FARMERS FIRST?
Towards a neural network perspective on farmer seed systems

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Introduction

"Farmer first" seems at times to make unreasonable claims for the scope of farmer knowledge. This allows the experts back in, on expert terms. The problem (this paper argues) is adoption of the wrong model of cognition and learning. Farmer knowledge is not "in head" but distributed across a working environment (i.e. it belongs to a network of social interactions). The recent development of methods by anthropologists for studying experiential learning and distributed cognition, in fulfilment of a programme first envisaged by Durkheim, Vygotsky and others, and the absorption of this socially distributed approach into artificial intelligence research (e.g. in artificial neural network modelling) offers (it is suggested) an appropriate framework through which the skills and knowledge of farmers and researchers can be treated on level terms, thus settling a troubling argument that has held back the development of the "farmer first" paradigm.

Knowledge networks

One of the pioneers of recent developments in distributed cognition notes that psychologists – in appropriating cognitive studies at an early stage – imposed a self-denying ordinance (Hutchins 2002). They decided to keep cognition "in head" to make it more tractable to study by available psychological means. This shut out, for example, the promising programme of social cognitive studies implicit in the work of Durkheim and his school (e.g. the fixing of collective representations through alignment of emotions in ritual events). Equally frustratingly, Vygotsky's social psychology, based on the notion that learning is the internalisation of group norms, only spread outside the Soviet Union several decades after his death (from TB) in the 1930s.

Consequently, mainstream approaches still stress the brain as the cognising tool, and the individual as the seat of learning. This viewpoint was further entrenched by the success of brain/computer analogies. We live in a (machine) world in which it is widely presumed that computers require "brains" (central processors) to be able to compute.

The 1980s saw the development of a new approach, focused on "experiential learning" (Chaiklin and Lave 1993). A landmark was a study by Jean Lave on supermarket shoppers. Lave (1988) demonstrated that shoppers could undertake calculations in practice that they could not handle as formal operations in a class room. Her point was that calculation involved more than mental operations. Shoppers were computing through the way their bodies engaged with a familiar environment. The approach can be traced back to Marcel Mauss, who grounded anthropological studies of technology in "techniques of the body" (Schlanger 2006).

Edwin Hutchins then published his path-breaking monograph on navigational practices, *Cognition in the wild* (Hutchins 1995), explicitly seeking to revive the social approach to cognition. The book begins with a review of Polynesian navigation (in which the direction finding means is the canoeist's body in relation to a starscape and imagined horizon) and continues with a technographic account of how the knowledge necessary safely to direct a US naval warship during "sea and anchor" navigation results from the work not of individual cognising agents but from the interactions of a team. This brought cognition out into the open (as it were). Positional knowledge (it became clear) was the product of team work. No single member of the team held a complete picture, and yet so long as the team did its work the ship sailed safely.

Paralleling these developments, computer scientists began to question Turing's brain/computer analogy (Whitby 1997) and rediscovered the potential of network computational devices (artificial neural networks, ANN). In ANN there is no single "central processor" with an overview of the task, issuing sequential commands. Memory and knowledge are properties of the system as a whole, not of specialised modules within the system, as in conventional computers (Picton 2000).

ANN typically involve high levels of interconnection and feedback. The passage of traffic (electronic signals and so forth) in ANN depends on the frequency with which different interconnections are activated. Memory and other "cognitive" functions such as pattern recognition or categorization arise from the way nodes become weighted by use (or lack of use) – so-called "Hebbian learning" (Hebb 1949). Some networks can be "primed" to recognise patterns (i.e. they are taught); others achieve pattern recognition through stochastic processes (Hopfield 1982). This distinction between supervised and unsupervised learning is conceptually useful (I shall suggest below) in re-addressing our central problem of what it is that "farmers" and "researchers" know.

A seed system example[1]

The remainder of this paper discusses how we might apply some of the insights of experiential learning, distributed cognition and neural network computation to issues of "farmer first" knowledge. To keep things short, as required by the organisers, I offer a sketch of how knowledge states in farmer seed systems might be modelled, referenced to West African materials.

(i) What is a seed system?

Crop farming requires planting material (seeds etc). In West Africa the earliest seeds of indigenous crops (millet, Digitaria, African Rice, cow pea etc) were collected from the wild. Over many generations seed types were modified by repeated selection, e.g. types prone reduced shattering began to dominate (Fuller 2005). These were true cultivars (i.e. types dependent on human management). Existence of cultivars implies conscious human strategies to retain, maintain and distribute seed for planting (i.e. local seed systems developed). Such systems are crop specific (e.g. vegetatively propagated crops such as yam require different systems from grains, such as African Rice.

Seed systems for indigenous cultivars typically involved links with wild gene pools. Even today wild and weedy rice varieties are found flowering alongside cultivars in local rice farms, and some proportion of farmers engage in the periodic re-domestication of wild and feral yam types. Local practices of seed selection, storage and distribution are known for specific crops and agronomic contexts (Richards 1986, Jusu 2000, Nuijten 2005). Less is known about longer-term temporal and regional dynamics, e.g. the impact of major dislocative events including war, drought and climatic change, and how far and through what means seeds diffuse across regions (but cf. Nuijten 2005). This is because attention to the relevant materials has been sporadic rather than systematic. Gene bank collections are partial, and only rarely have accessions been fully documented in terms of social and agronomic contexts. West Africa is one of the world's most linguistically diverse regions and it is unclear (in the absence of genomic characterization) whether different variety names reflect genetic difference or mask similarity of types under a wide variety of synonyms.

In some cases markets became important elements in local and regional seed systems, but more generally small-scale West African farmers remain significantly dependent on local informal modalities of seed acquisition. For planting, supply from the previous year's farm remains the dominant source in many areas, supplemented by loans-in-kind from merchants or better-supplied farmers. Local seed systems have a second important aspect – experimentation (Richards 1986). Experimentation with unfamiliar seed types is common. Farmers typically beg, borrow or are given small amounts of seed they assess for suitability in their own farming conditions. Women are very active in this area, and much material passes through informal kinship or friendship channels. Some is acquired through natural or accidental processes of seed dissemination (e.g. wind or water, or activities of birds and grazing mammals). Other items are "borrowed" from research sources.[2]

[1] This section draws on an article in preparation "Seed systems for African food security" (Richards et al. 2007)
[2] The links between research stations and local farmers include the fact that many labourers on experimental sites are also local farmers. They quietly acquire interesting materials, sometimes developing items that researchers discarded.

A full description of the functioning of, and knowledge states within West African seed systems would require account to be taken, therefore, of a range of seed acquisition strategies and distribution processes, including on-farm selection and retention strategies, seed loans, market acquisition and local and scientific experimentation. Seed systems thus assume complex network forms. Attempts to attain planned outcomes (e.g. widespread adoption of a few superior seed types) tend to founder on this complexity.

(ii) Modelling distributed knowledge states by ANN

Technology studies can be divided into two broad fields – engineering approaches and the study of skill (i.e. technique). The latter is the predominant approach of social scientists interested in technology. In a foundational move, Mauss & Hubert (1902 [Mauss 1972]) identified the basic significance of experimental technique. All experimentation (they stress) involves a social context – an anxious group of stakeholders with a problem to be solved (i.e. a user network). Technique is stabilised as practice through the social endorsement it receives. Modern studies utilising this approach refer to knowledge or understanding as a product not of the individual "experimenter" but of group interaction (i.e. they apply the notion of distributed cognition).

Any context involving group or human-tool interactions can be analysed in terms of distributed cognition (tool is to be understood in the widest context, to include any entity, including plants and animals, offering "affordances" [Ingold 1999]). Knowledge states are assessed for the "actor network", and not for individual "minds" or "consciousnesses". ANN are appropriate to the computation of knowledge states in such situations, since (in ANN) memory, classification, and pattern recognition are a function of signal traffic within a network, modified by nodal weights and threshold values.

The literature on ANN commonly distinguishes between supervised and unsupervised learning (Picton 2000). In the former case, a system is shown a set of training weights. These serve to "teach" the system to attain correct outcomes. But another family of ANN attains stable outcomes through feedback. Inputs are treated as random variables. The stable states of the system are emergent properties of a network with massive feedback. Such devices are sometimes referred to as recursive stochastic networks, and are thought to offer better ways of modelling a number of real life processes or undertake problematic computation tasks (such as facial recognition) than supervised ANN. The distinction between supervised and unsupervised learning captures quite well some of the basic differences between the two kinds of seed system outlined above.

(iii) Modelling knowledge states in seed systems by ANN

The focus here is on the local seed system as an instance of distributed cognition in an unsupervised neural network. Farmers receive, process and pass on seed materials in a probabilistic manner. Seed can be begged from friends, or gifted impulsively. Some is acquired truly randomly (from accidental finds). Farmers test and select unfamiliar materials, and chance (rainfall fluctuations, choice of site, pest damage, etc) plays a part in sifting material for continued usage. Farmers with unusual material recurrently hand on small amounts through a variety of channels, depending on availability.

Each agent can be considered a "synapse" in a network, with a specific propensity to hand on or receive material through "weighted" connections (reflecting strength and density of bonds of kinship, friendship, clientship, etc). Patterns of activation influence the likelihood of future transactions taking place. Frequently activated links are more likely to "fire" on subsequent occasions (thus fitting the definition of Hebbian learning). Subsequent knowledge states (i.e. patterns of distribution of adapted seed materials) are distributed across the system as a whole, shaped by feedback activity. In short, the seed exchange network is modelled as a stochastic recursive system with emergent properties.

(iv) Supervised and unsupervised learning in seed systems

As noted above, ANN modellers distinguish between supervised and unsupervised learning processes. Pattern recognition in a supervised ANN is achieved by showing the network a correct configuration to which outputs should correspond. In unsupervised learning the system "teaches itself" by finding stochastic equilibrium states.

Controlled attempts by governments and development agencies to shift knowledge states among a mass of small-scale farmers towards use of breeder seeds may be seen as kind of supervised learning. Breeders know what works, and the aim is then to induce the mass of farmers to adopt superior genotypes. This is the classic Green Revolution approach.

The "farmer first" approach, by contrast, is to place more reliance on the myriad actions of farmers screening and diffusing locally adapted seed materials. The battle is lost when it is conceived as a contest between the individualised knowledge of breeder and farmer. The argument could be usefully restated in terms of the relative merits of supervised and unsupervised ANN. Viewed as unsupervised learning farmer seed exchange can be seen as a "feedback" driven process through which local seed systems attain genotype-environment equilibrium. When the environment changes the system hunts for a new equilibrium.

It is possible that unsupervised learning in ANN may confer greater "plasticity" (i.e. greater adaptive flexibility in regard to environmental fluctuation). If ANN models of real seed systems could be developed then they might be used to simulate whether or not such adaptive efficiency is conferred, under various scenarios for environmental change (cf. Curran & O'Riordan 2002). This is a current research ambition for African Rice.

(iii) Priming unsupervised seed systems with genomic information

An advantage of the supervised model is that it links seed users with genetic information in a rather direct way (the teachers in the system – i.e. plant breeders - know a great deal about the genetic pedigree of recommended seeds). In the model of local seed systems as unsupervised (farmer-to-farmer) learning the relationship between farmer seed exchange activity and genetic information is less clear.

Unsupervised neural networks (e.g. the Hopfield model [Hopfield 1982]) sometimes encounter a problem of local equilibria (i.e. they settle into sets of localised stable states rather than assuming a system-wide pattern). In seed system terms, we might anticipate such results where groups of farmers exchange different named varieties across a linguistic boundary that turn out (on closer analysis) to have the same basic genetic composition. System learning has taken place, but it is (in adaptive terms) "wasted effort".

It might be important to know (via a modelling approach) when unsupervised learning approaches some kind of limit. For example, if it was known whether farmers were "fishing" in a locally exhausted gene pool systematic base-broadening might then be attempted to "re-boot" the farmer seed system. Thus it would seem to be advantageous if we could find some way of heightening the responsiveness of local seed systems to precise genetic information, but without harming the recursive properties that convey adaptive flexibility. This then sets us a problematic to be resolved through work in progress:

- What are the contexts in which (increasingly readily available) genomic information add value to learning activities in local seed systems?
- In what ways would genomic information "register" within unsupervised seed systems learning (more specifically, is a genetic component already reflected in existing farmer seed networks, and if not, how could such a component be introduced?)
- What are the practical and organizational opportunities and limitations to providing such information in African countries?

Conclusion: back to "farmer first"

"Farmer first" argued that experts had no monopoly on technical knowledge when it came to improving small-scale agriculture for poverty alleviation. Brave attempts have been made to operationalise, and up-scale, this insight (e.g. the FAO-led "farmer field school" movement). Yet three decades after the initial debates it still common to hear the objection "are you trying to say farmers know better than scientists?". In fact, the experts have extensively colonised the new participatory forums for farmer knowledge. Surveying the extensive experience with farmer field schools in Uganda, Isubikalu (2007) was forced to conclude that farmers' own research problems remained low on the list, elbowed aside by researcher priorities. What has been suggested in the brief argument outlined above is that the model of learning urgently needs to be changed. We need to move from “farmer first” (implying an “in head” model of cognition and knowledge formation) to “farmers first” (the idea that cognition is distributed across a network of actors). Here it has been suggested that the case for “farmers first” rests on the presumed superiority of unsupervised over supervised learning in complex networks for the exchange and utilization of genetic (and other agrarian) information. Empirical (technographic) studies of farmer “cognition in the wild” are now needed to substantiate such notions, at the same time as hypotheses about the adaptive advantages of unsupervised learning are tested through simulation modelling exercises. Seed systems make a logical starting point, since they seem to lend themselves both to the methods of distributed cognition and neural network modelling. Work is currently ongoing on modelling the adaptive potential of rice seed systems in coastal Upper West Africa (from The Gambia to Ghana). With such developments, we may expect a new lease of life for a pluralized, socialised variant of the “farmer first” paradigm.

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