A citizen science colonisation model for the Koprulu Sector in StarCraft 2, micro Terran to defeat Protoss and Zerg?

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ABSTRACT
We present results from a citizen science outreach project to develop models of interstellar colonisation based on the multi-player strategy game StarCraft 2. Data were gathered from the online gaming community to provide a test set of outcomes for encounters between several fictitious alien species, each following various economic and military strategies. We perform a series of 100 Monte Carlo Realisation simulations to investigate the emergent properties of these alien civilisations in a region of space representative of the average stellar density and star-formation history of the Milky Way. It was found that the deliberate in-built balance between civilisations in StarCraft 2 prevented any one species/strategy from obtaining complete dominance in any single simulation. However, the mean stellar occupancy of each civilisation averaged over the 100 realizations shows that the Terran inhabitants of the fictitious Koprulu Sector, pursuing a strategy of early pressure against their opponents, would eventually conquer their Zerg and Protoss adversaries. While this science outreach project certainly does not represent any development in our understanding of possible extra-terrestrial life, we hope to highlight the increasing scientific potential of the rapidly expanding video-game industry, while also increasing public understanding of the scientific method.

1 INTRODUCTION
Over the past decade, the field of astrobiology has undergone an observational revolution with the detection of over 860 extra-solar planets¹ around stars in the Milky Way. Despite current observational limits and biases, the measured variety in mass and orbital radius has for the first time allowed statistically meaningful statements to be made regarding the properties of planets beyond the solar system. While these data allow for estimates to be placed on the demographics of the planets themselves, and on the number of planets in potential “habitable zones” (Kasting et al. 1993), the study of potential extraterrestrial life is hampered by the absence of any direct observational data.

Perhaps the most speculative area of astrobiology pertains to the frequency and behaviour of intelligent extraterrestrial civilisations. In the absence of detections (see e.g. Semion et al. 2013), a number of authors have undertaken numerical modelling to explore the potential detectable signals of extraterrestrial civilisations (e.g. Arnold 2005, Forgan & Elvis 2011, Glade et al. 2012, Loeb & Turner 2012). Recently, Starling & Forgan (2013) performed a series of Monte Carlo Realisation simulations which investigate the “civilisation as symbiont” model, where civilisations pursue a variety of different relationships with their host planet (from mutualism to parasitism), to identify which strategy might be dominant in competition with others. However, while these results are of interest for interpreting future observations, the absence of any observational data significantly limits their development.

We further develop the Starling & Forgan (2013) models using a test sample of data gathered from the multi-player strategy game StarCraft 2. The strategies developed by the online gaming community and behaviours of the fictional alien races portrayed in the game are translated into a numerical model, constrained by the physics of the Milky Way and allowed to develop according to these characteristics. The fictional universe of StarCraft 2 and its denizens are described in Section 2.

The use of online games in research is a relatively modern concept (Bower 2007), perhaps best illustrated in publications derived from the “corrupted blood incident” (Balicer 2007, Lofgren & Fef- ferman 2007) in the Massively Multiplayer Online Role-Playing Game (MMORPG) World of Warcraft (WoW). With a subscriber base numbering in the millions, the player-controlled characters in WoW exist in a rich and complex virtual world based in a fictitious fantasy setting. The interpersonal relationships between the users, and their interaction with the non-player computer-controlled populace, often mirrors the behaviour of populations in the real-world. The environment itself contains many elements which parallel real-world institutions, such as an auction-driven economy, a distribution of population centres, and a complex transport network. During the corrupted blood incident, an unplanned outbreak of an infective communicable disease was transmitted between both the virtual player and non-player characters populating the game servers. The virtual outbreak, and resulting behaviours of the player base, were found to display surprising similarities to real-world epidemics. This similarity suggests that MMORPGs could provide a platform for testing novel interventions to control emerging communicable diseases.

In addition to the corrupted blood incident, blogger and games consultant James Wallis conducted a “geophysical survey” of the fictitious world Azeroth from WoW, using a combination of real-world extrapolations and measurements gathered “in-game”. While highlighting the non-physical nature of the virtual world, the project provides an excellent public outreach platform and conveys the value of the scientific method.

¹ http://exoplanet.eu
The original StarCraft engine has also been used as a platform for the development of artificial intelligence (AI). During the 2010 Artificial Intelligence and Interactive Digital Entertainment (AIIDE) Conference, held at Stanford University, competing AIs were placed in conflict to determine which could develop the best strategy to overcome their opponents. Critically, any such AI must be able to make semi-intuitive responses to new information, combined with balancing investment in the game’s core resource-gathering vs military spending concept.

The science outreach project presented here certainly does not represent any development in our understanding of possible extra-terrestrial life. However, we hope to highlight the increasing scientific potential of the rapidly expanding video-game industry, while also increasing public understanding of the scientific method. To this end, we demonstrate how to translate parameters from the StarCraft 2 universe into a numerical simulation, which are then explored in a setting based upon real-world physics. It is our hope that this study will demonstrate the core properties of a research paper, and provide a greater understanding of how data are presented in scientific research.

2 STARCraft 2 AND DATA GATHERING

StarCraft 2 is a real-time strategy game developed by Blizzard Entertainment (see copyright/trademark notices). As described on the Blizzard StarCraft webpages, “In typical real-time strategy games, players build armies and vie for control of the battlefield. The armies in play can be as small as a single squad of marines or as large as a full-blown planetary invasion force. As commander, you observe the battlefield from a top-down perspective and issue orders to your units in real time. Strategic thinking is key to success; you need to gather information about your opponents, anticipate their moves, outflank their attacks, and formulate a winning strategy.”

Within the StarCraft universe, three alien civilisations are in conflict for a region of space known as the Koprulu Sector, situated on the galactic fringe of the Milky Way. These civilisations comprise a human penal colony offshoot group known as the “Terran Dominion”, the insect-like hive-minded “Zerg”, and the technologically advanced telepathic “Protoss”. The player-controlled conflict between these species provides an excellent test case for our numerical modelling of interstellar colonisation; and while arbitrary in nature, these user-driven strategies and tactics represent a large and evolving data set constructed independently of observer bias.

Data were gathered from analysis of player vs player (PvP) encounters between “grand master” level users of the North American, European, and South Korean Blizzard Battle.net servers, and from professional ESPORTS tournaments. We specifically select from this elite player base to ensure a roughly equal level player of ability. Results were obtained from a random sample of game replays released by both professional level StarCraft 2 players, and ESPORTS “casters” who also provide commentary and analysis. Data were obtained over a six-month period, encompassing versions 1.3 and 1.4 of “StarCraft 2: Wings of Liberty”.

The outcome of player vs player encounters in the StarCraft 2 universe (assuming a roughly equal level of player ability) should typically depend on the adopted strategy of the players, both on a macroscopic resource managing scale and the smaller fine control of the manufactured military units. Initially, each player will pursue a strategy they believe to be optimal against their opponent, which is then modified by information collected during the game regarding the opponent’s actions. The game as a whole is continually updated to ensure a reasonable balance between the three races for all games played, and while there are numerous fluctuations which affect the outcome of any individual game, we explore the efficacy of adopted strategies over numerous games to identify large-scale statistical trends.

We identify the dominant factor in each match to determine how the player’s chosen strategy performs against that of their opponent. On a simplistic level, each player can be said to follow either a “macro” economic strategy, designed to increase the amount of resources gathered and eventually overwhelm their opponent, or a “micro” economic strategy, with emphasis placed on the rapid development of a military force to eliminate their opponent at an earlier stage of the match. We further sub-divide these two strategies into “high-tech” and “low-tech” approaches, where by a player chooses to invest in either a small number of advanced and powerful military units, or the mass production of less advanced units to overrun their adversary. Given the limited number of games analysed in this study, we were forced to focus primarily on the interactions between the macro vs micro economic model, and how each race performs against the other potential race/strategy combinations.

Data were collected from ~ 500 publicly available game replays, for which analysis and commentary was provided by several casters (listed in the Acknowledgements section). The results of these games were categorised into 30 possible race/strategy combination outcomes, representing two versions of each race (i.e. Terran/Zerg/Protoss) pursuing either a macro or micro focused strategy. These win/loss rates were converted into a probability for victory in any given encounter. This “game-table” provides the basis for our model, with the results of encounters between the various race/strategy combinations taken from the appropriate entry in the table. It was found that the balance within the StarCraft 2 game itself was excellent, with on average less than 5% fluctuation in win/loss rates for each civilisation.

In addition to these core win/loss statistics, several supplemental parameters were measured from the game replays to augment the model. During professional StarCraft 2 tournaments with multiple games, the previously defeated player will typically select the map for the subsequent match. The terrain and resources availability of certain maps will favour various play styles over others. We measure the ratio of victories obtained where a player selects the map versus those where their opponent has chosen. This ratio is used in our model to augment the probability from Table 1 when determining the outcome of encounters between an invading force and one already in place. We give this “defenders advantage” to macro civilisations, as it might be expected that a civilisation which invests in development of infrastructure could mount a superior defence to that of a micro civilisation’s which colonises a planet and then rapidly moves on to the next available target.

As a counterbalance to the defenders advantage for macro civilisations, we measure the average length of games between macro and micro opponents as a proxy for the colonisation rate of that civilisation through the model region. Conflicts where one or both of the opponents employ a macro economic strategy typically last longer than those of micro civilisations. We use the ratio of these two average game lengths as a proxy for the expansion times of the civilisation, with micro civilisations rapidly expanding to neighbouring systems after initial colonisation, and macro civilisations taking a longer period of planetary buildup before eventually expanding to the next system.
It was found that the defenders advantage for macro civilisations and the faster colonisation rate of micro civilisations were seemingly well balanced. Given the non-homogeneous nature of our simulated region of space (see Section 3), we would therefore expect to see an increased rate of colonisation in high-density regions for micro civilisations, and increased success for macro civilisations in sparsely populated areas.

3 MODEL

To investigate how the StarCraft civilisations would fare in a realistic Galactic environment, we carry out Monte Carlo Realisation (MCR) simulations of a region of the Milky Way. Each realisation is an independent simulation, where the six civilisations compete to colonise all stars in the region. As the simulation evolves, the civilisations expand their occupied regions, come into contact, and fight for the ownership of star systems. Running multiple MCRs allows us to characterise the random error in this process (see e.g. Vukotic & Cirkovic 2007, Forgan 2009). The MCRs were carried out in a cubic domain, with $N_{\text{star}} = 10^6$ stars placed randomly according to a constant stellar number density of 0.14 pc$^{-3}$. This set the box length to be $\sim 191$ pc (or around 620 light years). A neighbour sphere was constructed for each star of radius 5 pc. All stars found within this radius are added to a neighbours list - for a constant stellar density, this corresponds to a typical neighbour count of 73. However, while the overall density is uniform, there are small overdensities and underdensities present in the domain. This will become important for civilisations attempting rapid colonisation.

In each realisation, one civilisation of each type was randomly seeded onto a star. Civilisations then select the nearest star in that star’s neighbour list unoccupied by their own species, and travel towards it at fixed velocity. When a civilisation colonises a new star, the civilisation must wait for a fixed time interval before initiating a new colonisation mission, to represent the building time required. Only one colonisation mission is allowed at any time for any one star. The simulation selects a time-step according to the smallest time interval required for any one colonisation mission to arrive at its destination. Colonisation missions that arrive at a planet occupied by another species engage in combat. The attacking civilisation has a probability of victory against the defender specified by the StarCraft 2 user data. This probability is used to decide the victor. If the attacker wins, they assume control of the star system and begin building a new colonisation mission. If the attacker loses, their colonisation mission is destroyed, and the attacker must launch a new colonisation mission from their original location. This process of initial expansion, contact with opponents, and eventual total occupancy of the model region is shown in Figure 1. In this figure, several two-dimensional projection “snapshots” are shown from an early (top), middle (centre), and late (bottom) stage of the simulation. The conflict between civilisations will therefore primarily occur on the border regions, which will shift and develop based upon the outcome of conflict. The simulations were run until one of the following conditions was met:

(i) One civilisation controls more than 70% of the total stellar population.
(ii) The number of occupied star systems for each civilisation remains roughly constant over several time-steps.
(iii) The box is completely occupied for a sufficiently long period of time. We set this time period to be 50% of the total runtime.

We then performed 100 simulations for three different variations on the base model:

(i) A Control Scenario, where the probability of victory is 0.5 for all attackers, and all species possess the same colonisation speed and building lag time. In short, all species are identical.

(ii) A Standard Scenario where the probability of victory is determined by the StarCraft user data, and all civilisations possess the same colonisation speed and building lag time. The species are now distinct in their combat ability - species A (adopting strategy a) will be better equipped to defeat species B (adopting strategy b), while being more prone to defeat from attacks by species C (adopting strategy c). However, we still assume that each strategy (micro vs macro) is identical in its propensity to colonise space.

(iii) An Enhanced Scenario where the StarCraft user data determines the probability of victory and the colonisation speed/lag time for each civilisation. We now fully utilise all data obtained from the StarCraft user data, and fully distinguish species and strategy types.

The results and motivation for performing these varied types of model run are described below in Section 4.

Figure 1. Two-dimensional snapshots of the six civilisation race/strategy combinations expansion into the model space shown at an early (top), middle (centre), and late (bottom) stage of the simulation. The rectangles are 80×80 parsec projections of a cubic region of space. Each civilisation is colour-coded, including Terran macro (dark blue), Terran micro (light blue), Zerg macro (dark red), Zerg micro (pink), Protoss macro (Orange), and Protoss micro (yellow).
4 RESULTS

The total mean stellar occupancy for each species/strategy combination summed over all 100 realizations (for all three model variants described in Section 3) is shown in Figure 2. To reiterate, the deliberate in-built balance between civilisations in StarCraft 2 prevented any one from obtaining complete dominance in any single simulation. Therefore, it is apparent that no one species/strategy combination has a clear advantage in any individual match. However, by observing the average mean stellar occupancy of each civilisation over all simulations, we are able to trace any smaller effects which present only on a larger statistical level.

4.1 Control Scenario

In this first set of simulations, where the probability of victory for any one civilisation in conflict with another is 0.5 (i.e. the outcome of each bout is 50/50), we would expect to see (on average) an equal distribution of mean occupancy. In any individual simulation the arbitrary starting position will influence the success of any species/strategy combination, but by averaging over many simulations these effects can be mitigated. The results seen in the top panel of Figure 2 are consistent with such a flat distribution, with only slight fluctuations (e.g. micro Protoss and Terran) resulting from the limited sample size. However, it is important to note that no civilisations has a mean stellar occupancy higher or lower than any other within the given uncertainty.

4.2 Standard Scenario

Within this model, encounters between civilisation/strategy combinations are no longer 50/50 as in the Control Scenario, but determined by the results collected from online PvP encounters. With all other parameters identical to the Control Scenario, any increase or decrease in a civilisations mean stellar occupancy relative to the Control Scenario will result from the influence of the game-table. The mean stellar occupancy from these simulations are shown the central panel of Figure 2. It was found that the Terran civilisation, following a micro-economic strategy, colonises more planets than expected by chance. This \(5\sigma\) result, while statistically significant, should be considered in the context of the large uncertainties resulting from the limited number (100 MCRs) of model runs. However, the overall implication from these simulations indicates that the Terrans in StarCraft 2 on average performed better than their competitors during the period of data collection. It is also apparent that the Protoss, when following a micro economic strategy, seemed to perform significantly below the expected values.

4.3 Enhanced Scenario

Finally, the Enhanced Scenario incorporates the game-table-based combat outcomes as described in the Standard Scenario, with the addition of increased colonisation rate for micro civilisations and the defenders advantage of macro civilisations determined from average game length and map selection respectively. The results from this scenario are shown in the bottom panel of Figure 2. Unlike the reasonable balance seen in the Standard Scenario, the complete dominance of the micro strategy over the macro strategy indicates that the parameters we have estimated to represent the expansion rate of a civilisation are not balanced by the defenders advantage. As these parameters were estimated from a non-real source, we can make no statement regarding true efficacy of rapid vs methodical colonisation strategies, simply that the micro strategy seems to provide a significantly higher return if the StarCraft 2 civilisations were to come into conflict in a region of moderate stellar density.

Figure 2. Total mean stellar occupancy for each species/strategy combination summed over all 100 realizations for the Control Scenario (top), Standard Scenario (centre), and Enhanced Scenario (bottom). Error bars represent a 1\(\sigma\) uncertainty on the result.
Colonisation of the Koprulu Sector in StarCraft 2

5 CONCLUSIONS

We present results from a citizen science outreach project to develop models of interstellar colonisation, based on the multiplayer strategy game StarCraft 2. Using a series of simulations, we investigate the behaviour of several fictitious alien civilisations in a region of space representative of the average stellar density and star-formation history of the Milky Way. While this science outreach project certainly does not represent any development in our understanding of possible extra-terrestrial life, we hope to highlight the potential importance to science of the video games sector, and to increase the public understanding of the scientific method.

From the analysis of these model data, it was found that the deliberate in-built balance between civilisations within StarCraft 2 prevented any one species/strategy from obtaining complete dominance in any single simulation. An example of the roughly equal stellar occupancy during an individual model run is shown in Figure 3. However, analysis of the mean stellar occupancy of each civilisation averaged over all realizations shows that in StarCraft 2: Wings of Liberty, the Terran inhabitants of the fictitious Koprulu Sector, pursuing a strategy of early pressure against their opponents, would eventually conquer their Zerg and Protoss adversaries.

With future modifications to StarCraft 2, the balance of power will certainly shift in the ever-changing Koprulu Sector. Humanity’s future in space looks promising for now; however, based upon these results, it seems like “the sooner the better” when it comes to our expansion into the Milky Way!

LEGAL

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