

# Network Farming for the Analysis of Complex Network Systems

## Extended Abstract — 22 July 2004

Anthony Dekker, DSAD, DSTO ([dekker@acm.org](mailto:dekker@acm.org))

Many Complex Adaptive Systems have the form of a **network**, and understanding such systems requires network-aware analysis techniques (Carling & Carlsen 2002). In this paper, we describe one such technique, which we call **network farming**. We will describe a number of applications of this technique to organisational (Dekker 2003) and technical (Dekker & Colbert 2004) systems.

A powerful technique for exploring complex systems is **data farming**, developed by Gary Horne (Horne 1997, Brandstein & Horne 1998). Data farming studies a complex parameterised process  $P(x_1, \dots, x_n)$ . Data farming was developed for the US Marine Corps, and hence the parameters  $x_1, \dots, x_n$  originally referred to such technical and social variables as vehicle speed or morale. The process  $P(x_1, \dots, x_n)$  is simulated by a computer model (often agent-based, and with a random component), and experiments are conducted by running the model  $P(x_1, \dots, x_n)$  with some parameters fixed ( $x_i = a_i$ ) and some parameters varying across a range ( $b_j \leq x_j \leq c_j$ ). As these experiments are repeated, an overall perspective of process behaviour can be obtained by **zooming out**, i.e. varying more parameters, over wider ranges  $b_j \dots c_j$ , but for fewer values in those ranges. A more detailed understanding of particular parameter ranges of interest can be obtained by **zooming in**, i.e. varying fewer parameters, over narrower ranges  $b_j \dots c_j$ , with more values in those ranges. Zooming in also requires more iterations of the simulation in order to average out any random factors and better understand the landscape of possibilities. The understanding obtained by zooming in can then be discussed with domain experts and applied to other experimental or analytical strategies. This will in turn suggest other parameter ranges of interest that might be explored.

A key aspect of data farming is visualisation and analysis of the data produced. In the case where we are varying only two parameters and measuring only one output (performance) variable, a **fitness landscape** provides a useful way to visualise average behaviour, as shown in Figure 1.

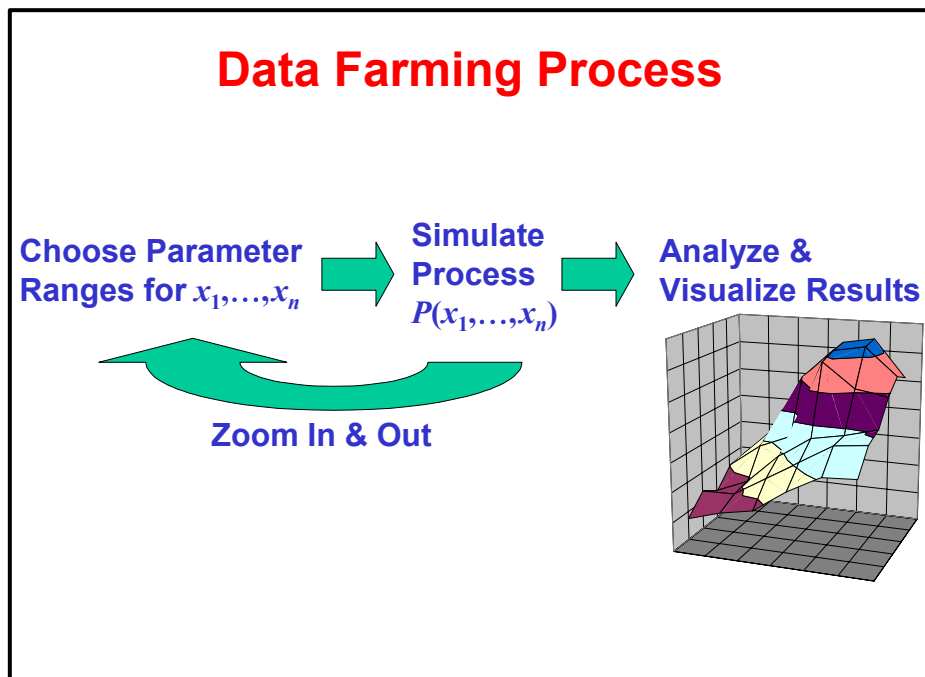


Figure 1: Data Farming

In order to study network-based processes, we have developed an extension of data farming which we call **network farming**. In network farming, the process  $P(N, x_1, \dots, x_n)$  which we are studying is

parameterised not only on a list of numbers  $x_1, \dots, x_n$ , but also on a particular network topology  $N$ . Examples of such parameterised processes include the performance of a network in combat (as studied by NCW-enabled agent-based models) or of a network in the face of terrorist attack.

In order to study the process  $P(N, x_1, \dots, x_n)$ , we must generate a large list of different networks  $N$ , as well as choosing values or ranges for the other parameters  $x_1, \dots, x_n$ . This generation process may involve a pre-existing library of different networks and/or the use of various random graph generation approaches (Bollobás 2001). We then simulate the process using the different networks and parameter values.

For the purpose of analysis, we derive various numerical **metrics**  $M_1(N), \dots, M_m(N)$  for each network  $N$ , such as node connectivity and average degree (Dekker & Colbert 2004). We can then use the same visualisation and analysis techniques that data farming uses, in order to see how performance varies with the numbers  $x_1, \dots, x_n, M_1(N), \dots, M_m(N)$ . However, it is important to verify that the distribution of values for the metrics  $M_i(N)$  is not so irregular as to give deceptive results. Figure 2 illustrates the process of network farming.

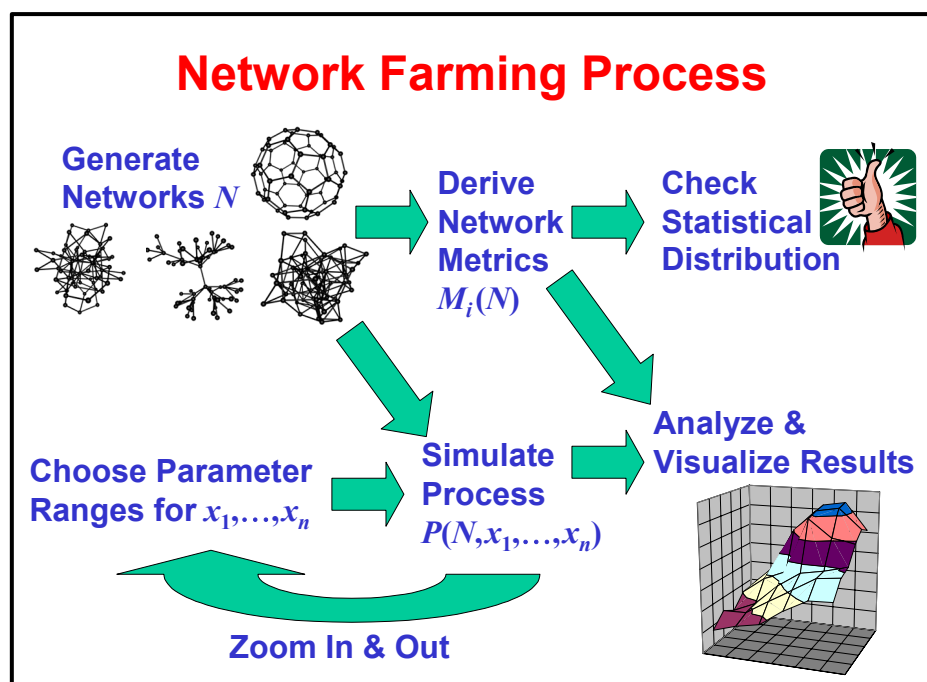


Figure 2: Network Farming

## References

- Béla Bollobás (2001), *Random Graphs*, 2nd edition, Cambridge University Press, 2001.
- Alfred G. Brandstein & Gary E. Horne (1998), "Data Farming: A Meta-technique for Research in the 21st Century," *Maneuver Warfare Science 1998*, US Marine Corps Combat Development Command Publication. Available at [http://www.mewl.quantico.usmc.mil/divisions/albert/research/documents/data\\_farming.rtf](http://www.mewl.quantico.usmc.mil/divisions/albert/research/documents/data_farming.rtf)
- Christian Carling & Henrik Carlsen (2002), "Project Metanet: Methods for Analysis of Complex Networks," *Proceedings of the 7th International Command and Control Research and Technology Symposium*, Quebec, Canada, September. Available at [http://www.dodccrp.org/events/2002/7th\\_ICCRTS/Tracks/pdf/040.pdf](http://www.dodccrp.org/events/2002/7th_ICCRTS/Tracks/pdf/040.pdf)
- Anthony Dekker (2003) "Using Agent-Based Modelling to Study Organisational Performance and Cultural Differences," *Proc. MODSIM 2003 International Congress on Modelling and Simulation*, Townsville, Queensland, pp 1793-1798. Available at <http://mssanz.org.au/modsim03/Media/Articles/Vol 4 Articles/1793-1798.pdf>
- Anthony Dekker & Bernard Colbert (2004) "Network Robustness and Graph Topology," *Proc. 27th Australasian Computer Science Conference*, Conferences in Research and Practice in Information Technology vol. 26, V. Estivill-Castro, ed, Dunedin, New Zealand. Available at <http://crpit.com/confpapers/CRPITV26Dekker.pdf>
- Gary E. Horne (1997), "Data Farming: A Meta-technique for Research on 21st Century Questions," briefing presented at the US Naval War College, Newport, Rhode Island, November.