Is Geb Indefinitely Scalable?

Alastair Channon[1]

[1]School of Computing and Mathematics
Keele University
a.d.channon@keele.ac.uk

Abstract

This work aims to answer two related questions: can a (possibly) open-ended evolution (OEE) system such as Geb generate an unbounded increase in maximal individual complexity? and is diversity in Geb indefinitely scalable?

Considering the relationship between diversity and complexity leads to the general idea that complexity at one level of analysis can be considered as the diversity of components at the level(s) below. Thus the two questions reduce to one.

The notion of unbounded diversity is criticised for finite systems (including nature), and Ackley's concept of indefinite scalability is employed to give a more precise notion for this.

Indefinite scalability in maximum individual complexity (which would imply indefinite scalability in diversity) is tested for in Geb by varying two parameters: the hard-coded limit on the number of neurons an individual can have, and world length, which gives a bound (length squared) on population size.

The results show maximum individual complexity to be asymptotically bounded when scaling the maximum number of neurons per individual alone but indicate that it may be indefinitely scalable when scaling both the maximum number of neurons per individual and world length together. However, this is not yet a clear finding, and results when scaling world length alone indicate that there may be a general problem of false positives from this approach. Further analysis is needed.

Diversity and Complexity

One of the most interesting questions that OEE systems can address is whether or not OEE can be the cause of an unbounded increase in maximal individual (or group or system) complexity. This, of course, requires a definition of complexity.

One unsatisfactory general measure of complexity is the number of components in an entity. A more satisfactory genearl measure of complexity is the number of different components, sometimes referred to as the diversity of components. The number of different components is still not a very satisfactory measure of complexity, just as it is not a very satisfactory measure of diversity, but this does lead us toward the general idea that complexity at one level of analysis (e.g. individual; species; or system) can be considered as the diversity of components at the level(s) below (e.g. genes; genes or individuals; genes or individuals or species). The same desirable tweaks to discount redundancy (e.g. to count only adaptive components, measure information content, …), and to include behaviours and interactions as well as artifacts, apply to both.

Unbounded Diversity???

In Bedau et al.'s classification of long-term evolutionary dynamics, the class of systems with unbounded evolutionary dynamics is divided into subclasses: (a) those with unbounded diversity of components but bounded adaptive success (cumulative evolutionary activity, based on adaptive persistence) per component; (b) those with bounded diversity but unbounded adaptive success per component; and (c) those with unbounded diversity and unbounded adaptive success per component.

Yet, while adaptive success per component can be truly unbounded (if measured based on adaptive persistence and over unbounded time), the diversity of adaptive components (both the number of different components per entity and the diversity of entities) is necessarily bounded: in artificial systems by unavoidable physical limits such as computer memory, and in nature (whether considering the biosphere or the Universe) again by physical limits such as number of atoms. A claim of unbounded diversity in the biosphere is really a claim that diversity is not practically bounded, or that it has not reached the upper bound yet. A more precise notion than "unbounded" diversity (of entities or of adaptive components per entity) is needed.

Indefinite Scalability

Ackley's concept of *indefinite scalability*, "defined as supporting open-ended computational growth without requiring substantial re-engineering" (Ackley 2014) now enables us to address this. The key criteria for indefinite scalability is that should an upper bound be reached, increasing the values of physical limitations (such as available matter, population size or memory) should enable an unbounded sequence of greater upper bounds to be achieved (after sufficient increases in the limitations); in the case of diversity, of greater upper bounds on diversity.

However, it is not possible (in finite system time) to establish that a metric (for example a measure of adaptive success per component) is truly unbounded. And it is not possible (over a finite number of increases in system parameter(s)) to establish that a metric (for example a measure of diversity) is truly indefinitely scalable. Further, an increase in parameter(s) may require a longer system (run) time before a greater scale (higher value metric) is achieved. Claims about systems can, though, be expressed and evaluated in terms such as a metric (for example a measure of adaptive success per component) increasing apparently without bound *up to* a certain system time (or number of generations, etc.); or a metric (e.g. diversity) increasing *up to* certain value(s) of system parameter(s) being reached, where it was necessary to increase these to establish increases in scale (e.g. of diversity) over successive runs.

Testing for indefinite scalability in Geb

This work investigates whether or not the maximum complexity of an individual is indefinitely scalable in Geb (Channon 2001, 2003, 2006), where an individual's complexity is measured as the diversity of components in it. Note that if the diversity of components in an individual is indefinitely scalable, then so is the diversity of components in the system, so the questions of which subclass (a, b or c) Geb is in is also being addressed.

As in previous work analysing Geb's long-term evolutionary dynamics, a component is, in loose terms, an active gene: a gene involved in the agent's neural development; see (Channon 2006) for details. So, here, an individual's complexity is measured as the number of different genes involved in its neural development.

Two parameters cause diversity to be bounded in Geb: 1. a hard-coded limit on the maximum number of neurons an agent can have; and 2. the 2D world's length L, as there can be at most L^2 individuals in the population at any one time. These are the two parameters that are scaled. 20 runs were carried out for each combination (value pair) of these parameters, and the average (over 20 runs) maximum individual complexity recorded and graphed using a running average of length 1000 to reveal underlying trends.

Results and Conclusions

Maximum individual complexity appears to be asymptotic when scaling (just) the maximum number of neurons per individual (figure 1).

Maximum individual complexity *appears* to be indefinitely scalable when scaling (just) world length (figure 2) *but* only above some threshold for the maximum number of neurons per individual, not below it; this indicates that the scalability will not in fact be indefinite. This raises the question of whether or not there is a general problem of false positives from the approach.

There is some indication (figure 3) that maximum individual complexity may be indefinitely scalable: when scaling both the maximum number of neurons per individual and world length together, this appears to be the case. If this is true, the only bounds to complexity and diversity would be time and computer memory (similarly to nature) and Geb would be in subclass c. However, this is not yet a clear finding; further analysis is needed.

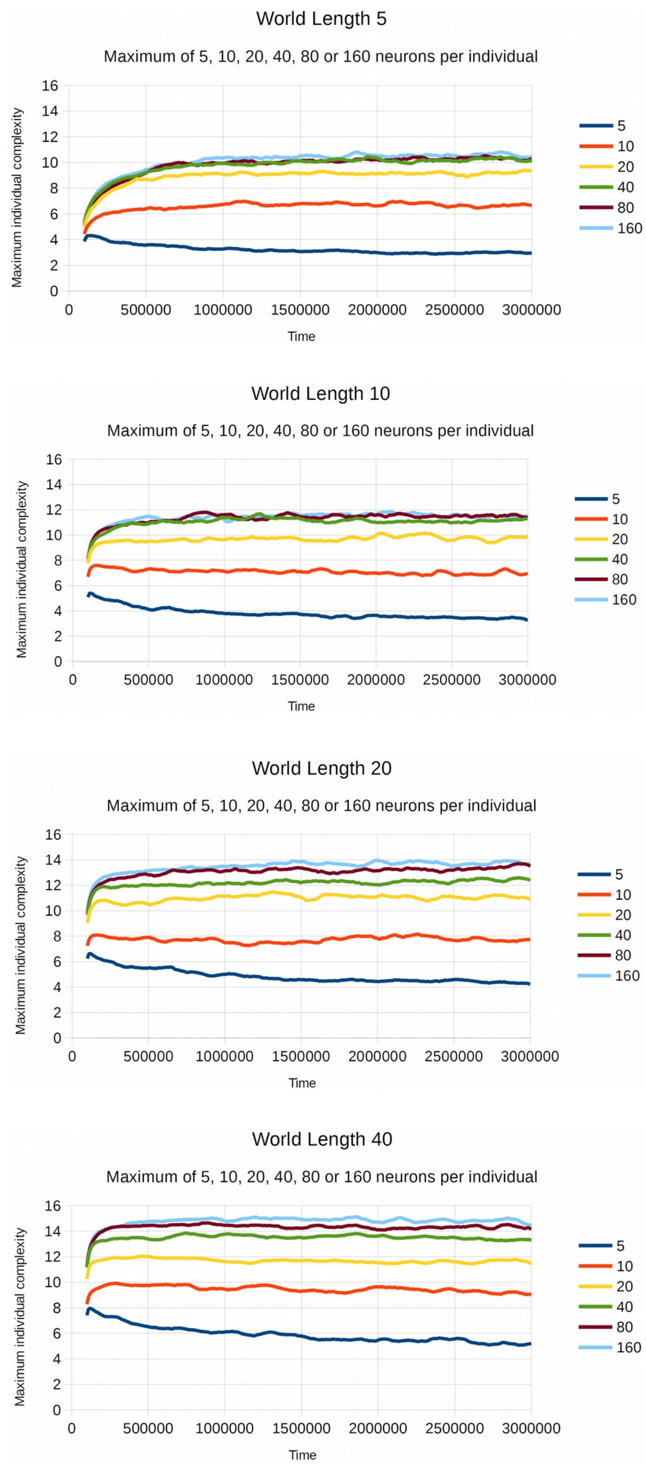

Figure 1: **Results when scaling the maximum number of neurons per individual (at different world lengths).**

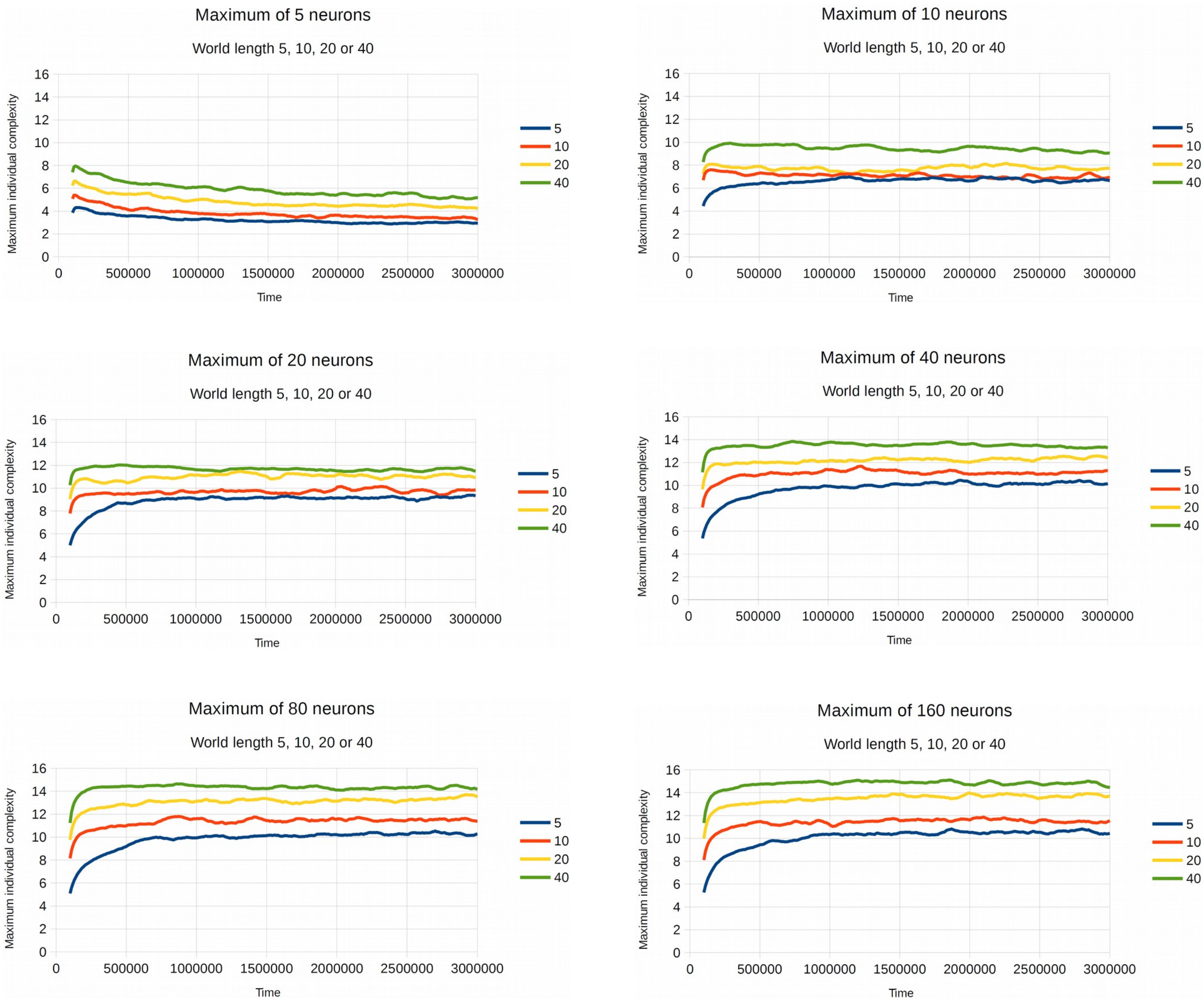

Figure 2: **Results when scaling world length (at different maximum number of neurons per individual).**

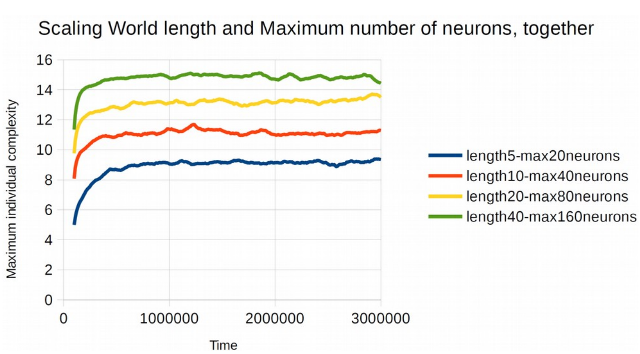

Figure 3: **Results when Scaling both world length and maximum number of neurons per individual, together.**

References

Ackley, D. H. and Small, T. R. (2014). Indefinitely scalable computing = artificial life engineering. In *Artificial Life XIV*, pages 606–613, MIT Press.

Bedau, M. A., Snyder, E. and Packard, N. H. (1998). A classification of long-term evolutionary dynamics. In *Artificial Life VI*, pages 228–237, MIT Press.

Channon, A. D. (2001). Passing the ALife test: Activity statistics classify evolution in Geb as unbounded. In *Advances in Artificial Life: Proceedings of the Sixth European Conference on Artificial Life*, pages 417–426, Springer-Verlag.

Channon, A. (2003). Improving and still passing the ALife test: Component-normalised activity statistics classify evolution in Geb as unbounded. In Artificial Life VIII. pages 173–181, MIT Press.

Channon, A. (2006). Unbounded evolutionary dynamics in a system of agents that actively process and transform their environment. *Genetic Programming and Evolvable Machines*, 7:253–281.