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Gender Diversity Population Simulations in an Extended Game of Life Context

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ABSTRACT Cellular automata studies have been instrumental in computational and biological studies for simulating life contours based on simple rule-based strategies. Game of Life (GoL) presented us with one of the earliest automata studies that led the way in exemplifying non-linear spatial representations, such as large-scale population evolution scenarios depicting species dominance, species equilibrium, and species extinction. However, the GoL was driven by interactions among vegetative entities comprising live and die states only. This paper extends GoL to gendered-GoL (g-GoL) in which male phenotypes and female phenotypes interact in an extended world to procreate. Using the g-GoL, we have demonstrated many evolution contours by applying gender-based dependence rules. Evolution scenarios have been simulated with skewed gender ratios that favor the birth of male offspring. Preference for a male child is common in certain cultures; therefore, empirical data realized with skewed gender settings in g-GoL can reveal the long-term impact of non-egalitarian gender societal structures. Our model provides a tool for the study of emergent life contours and brings awareness on current gender imbalances to strengthen multi-disciplinary research inquiry in the areas of social practices, mathematical modeling, and use of computational technologies.

INDEX TERMS Cellular automata, game of life, gender inequity, population evolution, procreation, skewed gender ratios.

I. INTRODUCTION

Exploratory studies on emergent artificial life contours are informed by simulations that use continuous strategy-based interactions. Microscopic entities exchange information with neighboring entities within a bounded space (called their world) using some rule-based evolution strategy. When an entity's interactions with its neighboring entities conforms to a specified dependency rule, then this entity self-organizes itself in the following generation. A bird's eye view of ongoing entity interactions and their subsequent self-organization reveals many abstruse kaleidoscopic arrays of patterns [1], [2]. These patterns that unfold have excited philosophers and scientists alike, who conceptualize patterns to swarm tactics as made by atypical microbes in ecology (e.g., foraging and path-finding activities of ants), or to binary cell switching patterns in computing fields (e.g., pseudo-objects, puffer trains, glider guns or collisions resulting in debris dispersed over the grid lattices) (e.g., [3]–[7]). However, lack of dependencies among entities could cause the patterns to converge into a still-life shape or into a repeating pattern cycle. Such convergence scenarios occur when subsequent interactions among neighboring entities do not yield dependencies that could lead to their further self-organization.

Game of life (GoL) offers non-linear simulations of cellular automata scenarios in which populations of simple entities switch to dead or living states as generations progress. It was conceived by John H. Conway and furthered by Gardner's paper [8] in *Scientific American* [9], [10]. GoL has been used by scientists to model populations (e.g., growth, decay or blend scenarios), form different shapes (e.g., random blobs or recursive gliders), or simulate war zone tactics (e.g., predator prey) in many researches (e.g., [11]–[14]). Advances in ecology studies have led to modeling of existing ecosystems that can simulate complicated interactions and depict collective behavioral patterns. For instance, foraging ants trigger responses from surrounding ants by laying a pheromone trail (or chemical secretion) thereby leading the ant community to the food target [5]. Computational models can therefore assist us in unraveling behaviors of interacting organisms or study changes in ecosystems when some form of disturbance is introduced in interconnected environments.

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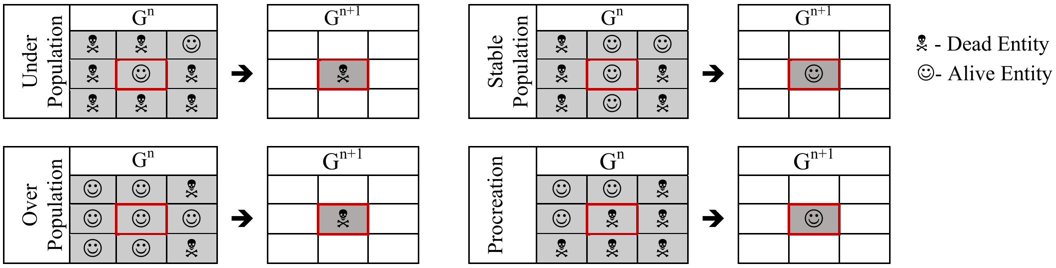


FIGURE 1. **GoL world rules.**

The topic of evolution continues to be a morass of contradictory and confusing assumptions [15] with equally strong agreements and dismissals over a myriad of probable explanations. Technologization of science (or technoscience) ties scientific content with technological applications [16] and can lead to new knowledge related to interactions in our epistemological terrain [17]. Technoscience is a creative process as a result of interdisciplinary collaborations between artists, scientists and engineers [18]. By using technoscience techniques, we can make assertions on laws of nature; however, in doing so, researchers must apply a balance between simplicity, parsimony and fitness of purpose [19]. Computational models can provide us a nature-driven technoscientific perspective and empower us to pose questions around population diversity, heredity, fitness, selection or behavior amongst others [20]. Moreover, digital technologies can provide different societal perspectives that have implications for policy and practice in areas of sciences and humanities [21]. In this study, we have combined social and environmental knowledge with computational knowledge to study population evolution scenarios. The offspring's gender preferences have been skewed to emulate preferences for a male child to illustrate a commonly known social problem that occurs in certain cultural groups.

Building on GoL strategies, we modeled ecosystems in which microscopic entities are given an additional gender attribute. GoL comprises vegetative entities confined to basic live and die states; however, we developed a gendered-GoL (g-GoL) that considers interactions among gendered entities. Our computational model demonstrates biological population evolution scenarios using male phenotypes and female phenotypes in an extended bounded space (or extended world). Rule-based automaton strategies defined in GoL have been leveraged to inform the g-GoL ecosystem. The following section briefly outlines the GoL rules that framed this study. Next, we describe the extended g-GoL rules for interactions among male phenotypes (M) and female phenotypes (F). Rich empirical data swarms simulated from g-GoL have been analyzed next to give a holistic picture of the new ecosystem. Data swarms generated from g-GoL have revealed how nature-driven phenomena can be altered with skewed gender ratios. Empirical data swarms hold much value in conducting analytic work such as pattern recognition and observation for enrichment of studies in humanities, social and natural sciences [22]. Therefore, by simulating artificial life contours as a consequence of gender imbalance, we can inform the technoscience community and policy makers on the long-term effects of non-egalitarian gender attitudes.

II. GAME OF LIFE

The GoL offers a simplistic simulation of how simple life patterns evolve over generations in a 2-dimensional grid. GoL rules are simple. Each entity can be in either of the 2 states: dead or alive in a particular generation (G^n). Its subsequent state transition in G^{n+1} depends upon states of the 8 adjacent entities in a bounded 3×3 matrix area (i.e., the entity's world). The 4 rules governing the entity's state transition from G^n to G^{n+1} are: (1) Under population: A living entity with less than two live neighbors dies in G^{n+1}, (2) Stable population: A living entity with two or three live neighbors lives on in G^{n+1}, (3) Over population: A living entity with more than three live neighbors dies in G^{n+1}, and (4) Procreation: A dead entity with exactly three live neighbors becomes alive in G^{n+1}. It should be noted, however, that GoL is not meant to be a realistic model, rather its purpose is to demonstrate degrees of flux in non-linear systems when simple entities self-organize dynamically according to some criteria [23]. Figure 1 demonstrates the four rules that apply to the central entity that is confined to a 3×3 matrix (world).

The under population rule applies when the central entity has few neighboring entities resulting in its subsequent death, or we could say it dies due to loneliness. The stable population rule reveals survival conditions for an entity to survive and live on to the next generation (G^{n+1}). The over population rule relates to a situation when an entity has too many neighboring entities; therefore, all entities could be fighting over limited resources resulting in its subsequent death in G^{n+1}. Finally, the procreation rule applies when optimal living conditions exist in G^n resulting in procreation and the birth of a new offspring in G^{n+1}.

The fate of each entity in G^{n+1} depends on the state of its 8 neighboring entities in G^n. Accordingly, entities may self-organize itself in G^{n+1} as alive or dead; although some dead entities may not affected by any of these rules and continue to remain dead in G^{n+1}. These dead entities are referred as quiescent entities. Thus, G^{n+1} entities have been derived from G^n, which in turn from G^{n-1} and so on. As each entity continues or flips its state in the next generation, the population density varies producing non-linear spatial patterns. The overall non-linear topological configurations resulting from

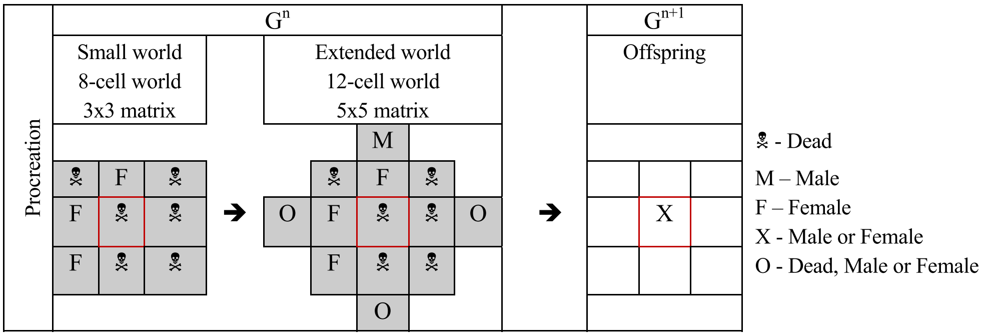


FIGURE 2. **g-GoL search in two worlds.**

entities' self-organization can demonstrate aspects of species dominance, equilibrium and extinction scenarios.

III. GENDERED GAME OF LIFE

Whilst GoL modeling is restricted to simple entities, this study extends simulations to ideas derived from population evolution in natural societies. Natural societies comprise observable entities having personal characteristics (e.g., shape, plumage, color, gender) that factor in for determining their very existence. Laws of nature state that future life forms evolve based on their predecessors' actions, for example procreation in natural societies is a result of male and female interaction. Life forms in g-GoL are gender based, and therefore local interaction between a male phenotype and a female phenotype is essential for creating a new life. In other words, existing neighborhoods in G^n must comprise both male (M) and female (F) entities for creating an offspring in G^{n+1}. The offspring's gender is randomly generated as either male or female (X). Further, the offspring in G^{n+1} will play a role in procreation of an offspring in G^{n+2} and so on.

The gender predominantly affects the procreation rule. This is because an offspring in G^{n+1} is created only if the G^n neighborhood exhibits a diverse phenotype domain (i.e., {M, F}). Therefore, while in GoL we could state with certainty that the fourth rule of procreation will lead to descendants in G^{n+1}, this statement does not hold true for g-GoL. An offspring will not be created in G^{n+1} if the surrounding 3 × 3 matrix comprise same gendered entities thereby limiting population evolution. To bring some parity across GoL and g-GoL, the procreation search is stretched to two steps. The first step comprises a smaller world search limited to 8 neighbors in a 3 × 3 world. If this search is unsuccessful, then in the second step, an extended world search comprising 12 neighbors is conducted. The smaller world search is conducted to identify exactly 3 living beings from the phenotype domain {X, M, F}. In the event of a successful search result, an offspring will be procreated in G^{n+1}. However, if the smaller search yields all 3 living beings to have the same gender (i.e., {F, F, F} or {M, M, M}), then an extended world search will commence. The aim of the extended search is to find a different gendered being from the 3 existing neighbors. The extended world includes 4 more grid locations. These grid locations are aligned horizontally and vertically to the searching entity in a 5 × 5 matrix. An offspring will be procreated in G^{n+1}, if at least one opposite gendered entity is found in these 4 cell locations.

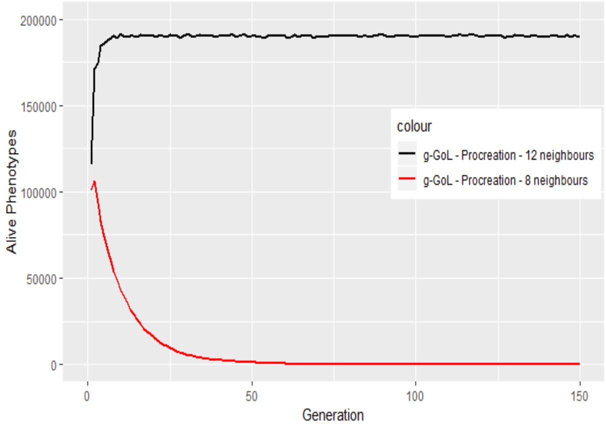


FIGURE 3. **Comparison of the number of alive entities in GoL versus g-GoL simulations.**

Figure 2 demonstrates the search process for g-GoL. As can be seen there are three female phenotypes in the 3 × 3 world. Therefore, an offspring will be procreated in G^{n+1} if there exists at least one male phenotype in the 4 outer cell positions (of the extended world).

During g-GoL simulations, we found the under population rule to influence evolution, with still-life coming to effect at around G^{60} unlike GoL where emergent life contours continued over many hundreds of generations. Consequently, if less than 2 neighbors exist in the 3 × 3 matrix, the under population rule was altered to take account of living neighbors in the extended world. With this change, the evolution patterns did not converge at G^{60}, rather the kaleidoscopic arrays were ongoing illustrating longer durations of interactions. Moreover, it can be further reasoned that the reach of each entity is now to 12 neighbors (and not mere 8 neighbors); therefore, the possibility of interactions among neighborhoods increases. Figure 3 shows the alive entities in small and extended world simulations.

Further, the gender preference of the offspring can be adjusted in our model. The default setting for the offspring's gender is random (X) with equal probability assigned for its occurrence as male or female. The revised evolution rules

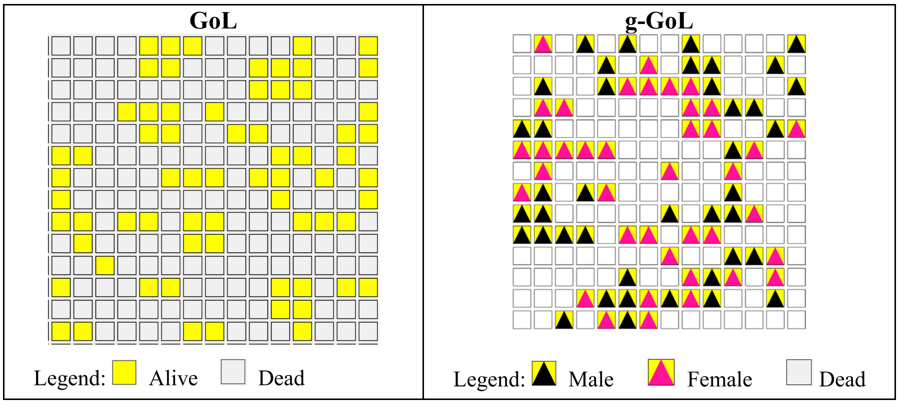
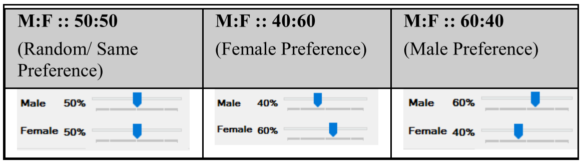


FIGURE 4. Topological configurations for GoL and g-GoL.



M:F :: 50:50 (Random/ Same Preference)	M:F :: 40:60 (Female Preference)	M:F :: 60:40 (Male Preference)
Male 50% Female 50%	Male 40% Female 60%	Male 60% Female 40%

FIGURE 5. Gender ratio variations for simulations.

with gendered entities affects the population density in G^{n+1}, and these changed population dynamics in turn affects the other rules (i.e., under, over and stable population).

IV. GoL VERSUS g-GoL

While GoL comprise entities in either dead or alive state with no other identifiable descriptors that can interact with 8 neighbors in a 3×3 world, g-GoL comprises entities with a gender descriptor ({M, F}) in an extended world that can interact with 12 neighbors in a 5×5 world. The gender introduction in g-GoL has led to projection of many population-based meta-heuristic experiences. This is because procreation may or may not occur for g-GoL in G^{n+1}. An offspring will not be created in G^{n+1} if the procreation rule identifies all male or all female phenotypes in the 12-cell search; although the probability for non-occurrence of an offspring is much reduced in the extended world. Figure 4 shows one topological configuration view for GoL and g-GoL.

A model is an estimation or an approximate representation to enable identification of a significant component that is "closest to the truth" [19]. McAllister cautions researchers to embrace a philosophical thinking stance while considering approximation errors as they make sense of the underlying message obtained from data [19]. Non-repeatability is another aspect since a subsequent simulation may not be able to reproduce every data point. The g-GoL simulations exhibit two random facets that affect repeatability. These are (1) random gender of the offspring phenotype (X), and (2) a small chance that procreation may not occur. Our stance on non-repeatability of data is that nature-driven life scenarios have a probability element attached to them, like the offspring's gender is unknown, or, that an offspring may not be born due to infertility of either parent or an offspring is aborted in the event of a miscarriage; hence, the trade-off is considered acceptable. Moreover, we did not observe frequent convergence scenarios (or end-of-life scenarios), rather we observed ongoing kaleidoscopic arrays over many hundreds of generations in g-GoL.

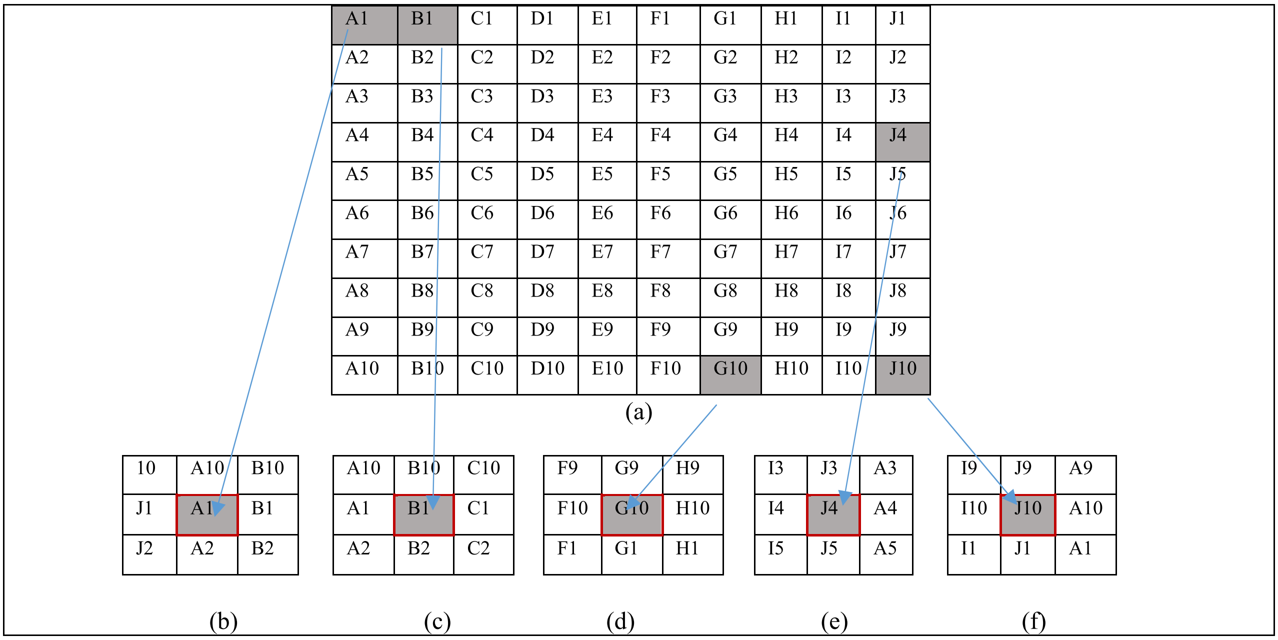
Finally, we conclude that while GoL focusses on simple rules for procreation, the g-GoL's focus is on partner-based evolution rules for procreation. The higher interdependence between living neighbors in g-GoL has more context since it is partner-based and is motivated by nature-driven rules; therefore, we affirm that g-GoL can provide us with many dynamic representations and evolutionary patterns of emerging ecosystems.

V. MODEL DESCRIPTION

A model is often the first step in formulating any empirical law of nature, since uncovering any regularity from the dataset originating from the model are done prior to making any explanatory hypothesis [19]. We followed this approach to computationally create very large datasets aligned with extended rules for procreation for advancement of gendered species over long time-spans. An artificial life computational program lens has been combined with the cultural notion of gender diversity to uncover scenarios that can inform philosophical and computational researchers on long-term effects of gender imbalance.

Our model can be set with an initial population size. For example, if the population size is set at 40% in a 10 × 10 matrix (that has 100 cell positions), the resultant structure would have 40 alive entities at the G^0 stage. The default setting for offspring's gender is random (i.e., an offspring has equal chance of being male or female). Further, programmatic settings to alter the gender ratio are provided. Figure 5 illustrates how skewed gender ratios can be simulated.

To simulate continuous population evolution scenarios with GoL and g-GoL, an unbroken 2-dimesional lattice structure was created by applying vertical and horizontal folds. A vertical fold for a 10 × 10 matrix (Figure 6(a)) implies that the top left cell or A1 is the neighbor of J1, A2 is the neighbor of J2, and A3 is the neighbor of J3, and so on. Similarly, a



A1	B1	C1	D1	E1	F1	G1	H1	I1	J1
A2	B2	C2	D2	E2	F2	G2	H2	I2	J2
A3	B3	C3	D3	E3	F3	G3	H3	I3	J3
A4	B4	C4	D4	E4	F4	G4	H4	I4	J4
A5	B5	C5	D5	E5	F5	G5	H5	I5	J5
A6	B6	C6	D6	E6	F6	G6	H6	I6	J6
A7	B7	C7	D7	E7	F7	G7	H7	I7	J7
A8	B8	C8	D8	E8	F8	G8	H8	I8	J8
A9	B9	C9	D9	E9	F9	G9	H9	I9	J9
A10	B10	C10	D10	E10	F10	G10	H10	I10	J10

(a)

10	A10	B10
J1	A1	B1
J2	A2	B2

(b)

A10	B10	C10
A1	B1	C1
A2	B2	C2

(c)

F9	G9	H9
F10	G10	H10
F1	G1	H1

(d)

I3	J3	A3
I4	J4	A4
I5	J5	A5

(e)

I9	J9	A9
I10	J10	A10
I1	J1	A1

(f)

FIGURE 6. Continuous 2D matrix structure.

horizontal fold implies that A1 is also the neighbor of A10, B1 is the neighbor of B10, C1 is the neighbor of C10 and so on. Figure 6(b) illustrates A1 as the center of 3 × 3 matrix structure having 8 neighbors J10, J1, J2, A10, A2, B10, B1 and B2. Likewise, Figure 6(c) illustrates B1 and its 8 neighbors, 6(d) illustrates G10 and its 8 neighbors, 6(e) illustrates J4 and its 8 neighbors and 6(f) illustrates J10 with its 8 neighbors.

VI. EMPIRICAL DATA COLLECTION FROM g-GoL

Large-scale datasets simulated *en masse* can render spatial patterns to help develop awareness of objects from large repositories with the hope of serendipitous discoveries [22]. Our proposition too is to demonstrate how male phenotypes and female phenotypes generated *en masse* in various artificial life scenarios can help develop cognition in unforeseen ways. An empirical dataset can provide evidence of multiple phenomena since multiple patterns can be exhibited in the data; hence, each pattern corresponds to some hypothesized case or phenomena of science [19] and is a legitimate object of investigation by social or computational scientists.

To make statistically significant contributions, the simulations were conducted over a 1000 × 1000 grid, thereby constituting 1 million grid locations. Male phenotypes and female phenotypes were randomly spawned on the grid. Since the initial generation step (G^0) had no predecessor, therefore, the rules came into effect in G^1. Hence, G^1 shows a different population size from the starting point G^0. The dataset for analytic purposes has therefore been considered from G^1. The first experiment considered population evolution scenarios and impact of the four rules on the overall population under default settings. The gender attribute was not considered here, rather we looked at the overall population dynamics only. The second experiment deliberated on evolving populations by focusing on varying gender preferences. The following subsections elaborates on both experiments.

A. POPULATION EVOLUTION SCENARIOS WITH DEFAULT SETTINGS

This section gives an overview of population evolution scenarios related to g-GoL. Population evolution experiments were designed with equal percentages of alive population (i.e., 50%) at the G^0 stage. Also, the default setting for gender preference (i.e., equal probability for occurrence of male and female offspring) has been selected. After five generations (i.e., G^5), the experiments showed steady populations, that is, no major fluctuations in total living or dead populations were observed. With equal gender preferences, the number of males and females were more or less equal; although with ongoing interactions in extended world settings, their grid locations were changing to reveal emergent life contours. Figure 7 illustrates the g-GoL simulations. It should be noted however, that the graphs indicate only the number of alive/dead entities, and does not disclose the changing patterns. So, if the species number remains same despite a changing pattern, this will not be detected in Figure 7.

B. SKEWED GENDER POPULATION EVOLUTION SCENARIOS

This section has isolated the study to include the gender feature only, so as to provide a family of graphs that can provide some population estimates for skewed gender ratios. Globally, males are produced approximately 3% in excess [24]. We know that some countries have age-old cultural preferences for male child or may have a one-child policy [25], [26], which has led to practices like infanticide or selective abortion.

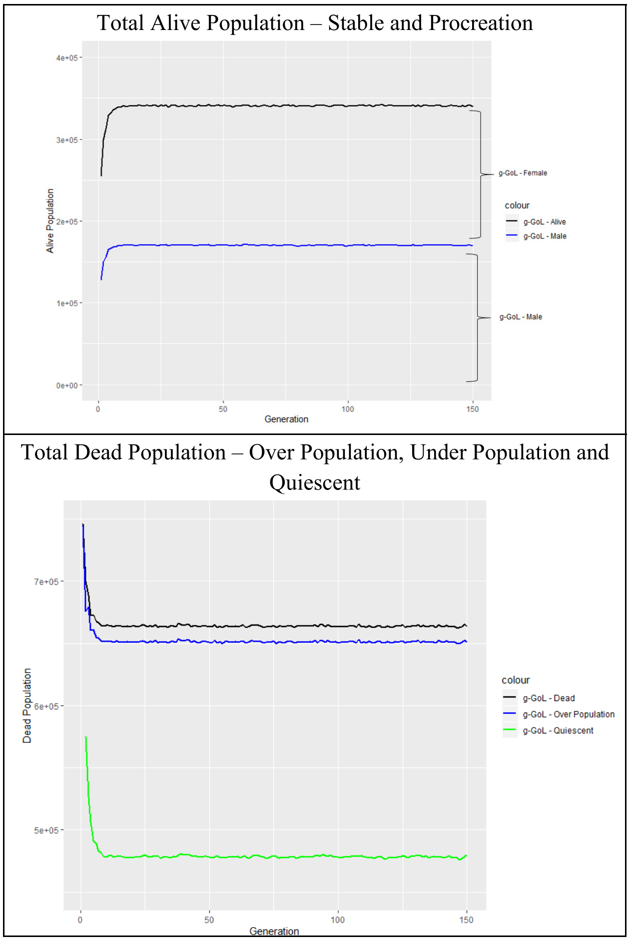


FIGURE 7. **Population evolution scenarios in g-GoL from G^1 to G^{150}(Population size at $G^0 = 500,000$ and at $G^5 = 331,977$).**

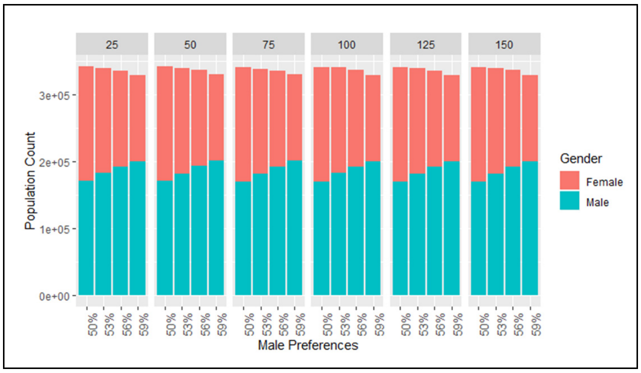


FIGURE 8. **Population scenarios at G^{25}, G^{50}, G^{75}, G^{100}, G^{125} and G^{1501} with differing gender ratios. $G^0 = 500,000$.**

Using g-GoL, we conducted simulations with variations in male gender preferences. To produce a single model for generating datasets, the initial population map used at G^0 in the 1000 × 1000 grid was same and comprised population size of 50% (or 500,000 phenotypes) with equal number of males and females. Subsequent generations (G^1 to G^{150}) were simulated by varying the offspring's gender preference. The starting map at G^0 was kept same for all simulations. Figure 8 shows population evolution scenarios at G^{25}, G^{50}, G^{75}, G^{100}, G^{125} and G^{150} with different male preferences. As can be seen that although total population count is more or less same, but female populations are reduced with progression of generations.

Figure 8 shows total male population versus total female population with equal and skewed gender ratio settings (i.e., 53%, 56% and 59% settings for male preference). When the gender ratio is random (i.e., male and female phenotypes have equal preference), the male and female phenotype population are same. But as the males are given more preference, the number of females reduce.

VII. DISCUSSION

An empirical dataset can reveal multiple phenomena depending upon the assumptions and the questions being asked from the data. Topological-centric terrains have long been embedded in ecological thinking, even if it is deficient of rigorous mathematical consideration [27]. The assumption here is that emerging topological patterns from g-GoL (with male and female phenotypes interactions in extended world settings) reflect gender-based nature-driven societal population evolution scenarios. Further, we wanted to know if these empirical patterns could help in drawing parallels with natural habitats. Picking a robust pattern which is closest to the truth is the key to answering the question. In doing so, we have considered convergence or closure when the pattern continued to be static in subsequent steps, or, when the pattern repeated itself (with minor changes) after a certain number of generation steps. A dynamically changing pattern implies evolutionary changes; therefore, pattern convergence has been hypothesized to still-life (static patterns) or pseudo-objects (repeating patterns) in our demonstration of nature-driven societal dynamics.

Experimentation showed that addition of gender attribute restricted procreation and affected the population numbers. Ecological interactions between gendered phenotypes involves selective pressures in simulating their lives and procreation over rugged landscapes (or localities) which impacts the overall population dynamics [28]. Gendered species are more susceptible to extinction (or, in our case convergence); therefore, we extended their interaction world and altered the procreation and under population rules. The search for a mating partner continued in the extended world for procreation and for a companion or friend in the under population rule. Our simulations with these two changed rules showed ongoing kaleidoscopic patterns over many hundreds of generations (similar to game of life simulations). To avoid convergence scenarios due to skewed gender ratios, the world size of each entity was increased; consequently, many generation progressions were witnessed before patterns converged to some end-of-life shape.

A United Nations report has identified global trends for male preferences as 52.5% in more developed countries (Europe, North America, Australia, New Zealand and Japan), 54.5% in less developed countries (some regions of Africa, Asia (except Japan), Latin America and most of the Caribbean region) and 52% in least developed countries (34 counties in Africa, 9 in Asia, 5 in Oceania, 1 in Latin America and 1 in Caribbean) [24]. Their study noted more unbalanced ratios are from Asian ethnicities who have more patriarchal societies, and where termination of female foetuses is a far commoner occurrence than of males. Ongoing female birth deficits has resulted in a wake-up call and many countries have now banned sex selective abortions [29]. Our empirical dataset has demonstrated the impact of skewed gender ratios to population scenarios. Gender preferences have an impact on the overall male to female ratio. A dwindling population combined with a skewed gender ratio results in non-egalitarian societal structures. Currently, the male population worldwide is 3% more than the female population [24]. If this trend continues, the likelihood of having a future ''world without women'' is not far away [30], which in turn could have serious ramifications on social harmony and family structures. Social programs are needed to change patriarchal attitudes to help avoid an epidemic crisis if trends for distorted gender ratios continue. It is indeed a wake-up call and time to take heed of the Nobel Prize awardee Amartya Sen's cautionary article that highlights the ''missing women'' published almost three decades earlier [31], [32], otherwise population specialists will deal with ongoing ''fertility crisis'' situations [30]. This is a pertinent time to debate on the issue of surplus men compared to the number of women, and consider the impact of non-egalitarian attitudes to future societal structures.

VIII. CONCLUDING REMARKS

This study has offered a simple proof-of-concept on non-linear simulations with male/female phenotypes. Ecological knowledge is incomplete, empirical, fuzzy, sparse and non-formal [33]. Computer-based simulations can make this knowledge more explicit. Visual illustrations increase the scope of collaboration between cognitive and behavioral scientists and computational scientists [19]. Model simulations can enable visual reasoning capabilities by creating different projections of some known phenomenon and bring social scientists, physicists, biologists and technologists on a more common platform. However, simulation-based environments are built for specific environments and may not be able to visually formulate detailed elements of the real world phenomena. Real world comprise of family structures that include father, mother and children, Partner preferences may be based upon age, race or religion amongst others. Procreation can result in birth of more than one offspring, such as twins or triplets.

But use of modeling techniques can structure one's thinking, especially in learning environments. For instance, students can be made to realize ecosystem changes across different environments without bogging them down with detailed mathematical concepts [34]. Also, visuals empower people to voice their thoughts and reflect on the knowledge representation [35].

Population evolution scenarios have been demonstrated using simple algorithmic automaton extensions. Simulations that can be applied to natural societies and in the study of real world issues have been conducted. Using continuous strategy-based interactions, we have demonstrated how population dynamics are built or suppressed. Entities residing in natural societies have personal characteristics, which affect their interactions within their localities. And as societies evolve, individuals build on the ecological properties of their predecessors. Societies may reach a critical state (or converge) where they cannot self-sustain if we interfere in social issues like gender preferences. Moreover, inequity in gender preferences has alarming social impact. For instance, sex-selective abortions, foeticide, poor health and nutritional discrimination leading to increased mortality are some of the negative social manifestations that affect the female population [36], [37]. A variety of reasons related to economic, social, religious or emotional needs play into this non-egalitarian attitude, which are reinforced by low literacy and unemployment. Social change intervention reform programs from policy makers will help promote gender equitable attitudes and address these underlying age-old cultural preference for males.

Research in social sciences often pertains to understanding multiple patterns and relating them to real world situations. Social scientists often use multilevel statistical tools to deal with datasets showing patterns at different scales [38]. Individual patterns in data can be adduced to analytic problems for theory building scenarios in social research. Social scientists and computational scientists have long struggled to overcome the boundary problem and bridge the gap between their subject ideologies and interests [39], [40].

Computational modeling of evolutionary aspects can lead to technoscientific artefacts which can be leveraged by scholars to pose philosophical questions on behavioral, sociocultural or environmental issues [1]. Such models can provide a tool for artificial life scenarios; for instance, in this study we have provided a long term view on population evolution changes resulting from skewed gender ratios. The ''social shaping of technology'' can strengthen new areas of inquiry in multidisciplinary research, policy and practice [21] (p. 177). We hope our socio-technoscientific research has highlighted the long-term practice of non-egalitarian gender preferences and will assist in addressing current gender imbalances by defining some policy inspiration strategies.

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