a few hundred meters away. For the capture, they must move on to the objective, deploy there, and survive. On the hill are two opposing agents, machineguns that shoot at any approaching enemy but can get pinned (i.e., unable to move or fire) if fired upon heavily. Certain cases are given below:

  ¤ **Case # 1: Simple Orders.** The ten soldiers must move ahead to capture the hill. They do so, but scarcely

advance beyond the trees before the two machineguns shoot or pin them down.

◻ **Case # 2: Cover.** Now if an additional rule lets soldiers use cover while moving towards the objective, they will remain safe at A or B as they have no additional information about the terrain.

◻ **Case # 3: Perception and Situational Awareness.** Adding an element of terrain perception makes agents aware of the arc-shaped depression behind them, causing them to pick one of the routes at random to the objective, via D to F or via E to G.

◻ **Case # 4: Hierarchy and Orders.** Now, modelling a hierarchy where one agent can issue orders to others who must obey, and programming that agent to prefer someone covering the objective with fire while others move, making designated agents move via D to F from where they fire, pinning the machineguns, while others move via E to G and swarm the objective before too many are killed.

◻ **Case # 5: Hits and Morale.** If some agents are motivated and willing to fire despite injury, and others more eager on self-preservation by withdrawing from fire, and one each of such agents are hit as the group moved from A to F, one would continue firing at the objective though unable to move, while another would drag to cover.

• The matrix would become more varied if more rules were introduced, such as letting the defending agents on the objective use high trajectory weapon to search the areas that they cannot observe.

• The above micro-model depicts skirmish level combat, but the same principles can be applied to higher levels at lower resolutions where agents are larger groups (platoons, battalions, flight packages). Authenticity of agent behaviour

here is greater than is manifested in equation-based models preoccupied with numbers, physics and geometry of battle, i.e., speed, effect of elevation on range, effect of the wind on accuracy.

ABM Applied in Military Context. In addition to social, sociological[24] or administrative[25] purposes, ABM has been used for military purposes, like swarm of drones[26] and policy-making.[27] Sokolowski[28] used an ABM to explore troop surge strategy in Afghanistan post 2007, while Jaeyeong Lee[29] applied it to optimising communication in network-centric warfare by using repeaters. Use of ABM to simulate battles[30] was pioneered in 1996 by Ilachinski, who brought together operational research and complex systems.[31] For the most, such attempts have met historical cogency. Other attempts are as under:

• Trautteur and Virgilio made a dynamical, high-resolution simulation of the Battle of Trafalgar, which agreed in a very strict way with historical data in contrast to a Lanchester-model of the same battle.[32] Making some counterfactual experiments, it concluded that Nelson's strategy was the most reliable and safest, and also that ABM was suited for analysis of conflict.

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• Scogings and Hawick's simulated the Battle of Isandlwana at a near-microscopic resolution with a total of 20,000 soldiers.[33] It attained considerable historical accuracy, demonstrating how ABMs can define heterogeneity of agents and examine alternative scenarios.

• Rubio–Campillo[34] used ABMs to study early 18th century development of drilled infantry and ranked fire. It modelled geometry of fire, such as height of discharge, angle and speed of musket ball, to reconstruct various types of application of fire by the infantry, viz., single fire, fire by ranks, platoon fire, and the Catalan system. It could also differentiate soldiers based on ability to reload and fire accurately, i.e., training, coherence and resilience.

• Waniek's[35] model of the battle of Kokenhausen (1601) produced historically

credible results, confirming that caracole tactics was a major reason for Swedish defeat, and allowed consideration of alternative scenarios. Its two levels of agents, soldiers, and regimental headquarters, demonstrated the ability of ABMs to model military hierarchies.

- James[36] used ABMs for course-of-action wargaming as part of the military decision-making process to improve the rigours of tactical wargaming.[37] Developing an ABM for representing logistics in wargames, they found the method more suited than traditional techniques to understand inventory management and supply chain behaviour.

Assessment. The above show that ABM can convincingly represent forces and other elements as unique agents, arrange them in hierarchies, and represent a complex adaptive system. However, ABM has not broken the link with mathematical-oriented modelling but has remained a niche field, with practitioners using non-standard methods and languages, and remaining set apart.[38] The following merit attention:

- The simulations were designed to progress from an initial state to an end. They could be rerun with same or different initial conditions but not accept inputs during runtime, and thus were not wargames.

- Being computer science-driven ventures, they exploited high processing power to use fine to very fine resolution (nearly each soldier or platform), and progress along very short time-steps. Such high resolutions allowed only short phases of battle, or homogenous battles without too many changes, to be modelled. Massively parallel computing can extend the system to vaster number of agents handled by libraries of rules accessed through a richly nested if-else conditional logic. However, complex, and chaotic systems, being impossible to anticipate after the first few steps due to combinatorial explosion of possibilities,[39] will make exhaustive definition of if-else routines nearly impossible.

Board and Table Top Games as Agent-based Models

The ABM at Figure 1 is reminiscent of manual, tabletop wargaming. Starting with the introduction of the Prussian wargame Kriegsspiel in the 18th century, such manual games were used by western armies for planning and training till the Second World War. After that time, wargaming grew complex, ingesting operational-research-based techniques and growing elaborate on distributed, networked computers. Also, it grew increasingly remote and 'Black-Boxed', and largely inaccessible to military users.[40]

Parallel to developments of the 'Serious Games', there appeared a genre of recreational gaming through the last century in Europe, playing boards with counters or tabletop dioramas with miniatures. Kriegsspiel itself was originally a recreational game. Manual, analogue games were supported by a strong commercial sector (such as early giants like Strategic Publications Inc. [SPI] or Avalon Hill, and current ones such as GMT Games [GMT's name comes from the first name initials of founders Gene Billingsley, Mike Crane, and Terry Shrum], Compass Games, Matrix Games or Multi-man Publishing). Clubs and societies of gamers used evolved house-rules. Also, while most hobbyists were interested only in fast play and detailed dioramas, a substantial segment, which included amateur historians and military students, experimented with realistic rules. This popularity of games in the West (a 1976 survey showed that 40,000 all ranks of the US Army were privately hobby wargamers[41]) gave armies pools of personnel that understood wargaming and could be used to design serious games. This advantage is not available to nations where the culture of wargaming does not exist.

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Recreational, analogue games have been used operationally. Victory Games' Gulf Strike, based on the Iran–Iraq war, and SPI's Firefight, were used by the Pentagon for immediate prognostication of the Kuwait invasion.[42] Later, Pentagon used Gary Ware's Internal Look, which incorporated detailed cartographic and military data on Kuwait and Iraq.

These games were so authentic that reports had to be prominently stamped with the disclaimer 'Exercise Only'.[43] Of late, recreational gaming has shifted towards computers, and is able to handle larger battles and forces, and provide appealing user-interfaces. But they also deny players insights into rules, and the erstwhile advantage of western armies is dissipating. Nevertheless, there remains a thriving sector of game producers that continue to experiment with modern scenarios, viz., One Small Step's Putin Strikes: The Coming War for Eastern Europe (launched in 2016), or Firefight Games' Putin's Pocket: Ukrainian Cauldron at Debaltseve pertaining to Feb 2015 (launched in 2019) and Putin's War pertaining to 2022 (launched in 2024). Compass Games' Indian Ocean Region: South China Sea deals with maritime operations at the politico–military level. GMT Game's Next War: India–Pakistan is pitched at the theatre level, also credibly portraying trade-offs and impact associated with appearance of China or the US, and the nuclear threat.

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Examination of analogue game mechanics suggests that these too are ABMs, but with crucial differences listed below:

• **Modelling Forces as Agents.** Limited data handling ability of analogue games enforced an abstraction, including reduced resolution.[44] The minor tactical-level 'Last Hundred Yards' (GMT Games) depicts squads and weapons detachments (not individual soldiers). The strategy and operational Third World War (Compass Games), depicts divisions, brigades and regiments, and air and amphibious units. Games treat these elements, which can be broken into finer resolution in lower-level games, as agents with individual parameters:

• **Size and Strength.** Manual games do not get embroiled in exact strength figures but use ordinal or nominal variables to represent size. In a skirmish/micro-tactical level game, a weapons detachment may have size as 1, and thus a platoon will be 8 or 9. At higher level games such as NATO: The Cold War Goes Hot, elements are brigades and battalions, with strength accounted for by step-losses. Illustrated in Figure 2, is an example of a mechanised division from the game Third World War, depicting ordinal values for size, and other factors.

• **Nominal Variables.** Can be used for size, such as very small, small, large to very large in Jim Wallman's classic Div Tac. Though crude, these methods successfully represent impact of relative size on how elements fight, occupy space, and receive casualties. Even casualties are treated as ordinal variables, as step losses in the strength value.

• **Combat Capability.** In combat, strength is modified by combat capability, which can be a single or a bundle of variables. Games such as Div Tac use single ratings, while Third World War, illustrated in Figure 2, or the Main Battle
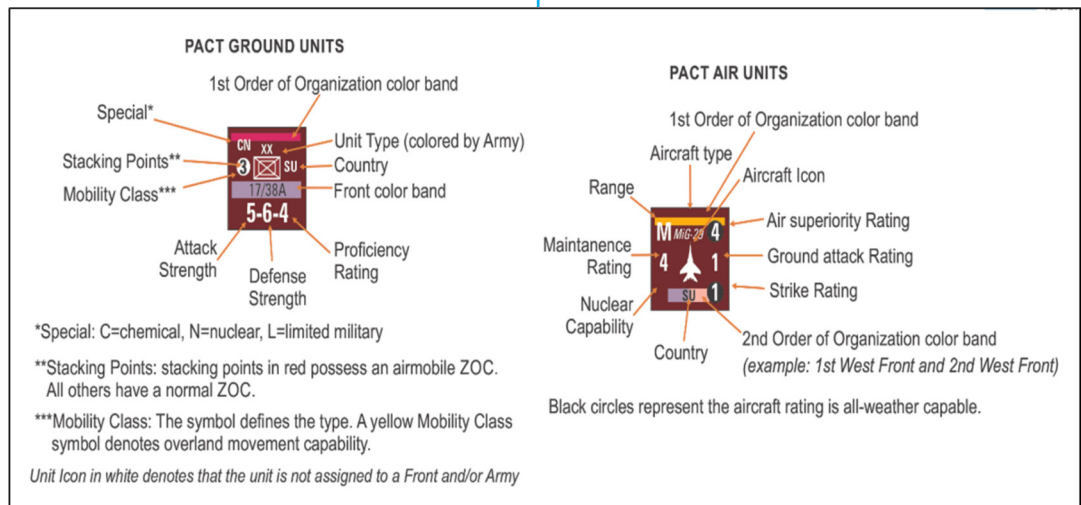

Figure 2: Illustrative Unit Symbol Third World War

Tanks (MBT) Series (based on MBTs of the period), use separate attack and defence ratings. As a basic, the lower the level of the game, the more diverse the types of combat. Thus, Last Hundred Yards uses separate attack and defence values for anti-tank and anti-personnel combat.

• **Intangible Qualities.** Manual games use qualitative values for intangibles. Larger level games, such as Third World War, use single values such as proficiency rating (Figure 2), while other games can use more differences, viz., troop quality, training, morale, or fatigue (Last Hundred Yards). Combat results are expressed in change in intangible values, which affect subsequent behaviour of agents.

• **Behavioural Attributes.** As discussed, conduct in battle is affected by perception, anticipation, and behavioural proclivities of agents. While defending forces may get surprised, forces standing to, or tasked for observation, are nearly impossible to surprise (unless poor troop quality). Manual hobby games handle such behavioural aspects using devices such as 'Mode' (Div Tac) or 'Command' (MBT). This tool, which resembles the state of an agent in an ABM, has not been optimally used in wargames but has immense scope for automating agents to choose between options (not necessarily optimally) and behave spontaneously (charge without orders to exploit an opportunity), or refuse to do things (poorly led or fatigued element refusing to budge), all of which are realistic military situations.

• **Simulation by Discrete Time.** The real world is perfectly synchronised, and minute-to-minute situational awareness and intervention at skirmish levels nests perfectly into increasingly removed awareness and reduced frequency of intervention. This is apparently represented in mathematical models which use continuous-time simulation, updating agent states per infinitesimal change in time (δt). In contrast, analogue games use the putative artificiality of progressing over turns of discrete time, when locations, strength, tasks, and other metrics are updated. This resembles ABMs, which by

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definition use discrete-time simulation. However, continuous time simulations have some issues and logical inconsistencies, as outlined below:

¤ If resolution of forces is restricted to battalions, but fires are updated by δt, it logically implies that the entire battalion is firing en bloc at a steady rate. In reality, battle is episodic, with parts of battalions firing or conducting other activities in fits and starts.

¤ Outcomes are highly bottom-up, yielding unsustainably high tempo of operations.

¤ Continuous-time games also require continual refreshing of agents for every δt creates enormous processing requirement.

¤ Thus, while continuous-time models may meet requirements of a skirmish-level game, time resolution must be reduced to match force resolution of a higher-level game. Like in analogue games, a turn-duration synchronised with periodicity of significant development, situational awareness, and intervention, will address this, and reduce data-processing load.[45]

Rules and Topology. Wargames represent entities (or agents) trying to follow orders to attain goals, orchestrated to meet goals of higher Headquarters. Agents are confronted with choices, but immediate conditions obligate agents to act in a boundedly rational, expedient manner. This is embraced in analogue games with behavioural metrics such as Mode (outlined above), which cause entities to act with autonomy, enthusiasm, recalcitrance, compelling or impelling them to behave in suboptimal ways at times disregarding player inputs (precipitating charges, coming to a standstill during attack, or holding on despite extremely heavy odds). Some other aspects are:

• Most mathematical models focus on the most spectacular and intense of functions, i.e., combat, subsuming other functions. Here too, they concentrate on output, rather than

more nuanced outcomes. In contrast, analogue games take heuristic approaches to dealing with outcomes such as the Combat Results Tables (CRT), outcome-oriented models of correlation between situations and probability of expected outcomes. Situations here are defined as strength ratios, adjusted to parameters (morale, fatigue, behavioural mode), tactical conditions (time of day, artillery fire) etc with modifiers, which define the epistemic part of uncertainty, the aleatoric part resolved by randomising the probability distributions.

• Results of CRTs are not limited to outputs, as in mathematical models, but include multivariate outcomes, like changes in tactical posture, fatigue, morale, and behavioural mode.[46] In other words, parameters of agents are both inputs and results. Inability to model synergy is easily addressed through CRTs, which forces agents to change behaviour. Militaries are social organisations, and agent behaviour impacts one another in desirable and undesirable ways; defeat of one may cause morale to plummet in neighbours; presence of a charismatic leader nearby may rally a shaken unit or precipitate a charge. This is well-represented in analogue games, where performance of agents continually triggers involuntary changes in other agents, thus causing a cascade of second and third order outcomes.

Victory and Defeat. Mathematical approaches determine defeat or victory by comparing casualties, assuming that a side breaks when a breakpoint is crossed. This is unrealistic. At tactical levels, an attacker trying to capture a foothold across a water obstacle with the intent of laying a bridge may stall without serious casualties if incoming fire is heavy. After a while, it may rally and establish a foothold. The defenders may withdraw but continue resisting with artillery, destroying the bridging column following the attack. This is local equilibrium, with attackers retaining the hold but unable to establish a crossing, and the defender containing but not evicting them. The question of who won this battle cannot be answered by models using metrics of casualties. Reasons for which are given as under:

> **Mathematical approaches determine defeat or victory by comparing casualties, assuming that a side breaks when a breakpoint is crossed.**

• Analogue wargames and ABMs are more comfortable with local equilibriums. Of the opposing agents arrayed around the foothold, agents crossing the river 'won', but bridging agents 'lost', while defending agents on the bank 'lost', but their artillery agents 'won'.

• This local equilibrium can be disturbed by influx of agents on either side (reinforcements, counterattack forces, or spare bridging train), or change in behavioural effect like defenders rallying to mount a counterattack due to arrival of a charismatic commander, or success in another part of the battlefield.

• Analogue wargames are also able to represent the continuity of the victory–defeat duality, such as in the multi-side geostrategic game, Indian Ocean Region: South China Sea Volume II, where a score starts at 10 and fluctuates between 0 and 20 for each side, the current figure indicating its relative position at any time.

Deductions

The above discussions suggests that the complexity and exponential possibilities of warfare is better handled through ABMs. It also arrives at certain deductions:

Manual, Analogue Games are Credible ABMs. Manual board and tabletop wargames satisfy all criteria of ABMs, and effectively represent warfare. Without enforcing linearity, they define forces as agents competing in a synthetic atmosphere, making choices and creating patterns.[47] Representation of victory and defeat as continued ability or inability to conduct its task is more realistic.

Manual, Analogue Games have Potential for Military Exploitation. Having been pioneered by computer experts, ABMs use an exclusive language and still are a niche field. However, the qualitative language of analogue games is more comprehensible, and can translate military precepts into rules of ABM, further explained below:

• They can better model heterogenous forces uniquely. Volunteers and regulars can be

differentiated by reducing training and cohesion value but increasing morale of the former by a sufficient margin.

• Abstraction is enforced by limited data-handling ability, restricting resolution to player level or outcome-modelling the subprocesses of combat (the wargame is process-model of conflict). This keeps commanders from micro-managing.

• CRTs can be easily understood, updated and adjusted by amending modifiers, conditionalities, and probabilities.

> **ABM is itself a form of AI using a 'whole of system' approach and has potential to model human domain and behavioural processes.**

• Manual games are bottom-up, with forces behaving uniquely according to parameters, viz., excellent to poor training, eagerness or disobedience, resilience or demoralisation. They represent warfare as a social event, creating greater non-linear possibilities. Being qualitative ABMs, they go beyond bean-counts and deal with outcomes. They can be easily adapted to newer forms of warfare, forces, and effects of so-called Fourth Generation Warfare (4GW).

Adopting a Qualitative, Agent-based Approach. Modern armies seek elaborately networked computer wargames in bespoke facilities. However, these not only have issues with the Operational Research (OR)-inspired modelling approach, but also are unable to upgrade easily or incorporate new forms of warfare, despite development at great cost and time, which has reinvigorated analogue gaming.[48] Adapting analogue games to such gaming systems can address several issues such as:

• Logical inconsistencies, including fascination with tangible outputs rather than outcomes, and multi-resolution modelling where required, will be handled.

• Be designed to provide authentic user-interfaces.

• Better understanding by military users who will contribute more to the development process.

• Lighter Systems will be able to handle larger, distributed games involving players from remote locations.

• Be easily upgradeable, viz., by changing a few parameters of existing agents, new types of agents can be defined; changes could be done on-the-fly itself.

Exploiting Artificial Intelligence (AI) for ABM. ABM is itself a form of AI using a 'whole of system' approach and has potential to model human domain and behavioural processes.[49] With improvements in AI and machine learning, rules of ABM-based wargames can be designed to evolve using means of 'Credit Assignment'[50] so that agents continuously hone their skills and eventually portray decision-making norms of armies and nations of interest

Recommendations

In addition to their potential of inculcating a inculcate wargaming culture, manual games have the scope of refining digitised, distributed games. This can be done in incremental stages:

• **Stage I: Exploiting Commercial–Recreational Analogue Games.** Many commercial wargames can be directly adopted for military use (with easy modifications), as at Table 1. Certain applications are given after the table:

¤ **Direct Applications of Commercial-Off-The-Shelf (COTS) Analogue Games.** Games can be adopted for crystal-gazing and prognosticating, including at levels of diplomacy and national security. Training establishments can reinforce seminar games with playing out alternate options on analogue games and comparing them later. Field formations can continue scenarios in higher-level games with analogue games.

¤ **Adjusting COTS Games to Professional Requirements.** Though highly effective, COTS analogue games are marked by inaccurate inputs,

Level\Name	Board Game	Tabletop	Remarks
Comprehensive National Power (CNP)–Strategic–Operational	Indian Ocean Region: South China Sea Vol II (Compass Games) Next War Series such as India–Pakistan war (GMT Games) Putin Strikes or Putin's Northern War (One Small Step)		Games apply CNP, joint forces, possibility and effect of collusions, and application of grey zone warfare. Comparatively few purely tabletop games are known at this level, but many boardgames exist.
Operational–Tactical	Fulda Gap (Compass Games) NATO: the Cold War Goes Hot (Compass Games)	Div Tac or OpCom at divisional to battalion level Stonk at brigade to company level	Only adaptation to the equipment used and some parameters would be required
Minor Tactical–Skirmish	MBT or Last Hundred Yards (GMT Games)	Fistful of TOWs or Crossing the Wire	-do-

Table 1: Illustrative List of Games at Different Levels of Conflict

assumptions, and unclassified data and thus can be inaccurate. However, these can be modified inhouse by armies, classified data used where required, ORBATs defined, and parameters changed.

¤ **Course of Action (COA) wargaming.** COA wargaming, different from dynamic wargames, progresses in action–reaction–counteraction arguments using products of the Intelligence Preparation of the Battlefield. Adjudications of conflicts during these arguments could be formalised by developing CRTs and other ready reckoners using analogue gaming techniques.

• **Stage II: Designing Bespoke Analogue Games.** In addition to adapting existing commercial games, militaries must invest in developing analogue games adjusted ab initio to military data and procedures. Analogue games such as Dunn-Kempf[51] or Tacspiel[52] were used in Western armies (some of them evolved into computer games, like the McClintic Theatre Model). However, some of these games were influenced by the spirit of OR and indulged in intense micro-scale modelling and were nearly 'unplayable' because:

¤ As seen, recreational games provide many suitable techniques that could be identified and adapted to military purpose. Stonk's method of time delay in preparing an artillery fire plan, based on number of batteries and likely number of targets, and OpCom's (a tactical game based on Operation Market Garden) system of contaminating information, can be exploited together for command and staff friction and fog of war, including delays and contamination in information and orders.

¤ Adopting such approaches is not ethically wrong as the field of wargaming is incremental. The iconic Jim Dunnigan[53] himself dramatically encouraged designers to 'plagiarise'. In any case, such repurposing for levels, scenarios, and datasets would be like designing new games.

• **Stage III: Designing Bespoke Distributed Games for Computer Networks.** Exploiting the promise of qualitative ABM approach for networked, system games, the following steps must eventually be implemented:

¤ Use turn-based gaming (with the associated techniques of en passant move and event sequencing) to address logical inconsistencies of continuous-time models and reduce processing requirements.

> In addition to adapting existing commercial games, militaries must invest in developing analogue games adjusted ab initio to military data and procedures.

¤ Adopt the concept of mode to define behavioural predilections.

¤ Use outcome-based CRTs, using qualitative metrics to yield nuanced and multivariate outcomes. These are comprehensible to military wisdom and will keep players out of micro-modelling.[54]

¤ Use data-structures of wargames to collect data from exercises, observations, and historical assessment. Institutionalising methods of continual data-farming and refining models (adjusting modifiers and probability distributions) will progressively reduce epistemic uncertainty.

¤ Continuous data-farming will enable AI techniques to adjust rules, add agents and characteristics, and define new conditionalities and modifiers.

> **Exploitation of wargaming requires a culture going beyond using wargames for consideration by only senior leadership only, requiring junior leadership to only train on-ground with their men.**

¤ One major drawback of computerised professional games is that they consider aesthetics of interfaces irrelevant to serious gaming, denying players an immersive gaming experience. In contrast, aesthetics and packaging are important in commercial products. Professional system game designs must adopt this attitude to create interfaces based on military service

procedures, realistically restricting amount of information. The realistic approach should be:

º Company commanders should only get a small working map of his immediate area, while a divisional headquarter may have a greater number of maps with logistics, intelligence, and operational plans.

º Situations must not be continually updated on these maps, but only as per last reports received, duly filtered by the fog of war. This would mean that information of the player would be delayed and outdated, which is a reality that military commanders must learn to live with. If the game scenario allots an army with advanced information-processing systems, then the information available could be more recent.

º Such game interface will prevent players from noticing the artificiality of stepped time and use of CRTs.

Figure 4 below shows a transition from current practices of designing distributed computer wargames, through existing and bespoke analogue games, to distributed computer wargames using qualitative ABMs. The advantages accrued at the right-hand column are clearly visible.

Factors	Current/ Existing Systems		Proposed Systems	
	Current Computer Wargames	Existing Manual Games	Bespoke Manual Games	Agent-Based Computer wargames
Cost	Very Expensive	Cheap	Cost to adapt/ develop	Less expensive than current computer wargames
Complexity	Very Complex	Low	Low	Medium Complexity
Development Time	Very time-taking, can take years to roll out	Only time to procure	Limited time to develop	Far less than current computer wargames
Credibility	Low credibility to a military audience	Medium, as accurate information often limited	High, if adapted to accurate information. Yields credible decision-making situations	Can be highly credible, with immersive gaming experience

Figure 4: Transition—Current Wargames to Agent-Based Computer Wargames

- **Concurrent to All Stages: Wargaming Culture.** Exploitation of wargaming requires a culture going beyond using wargames for consideration by only senior leadership only, requiring junior leadership to only train on-ground with their men. This statement inaccurately assumes that wargaming conflicts with on-ground training as:

  ¤ Junior leaders require practice in decision-making under conditions of incomplete information, paucity of time, and the awareness that instructions will only be imperfectly implemented. Usually, for want of better means, training in these aspects is conflated with field exercises. However, limited time, huge expense, and paucity of training space are increasingly limiting opportunity for such on-ground training, and the limited opportunity must not be squandered in anything other than rehearsal of battle drills and procedures by fighting echelons and their leaders. Using this limited opportunity for practicing decision-making is wasteful and cognitive skills of decision-making must rather be practiced via low-level, minor-tactical wargames.

  ¤ Designing and implementing wargames is not an easy task,[55] and require unique mental skills to develop.[56] Thus, to inculcate a wargaming culture, it is imperative to 'catch them young'. Several Western armies have institutionalised 'Fight Clubs', where communities of junior officers and soldiers use and share their experience with commercial manual and computer games.[57] This exposure enhances critical thinking, and also builds pools of personnel that can be used in system game designing.[58] Such fight clubs can be similarly established, starting with extant wargames as even if set on other armies and historical periods as primary tactical concepts are true everywhere. Methods of inculcating critical thinking:

  º Games such as Last Hundred Yards can be used by junior soldiers and trainees as a means of considering tactical problems they are likely to face, before they practice the same on ground. The simple, hex-based Take That Hill, used as a wargaming primer by the Sandhurst-based 'UK Fight Club' is excellent for teaching techniques of fire and movement and how soldiers continuously get winded during battle and do not behave like automata.

  º Young officers and soldiers can themselves learn to innovate adaptations to incorporate actual military tactics and equipment. The MBT series games, built primarily for a non-military audience, does not permit speculative fire or enfilade fire, but these aspects, being important to military tactics, can easily be introduced by some clever tweaking of the rules.

  ¤ Allegations of being crude simulations lacking mathematical exactitude are irrelevant, and analogue games, which really are qualitative agent-based models, are better able to model conflict environments as complex adaptive systems. They can create far more realistic situations and decision-making opportunities, where decisions and actions have trade-offs that can turn the game in any direction, just as in reality. It does take mental change in attitude to accept recreational wargaming, especially tool of dicing which is seen as childish (but which can be 'hidden' even in manual games with more serious-looking random number generators). It is thus that famous aphorism attributed to George Box, 'All models are wrong', can be completed by adding '(but) some are useful'.[59]

Conclusion

Warfare is a complex adaptive system that shows aggregate behaviour, adaptation, and behaviour by anticipation. A few pioneering initiatives to represent warfare with ABM, acknowledged as best able to mimic behaviour of such systems, that have been made are experimental, highly

detailed, and mathematical, and focus on short and homogenous battles only. This paper argues that recreational wargames, such as boardgames and miniature-based games, are qualitative agent-based models whose techniques and devices have immense scope for creating credible and realistic games for professional military exploitation if adapted suitably.

End Notes

1   Models following reductive approaches are—free standing and fitted parameter analytical models, or killer–victim scorecards. Aggregative models are the Lanchester Equations the Quantitative Judgment Model (QJM) and other firepower scores systems.

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