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The democratisation of decision-making processes in the water sector II

Michael B. Abbott and A. Jonoski

ABSTRACT

The second part of this paper investigates one possibility of realising an inversion of the so-far established order of knowledge/power structures in that it corresponds to an inversion in power relations that is realised by an inversion in knowledge relations. The system proposed here by way of an example is then primarily a means of realising this inversion. The economic sustainability of such a system within a 'third world' context necessitates the consideration also of knowledge/value relations, and these are also briefly introduced. The system itself is essentially a knowledge self-management system, comprising three principal components:

- a knowledge centre connecting to (other) knowledge providers;
- an inner knowledge preiphery that receives, processes and transmits knowledge passing between the centre; and
- an outer knowledge periphery situated primarily at the end-user level.

The use of 'scientific discourse' at the centre and of 'narrative discourse' at the outer periphery sets the overall specification of the inner periphery.

Key words | knowledge-intensive agriculture, advice-serving system, fact engines, judgement engines

Michael B. Abbott
International Institute for Infrastructural, Hydraulic, and Environmental Engineering-IHE,
Westvest 7,
2601 DA Delft,
The Netherlands)
and
Knowledge Engineering,
BVBA,
Brussels,
Belgium

A. Jonoski
International Institute for Infrastructural, Hydraulic, and Environmental Engineering-IHE,
Westvest 7,
2601 DA Delft,
The Netherlands

KNOWLEDGE/POWER AND KNOWLEDGE/VALUE: RELATIONS AND STRUCTURES

Knowledge/power *relations* are inherent in all human and many other animal societies, such as between parents and children of a human family and α and β males and females in a wolf pack. These relations, however, become *structured* through habit and usage, finally often being codified in human societies in legal and other socially binding documents. In more recent times these relations and structures have been extensively researched in all manner of contexts, as exemplified in the well-known works of Foucault (e.g. 1963//1973/1989 and 1966//1970/1989). Foucault saw knowledge and power as so inextricably entwined that he initiated the practice of denoting them together as 'knowledge/power'. One of the defining concepts of knowledge/power is the deliberate restriction and canalisation of knowledge so as to gain and maintain power and, conversely, the use of power so as to control flows of knowledge.

On the other hand, hydroinformatics, as a postmodern technology and thereby necessarily a sociotechnology, is tied into a postmodern condition where 'knowers' transform increasingly into 'consumers of knowledge' and knowledge, as a result, becomes increasingly a kind of product. It is then, however, not a product like just any other product, but one that enters into all other products. Thus increasingly many industries, agricultures and services, as well as many professions, become 'knowledge-based' (Abbott 1999*a*,*b*). This condition is then supported by such developments as those currently occurring in the use of the Internet and in mobile telephony, so as to provide a 'New Economy' that makes up a large part of the value of all companies quoted on most stock exchanges. Within this business context, however, knowledge exhibits another aspect that supplements and even surpasses its traditional, long-established, relation within knowledge/power, which derives from the following simple observation: that the same knowledge can be sold or exchanged indefinitely, without in any way depleting the original store of knowledge. Knowledge in this sense is an undepletable resource.

Now the knowledge of one individual or social group has always had, when relevant, a value to other individuals or social groups, so that it could be exchanged for other goods or for money. Thus knowledge has a value, and in a postmodern society this becomes in the very first place a value to a consumer of knowledge for whom it is relevant. To some extent, at least, this is a *social value*, for which this consumer pays in one way or the other in money terms. This is to say that a transfer of knowledge then comes to constitute a *transaction*, which itself entails a cost that is called a *transaction cost*. In a world increasingly populated by knowledge consumers who access, use and then for the most part discard knowledge, many bodies of knowledge can be sold or otherwise exchanged much more frequently than previously, so that the money cost of each application of the knowledge can be reduced. This decrease in the cost of each application of a given body of knowledge, even when augmented by new kinds of transaction costs, in turn increases the circulation of *knowledge/value*. It is by these means that knowledge acquires another, and in the longer run much greater, value as a society passes into a postmodern condition. In such a society, therefore, the social value of knowledge to its provider no longer depends only, or even so very much, upon maintaining knowledge differences or 'gradients' between the more empowered and the less empowered. It depends much more on the rate at which knowledge can be sold or otherwise exchanged and so made available, and then ultimately always as a means of improving the perceived quality of life of those who, as a result, buy this knowledge. Thus, in a postmodern condition of society, the determining factor in estimating the *financial viability* of any knowledge provider is the *rate of circulation of knowledge/value*. Every knowledge-intensive activity, such as a knowledge-intensive agriculture, must base its financial viability on this measure. Thus, in so far as a large, and even very large, number of end-users can be brought to make use of the same repository of knowledge, the application costs for each end-user can be brought down to levels that are compatible with the advantages conferred by this knowledge.

At the same time, however, values are by no means necessarily measured in social value terms: *intrinsic* values, usually associated with the emotions that the individual experiences in giving or receiving knowledge, are often more important to overall *institutional sustainability* than are social, including money, values (Abbott 2000*b*). Thus, for example, even in current 'corporate business' applications, incentives to share knowledge with others in order to increase social value are commonly introduced by setting up gradients in intrinsic values. Closer physical proximity, enhanced means to promote sociability, and the encouragement of peer respect for those who contribute knowledge, are already well-known devices for promoting knowledge sharing in established business environments. For our part, we observe that 'creative business' begins when knowledge/value relations transform into knowledge/value structures in which value necessarily takes on both social and intrinsic attributes (Abbott 1999*a*, 2000*a*). In a case like the present one, that is directed to empowerment by knowledge provision, it may be useful to think of a triadic construction of 'knowledge/power/value' and the translation of this from a relation into a structure through a sociotechnical process.

KNOWLEDGE-INTENSIVE AGRICULTURE

A knowledge-intensive agriculture is then one that can only be sustained through a high rate of consumption of knowledge. It is correspondingly an agriculture that can use 'the same knowledge' so very often that it can both sustain the provider of this knowledge (who remains a 'knower', but now in an exponentiated sense) and bring down the cost of each application of this knowledge to a level that is justified by the gain that is thereby conferred upon its consumer in income and, inseparably from income, in empowerment. The advantage to the farmer of this arrangement is that this individual, family or other social group can then farm in ways that would not be feasible without this supply of knowledge. Now it can be no 'historical accident' that nearly all the forms of sustainable, 'ecologically responsible' or 'organic' farming that so proliferate around the world at the present time are marked by a need for ever greater rates of application of knowledge and associated understanding. For example, contributors to the *Indus Valley* Internet forum speak of employing some 12,000 species in their sustainable farming practices, with one farm typically using some 100–150 species. This is necessary in order for farmers to obtain a balanced diet for themselves and for their animals, to provide habitat and nourishment for other creatures, such as bees and predators on plant-destructive insects, to provide adequate cash crops and to maintain the nutritional balance of the soil. Sound irrigation and drainage practices and other soil-cultural practices that depend upon water to promote a justifiable productivity further necessitate knowledge relating these aspects to those associated with plant cultivation. It is at this place that hydroinformatics has such a vital role to play. Although types of crops and their yields vary widely over the great number and varieties of farming experiments and experiences of this type, estimates of increases of between two and five times in yields per soil area are regularly reported, together with much improved balances of diet, but then with little or no use of industrial–agrochemical inputs. Levels of mechanisation also tend to be considerably lower. On the other hand, most such agricultural practices are considerably more labour-intensive than those prevailing within the current Western paradigm, necessitating that a substantially larger part of the total working population is employed in agriculture. Although this part is so much larger than that of the most 'advanced' agricultures in Europe, not to speak of North America, this may be seen as an advantage in terms of the alleviation of poverty in many 'third-world' societies. Incomes in dollar terms can be expected to be considerably lower than those of farmers surviving the current round of industrialised agricultural 'consolidation' in North America, with the result that the advantage in increasing purposeful and sustainable employment can only be sustained economically when this labour force is properly informed and advised.

A POSSIBLE SOCIOTECHNICAL REALISATION OF AN ADVICE-SERVING SYSTEM

As mentioned earlier, the system as it is envisaged here is a sociotechnical system, and for its successful realisation it is necessary that both aspects, the social and the technical, are woven together in a carefully studied and analysed way. The crucial goals are to be achieved only if there is a recognition of the fact that the social and the technical are so interconnected and mutually dependent that they have to be approached and dealt with in a fully integrated fashion. Thus it in no way suffices to study only the social consequences of technological innovations or the technical innovations required to realise certain social changes. Sociotechnical studies of this kind do not belong to the category of social studies anymore than they belong to the category of technical studies: sociotechnical developments are qualitatively different from the social and technical developments from which they are composed. To follow an ancient analogy, the social is as one piece of thread and the technical is as another piece of thread, but the sociotechnical is as the piece of cloth that is produced when these two pieces of thread are woven together. The cloth is qualitatively different and has an entirely other use and value than the threads from which it is woven. Following this understanding, in the subsequent sections both the social and the technical aspects of the three system components will be treated simultaneously, even though they must be introduced in the order of writing as though they were separate.

Looking at the technical side, it is necessary first to introduce a general technical approach that may be applied for the conceptual design of the whole system. At its implementation level, such a system may advantageously employ many different and relatively advanced technologies of kinds that have been extensively researched and applied in recent years. However, regardless of the actual technical implementation, on a conceptual level the proposed system is most appropriately described using a framework based on *agent orientation using message-passing architectures*. The overall system design may then also be based on this conceptual framework. There are of course many definitions of 'agent' and 'agenthood' in the technical literature, but for our present purpose we may regard an agent as any software entity that combines methods and data such that it can initiate and perform certain tasks within a larger, system, context. Although agent-orientated architectures are usually associated with loosely coupled distributed systems with emergent properties, they will be introduced within the present context in a more limited and restricted way.

With respect to the tasks to be performed by the agents of this system, we may propose three basically different kinds of agents, with each kind associated primarily with one of the system components. The first one takes up and carries the physical, social, intentional and other features of the individual user of the system, for the most part situated within the outer periphery, and communicates these in the form of intentions and narrative knowledge, to the second kind of agents, situated for the most part within the inner periphery. This second class of agents then makes use of the information so communicated to pass on narrative knowledge translated into a scientific form suited to the workings of the centre. This is then used to synthesise judgements upon advisable courses of action to be taken by the individual user subject to all the knowledge and data that the knowledge centre can provide. This advice is then carried back by the first class of agents to the individual user in forms that this user can readily assimilate. The third class of agents is located in the knowledge centre and is responsible for maintaining the necessarily high level of software interoperability of the various software components (systems for representing of different classes and forms of narrative knowledge, different kinds of models, databases, software modules for extracting measured data, modules for satellite image interpretation, etc.). On requests from the inner periphery, these agents have to provide the requested facts by invoking whatever software component is necessary and then deliver the data back to the second class of agents in the inner periphery in appropriate form. In current 'business speak', the agents of this third kind are primarily concerned with 'supply chain management', albeit of knowledge rather than of material things. In this case, much of the same vocabulary – 'supply networks', 'parallel chains', 'enhanced concurrent activities', 'synchronised supply models', etc. – can be taken over from established business practice, even though applied in quite different ways.

In this respect, and as observed earlier, the systems envisioned here, although in essence knowledge management systems, proceed in almost the opposite direction to those taken by the knowledge management systems that are at the centre of most current interest. The current dominant paradigm in knowledge management is one in which the collective knowledge of an organisation, often called its 'corporate knowledge', is made accessible across the organisation in a manner and to an extent that is defined and controlled by corporate management. This practice can be seen as a natural extension of corporate information management and it makes use of many of the same tools by way of enabling technologies. In systems of the type considered here, on the other hand, there should be as little 'corporate' management as possible of this kind. The current paradigm has to do with such issues as 'Enterprise Resource Planning' (ERP) and 'Enterprise Asset Management' (EAM), whereas the paradigm introduced here is directed to providing knowledge, initially in the form of advice, to large numbers of individuals, families and other social entities. We might indeed try to emphasise this difference by describing the systems that are proposed here as particular kinds of 'knowledge self-management systems'. The orientation towards agent-based architectures in this class of systems can then be seen as a technological response to their quite different social intentions.

(We might proceed even further to describe these constructs as particular kinds of 'self-organising socio-technical systems'. This however has the consequence that, since they are intrinsically nonlinear, they must be expected to exhibit chaotic behaviour in the strict scientific sense, which is to say that they must be creative of an underlying order (Lorenz 1993; Ruelle 1993; see also, within the management context, Anderla *et al*. 1997). Thus the macroscopic analysis of these systems may be expected to require an extension of existing chaos theory (see, further, Kaufmann, 1993).)

The roles of these three classes of agents will be further discussed in the following subsections, weaving them into the expected social context. It may be anticipated that most of the challenges to appear from the social side will be in the outer periphery of the system, whereas the development of the inner periphery and the knowledge centre (with its relations to the external knowledge providers) will be facing predominantly technical problems.

The outer periphery

This is by far the most difficult part of the system to define at the present time. The main reasons for this are the following.

1. Most processes at this periphery proceed concurrently through experience, intuition, custom and tradition, commonly held in place by religious rituals. These interacting knowledge structures, many of them based upon so-called 'tacit' knowledge, are also endangered by such recent developments as the introduction of technocratic irrigation and drainage practices and genetically modified crops.

2. Being for a large part intuitive, these knowledge processes occurring at the periphery of the system are rarely verbalised by the persons directly concerned; indeed in many cases (and as commonly occurs in the case of using tools) verbalisation cannot suffice of itself, but must be accompanied by repeated exemplification. This and other constraints necessitate that the systems proposed for introducing the new paradigm must be supported by knowledgeable persons at the field level, so as to make them ever more definitively *socio*technical systems. The basic reasons underlying the preponderant role of women in staffing these systems, as has already been experienced by microbanking and telecommunications providers, has been investigated in Abbott (2000*a*) and Thein & Abbott (2000).

3. Systems of the type that have so far been proposed for sustainable 'organic' farming have necessitated levels of co-operation between their users that are in many ways beyond those of existing traditional agricultures, and even these are being further undermined by the ongoing intrusion of the technocratic paradigm. Thus the proposed new 'knowledge-intensive' systems must be designed also to promote changes in attitudes in the direction of more collaborative attitudes and enhanced social cohesion.

4. Similarly, following Heidegger's celebrated analyses of tool-using processes in general (see Abbott 1991) there can be no 'theory' of these processes but, at most, a theory of their possible descriptions and corresponding reductions, as 'phenomena'. Correspondingly, we regard the Husserlian/Heideggerian school of phenomenology as the underlying science of all such, sociotechnical, processes. Thus, even the existing relations between intentional acts and intentional objectives can only be made explicit generally within this kind of phenomenology.

5. 'Giving advice', implying as it does the changing of intentional acts, and occurring together in many cases with the introduction of new intentional objectives, necessitates a careful analysis of the existing phenomena and the changes that the adoption of this advice may produce. This analysis must then proceed, initially at least, through 'the phenomenological method' of extracting the essential features of processes from careful and profound studies of a wide range of practical situations, as 'examples' or 'case studies'. It should be emphasised again here that we are using such expressions for what they correctly denote, but not with the connotations most commonly associated with them at the present time. Thus, these are not 'case studies' in the usual sense of schools of business administration, for whom 'case studies' are means to understand the dynamics of social-organisational situations, or 'group dynamics' involving only persons. Here we are again dealing with something that is qualitatively different, which we might try to describe as the 'sociotechnical dynamics' of intersecting and interacting social and technical processes, as the warp and woof in the sociotechnical weaving process. This proceeds for the most part between people and equipment and, through the intercessions of both of these again, with the physical world.

6. Thus, although we may speak loosely of 'narrative discourse', and even 'narrative knowledge', the process of narration itself may take oral, textual, graphical, repetitive-exemplary and other forms. Accordingly, this 'discourse' may be extended and often quite diffuse, and the 'meaning content' of the narrative knowledge obscure

and ill defined by conventional predicate-logical, modern-scientific, standards. This implies that the applications of the established phenomenological methods will have to proceed iteratively, building further at every stage on their earlier results. In the language of classical Meinongian object/value theory, all such objectives will have to be 'implected' (Abbott 2000*a*).

7. These many basic differences between what is being attempted here and existing practice in the dominant corporate business environment imply that most of the existing literature on business studies, and on 'knowledge management' in particular, has little to say that is relevant to the present purpose. Certainly, the existing literature can have no use for studies in phenomenology, hermeneutics and existential philosophy. Indeed, such studies would be subversive of the whole thrust of the existing corporate paradigm, exposing its essential emptiness in human terms. Thus, as Heidegger first pointed out so long ago now (1927//1962) and subsequently amplified, technology in the modern era is no longer, simply the instrument of mankind, but it is mankind that has become increasingly the instrument of a certain distortion of technology, popularly called 'modern technology', so that mankind itself has become something 'technocratic' (see also Abbott 1999*b*, 2000*b*).

Although this situation is complicated further on its physical side by the sheer number and variety of the cases that have to be considered, it can also be much simplified in practice by drawing upon the facilities that have already been introduced by the existing micro-banking, mobile telephone and related networks at the village level. By the same token, the very success of these institutional networks in providing money-credit and communication facilities at the village scale indicates that the problems of introducing advice-serving arrangements at this scale are also solvable. Indeed, it is anticipated that many of the same persons and arrangements may be carried over from the credit-providing and repayment and telecommunications-providing roles to the advice-providing, advice-discussion and ultimately, advice-payment roles.

On the basis of this foundation in people, methods and technologies, and following existing and well-proven phenomenological methods, it is proposed to construct both the judgement engines (located in the inner periphery, and to be described shortly) and the means employed for their instantiation. This will proceed on the basis of phenomenological reductions of considerable numbers of field examples, regarded as 'case studies' in the sense described above. It is anticipated that this procedure will also play a valuable role in identifying the most relevant examples for prototype applications.

Microbanking and other such organisations have immediate interests in applying such advice-serving systems within the context of their own existing agricultural development foundations, since such services will immediately provide means for better protecting their loans and other investments. This means that in several knowledge/value-sensitive areas they need only move over to money payments for such advice as the self-confidence of farmers in their ability to use this advice and their trust in its relevance and reliability become better established. This can proceed initially by way of prototypes in those socio-technical environments where the greatest return from the availability of sound advice is to be anticipated. At the present initial stage, however, a more general analysis of the phenomenology of these sociotechnical processes has to be conducted and for the moment this is proceeding through academic studies carried out by nationals of the countries in which applications are most likely to succeed. The intention, however, is to proceed to field applications as the enabling technologies become increasingly, and increasingly cheaply, available.

Turning back now to the technical approach for achieving the tasks in the outer periphery, the first thing to be considered is the existing infrastructure of the telecommunications network which already exists at the village level. At this level there are still only a very few knowledge processors (often still called 'computers') which are cable connected and may be used for direct land-line communication with the inner periphery and further with the knowledge centre. This directs the design of the first class of agents located in the outer periphery initially to very 'light', purely message passing agents suited to the limited capabilities of current Wireless Application Protocol (WAP) technologies and so with only two primary tasks or 'responsibilities'. In the first direction of knowledge transmission these agents have to take the features and knowledge inputs of each individual user (physical, personal, social and others) as a message to the inner periphery. Upon completion of the requests through the actions of the agents in the knowledge centre and the inner periphery, these agents have to bring the advice, translated into narrative form, back to the individual user. We shall return later to the way in which this narrative form may be realised (voice message, written message, visual cartoon, etc.). Many of the features associated with this function appear to be only fully realisable with the introduction of complete 'third-generation' (3G) technologies, as anticipated by the years 2002–3, although the provision of simple base stations supporting a local wireless broadband computer network may suffice to support WAP enabled technologies in the meantime.

Since the first kind of agent here has the function only of carrying the truth-bearing messages of others and has, so to say, 'no voice of its own', we currently call such agents 'angels'. In conventional studies of agent-orientation they are often called 'flag agents', being said to 'flag-in' when activated and 'flag-out' when they deactivated themselves. Although we personally prefer the name of 'angels' (and even 'guardian angels') within the present context, because of the emphasis that we wish to place upon the truthfulness and personal relevance of the messages that these agents carry, we have to accept that many persons, not being acquainted with theological studies of angelology, may find this usage objectionable (see, for example, Barth 1944–1953//1960, pp. 369–418). Correspondingly, we shall refer to these agents simply as *messenger-agents*. The message that they deliver, insofar as it contains the description of the needs for knowledge of the end-user and the ability of this user to employ this knowledge, is called the *user profile* of that end-user (see Abbott 2000*a*).

The inner periphery

The second class of agents is composed of altogether 'heavier' and more earthly entities. If we may now turn to use the kinds of biological metaphors that are so widely employed in software engineering and artificial intelligence, we might say that these 'heavier' agents are 'impregnated', 'fertilised' or 'seeded' by the lighter and purely message passing, agents. They are agents that search the facts when they are so impregnated with the messages carried by the messenger-agents so as to collect just those facts that are the most relevant to the individual user. They then interpret these facts in such a way as to arrive at advisable courses of action for the individual users, as described later. Although we personally refer to these heavier, more Earth-bound, agents as 'saints', we may less controversially describe them as 'relational agents'. In more conventional software engineering terms, the impregnation or seeding first defines a navigation path through the facts and then defines the interests to which these facts are to be directed relative to the intentions and capabilities of the individual user, as also communicated through the impregnation by the user's individual messenger-agent with that user's profile.

We observe that although the number of messenger-agents may run from thousands into millions, their individual visitations may be quite few and far between. On the other hand, the number of relational agents that are subject to these visitations may be relatively small, even though each of these relational agents may have much more work to do, thereby taking a lot more time over responding to each visitation. The timing of visitations is clearly of great importance as it must be co-ordinated with periods of critical decision making by the individual user for whom the messenger-agent is, so to say, a 'guardian'.

The 'facts of the matter' must then be considered upon each visitation in relation to the profile of the end-user of the system. For this purpose the relational agents may be expected to make use of 'judgement engines'. These are devices that facilitate the making of judgements in general and in this case of judgements about the best advice that can be given to an end-user in the fact-given situation (Abbott 1999*a*,*c*; Yan *et al*. 1999). A judgement engine is a device that realises an inference string that has as its simplest form:

$$\text{(beliefs, facts)}\rightarrow\text{attitudes}\rightarrow\text{positions}\rightarrow\text{judgements}\rightarrow\text{decision}\rightarrow\text{action} \quad (1)$$

in which the beliefs are provided in the form of the user profile by the messenger-agents, while the merging of these beliefs with the facts is the task of the relational agents. The relational agent sets up or, instantiates, a judgement engine on the basis of the end-user profile. This is to say that the relational agent introduces the kinds of facts that are considered important by the end-user and the beliefs of that end-user concerning the desirability or otherwise of a range of possible facts within that user's personal situation. The knowledge provided by the end-user is also processed through the relational agent into a form whereby it can be assimilated by the centre.

Thus, to take a simple case, the value that a rice farmer might place upon each particular depth of water over his fields, at a given stage in the rice-culturing process, can be used to express the farmer's beliefs concerning the value that he (or she) would put upon a certain water depth were it to become a fact. In effect, in this way the judgement engine elaborates a belief-value-to-fact mapping, or function, of a kind that is conventionally represented by the curve of a graph. The water depth as actually predicted by the knowledge centre can then enter as a fact and this transforms through the 'fact-value' mapping or function into a value to the end-user. This is of course only one value among many others and the way in which the different results are aggregated according to the various criteria is a favourite subject of 'multi-criteria analysis' in economic theory. There are of course correspondingly many ways of conducting this analysis, of which three are employed in current engines (see, for example, Yan *et al*. 1999; Bazartseren *et al*. 1999; Jonoski 2000). Among other features, one of these methods allows for a calculation of the inconsistencies that are commonly inherent in the belief system of the end-user.

We may consider the relational agents as much extended 'search engines' which now, however, seek out facts and interpret these facts in the light of the profile of the end-user so as to provide this user with the best advice that they possibly can. The relational agents must then have access to the facts. All the devices that are used to provide the physical, biological and other such non-personal facts of the matter using all available narrative and scientific means are called *fact engines*. Being situated within the inner periphery of the system, the relational agents can draw directly upon all the productions of the fact engines of the knowledge centre for this purpose. Moreover, since the inner periphery will mostly be cable-connected to the knowledge centre, it can draw upon the outputs of all fact engines and otherwise make use of the facilities of the centre through a conventional system intranet. This intranet can also be used by the relational agents to transmit the narrative knowledge that they have garnered at the outer periphery to the centre in a scientific form. The intranet must then comply with the same standards as the World Wide Web (WWW). The facts may thus be assembled at the centre where they can be merged with the narrative knowledge garnered at the outer periphery and transmitted to the inner periphery using, for example, standard Geographical Information Systems (GIS) platforms.

The knowledge centre

The knowledge centre constitutes the knowledge core of the system. It is the most 'earth-bound' element of the system, being reduced to the 'mundane' application of scientific methodologies. It responds to the requests of the inner periphery for information, which is then so far as possible provided by the Web GIS systems. It must itself then prepare the material for transmission, on the one side by running models, interrogating measurement stations, requiring and interpreting satellite images and through other such scientific and technological activities, and, on the other side, by merging all this with narrative knowledge expressed in a suitable scientific format. Since however, by far the greater part of the scientific material can already be supplied by existing organisations, these become in their turn 'knowledge providers' to the centre. It is these that we have called the 'external providers' earlier here. It can be expected that the required high level of efficiency and interoperability of the various fact engines, located either in the knowledge centre or at some of the knowledge providers, will best be achieved if these fact engines are reconfigured so as to better comply with the requirements of the agent-orientated approach. From the perspective of this system they would then all fall into the third class of agents, which we shall here call 'service' agents. The system intranet then becomes a platform on which such service agents operate in order to provide the requested knowledge and (facts (data)) from the inner periphery. Once again the WWW becomes the instrument for enabling the provision of such knowledge and data, or more generally 'information', or more generally again 'content'. When seen in this perspective, the knowledge centre takes on the attributes of a 'knowledge broker' whose principle task is one of knowledge management in a rather more conventional sense. This role is strengthened further to the extent that a return flow of information is engendered from the outer periphery and transmitted through the inner periphery to the centre. In this case the knowledge centre can provide knowledge back in turn to what are otherwise its external knowledge providers. The door is thereby opened to a far superior relation between the work of the 'providing' organisations and the real world situation, or 'the situation on the ground', and this provides in turn a considerable added value.

The envisaged functioning of the system, achieved by the bi-directional flow of knowledge through the three system components introduced in the previous subsections, is schematised in Figure 1.

TECHNOLOGIES FOR THE DEVELOPMENT OF THE SYSTEM

Even with the introduction of the system so far, it is clear, as observed earlier, that the design and implementation of it will require the application of some rather advanced Information and Communication Technologies (ICTs). The tasks of the three different classes of agents operating within the three respective system components vary considerably, and it is obvious that a combination of different technologies will be required for their design and implementation.

As the connections between the outer periphery and the inner periphery will be for the most part wireless, the messenger-agents will have to make use of the emerging wireless Internet technologies. At present, the WAP has appeared as a standard upon which wireless Internet communication is mainly based. This protocol enables communication between the client (a wireless device such as a mobile telephone) and a WAP server connected to any number of other Web servers. The WAP server is known as a WAP gateway, which routes clients' requests to HTTP (or Web) servers. The communication is based on the so-called Wireless Mark-up Language (WML), which adheres to the XML (eXtendable—or 'eXtensible'—Mark-up Language) standard. Although there are ways of translating HTML-coded information into WML, because of the severe limitations of the present wireless devices (low bandwidth, low memory, limited screen size, etc.) most services are now being developed separately, either as static WML documents, or dynamic WML documents created on the server side. The dynamic WML documents can be generated with any server-side technology (CGI scripts, Active Server Pages, Java Servlets, Java Server Pages, Perl, Tcl, etc.). These documents are then sent to the client again through the WAP Gateway.

In the proposed system the WAP gateway will be located in the inner periphery, and it will be the task of the relational agents to handle the requests coming from the outer periphery through this gateway. The handling of the requests is, however, much more complex as compared to the provision of a simple service through a WAP server. In order to provide the relevant advice as a response to the outer periphery, the relational agents will have to initiate another communication process between the inner periphery and the knowledge centre. Upon receiving the relevant facts from the knowledge centre the relational agents will then be responsible for instantiating the judgement engine applications that are set up with the profiles of the individual users in order to assemble a 'best advice' for each of the individual users. After translation into narrative forms, this advice will be sent to the outer periphery through the WAP gateway. The translation may proceed through existing standard procedures for translating message strings (commonly in the form of binary strings associated with strings of natural numbers) into linguistic labels and assembling them into texts. The texts may be transmitted in textual form or synthesised into a vocal form, running together with illustrative material if required. Again, the form of delivery will depend crucially on the possibilities offered by the wireless technology, and with the arrival of the third generation (3G) wireless devices many of the present limitations may be overcome.

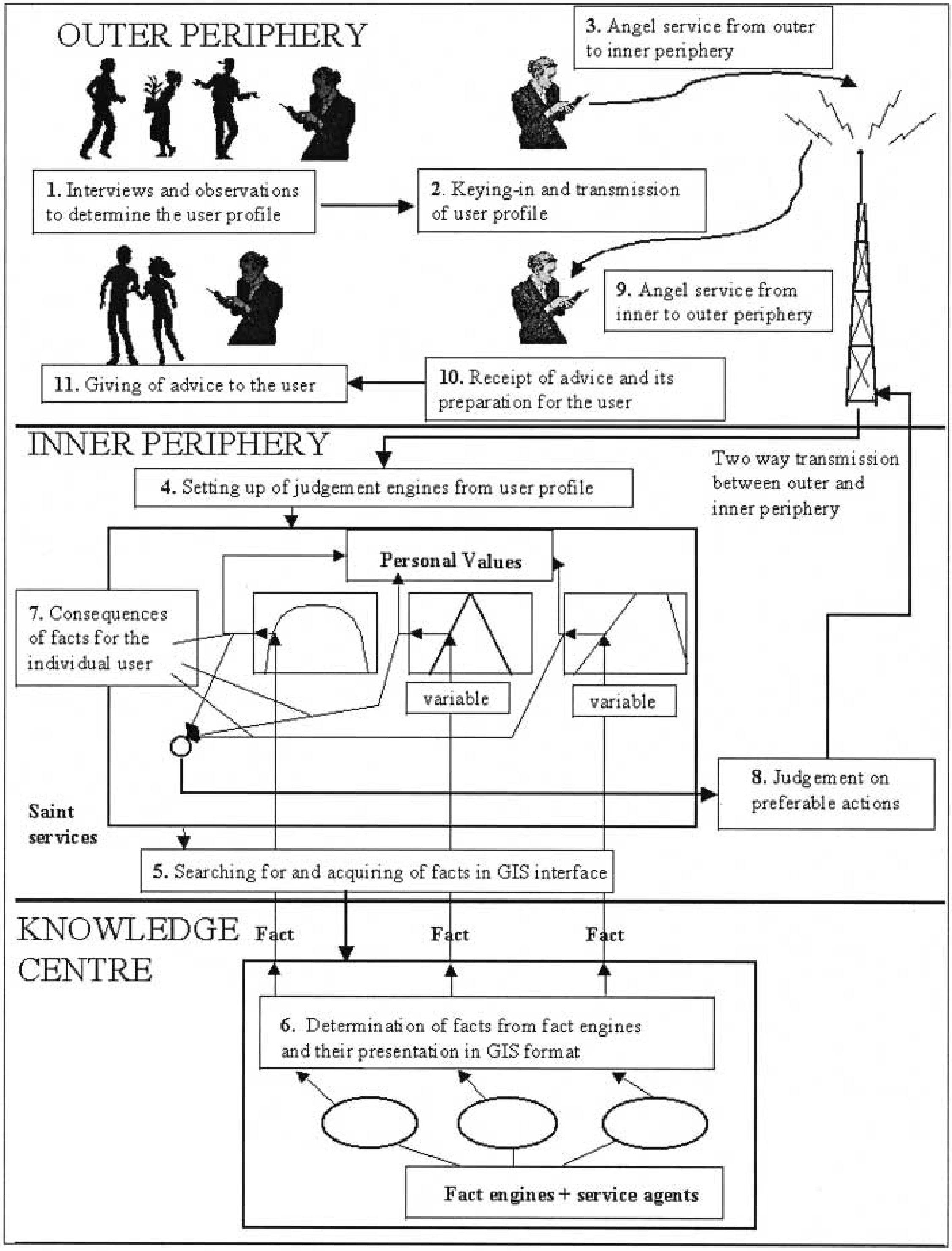

Figure 1 | Schematisation of bi-directional knowledge flow in the proposed system.

Even at this most basic stage there is already a vast panoply of tools for realising and facilitating the construction of such systems. In the direction of Computer Aided Telephony (CIT) these tools normally observe the need to satisfy the so-called asynchronous transfer mode (ATM) standard, providing major advantages at the moment only for cable transmission. Client profiling and advice serving can already benefit from the introduction of subscriber identification module (Sim) cards—the tiny smart cards in handsets which identify the customers and control their relationships with the network—as exemplified by the Virgin Mobile service. Of considerable potential significance here is also Ericsson's Bluetooth technology, which provides short wave radio connections between a wide range of devices and a computer network. It is to be expected that most advice serving systems will use Advanced Speech Recognition (ASR) and Text-to-Speech (TIS) software. Although the voice-enabled services thus provided can be accessed through web browsers, such as is in turn enabled through the use of XML, more powerful tools, such as Motorola's VoxML can be used. Typically for such tools, VoxML further provides a software development kit and a web site to promote it. Developments along these lines will be greatly strengthened through an industry-standard voice browser technology, such as Voice XML, which is currently being supported by several of the largest ITC companies. The new 'talking web sites' require new types of web servers, as represented by Lucent Technologies' SpeechServer, which connects directly to the service provider's database and to the (voice accommodated) internet.

The complexity of this whole process will not allow a design and implementation of the relational agents as simple 'middle tier' applications located between a client and a server. In fact the whole inner periphery cannot be reduced to a completely automated unmanned part of the system. Instead, it is proposed here that the inner periphery with the knowledge centre are together organised as the system intranet. This system intranet will have two extranet parts on the two respective ends. The communication through the WAP gateway with the outer periphery may be seen as the first extranet part, while at the other end the communication between the knowledge centre and the various knowledge providers may be regarded as the second extranet part.

The inner periphery and the knowledge centre, forming the system intranet, will be cable connected and the most obvious approach to their design is to use the existing technologies developed for the WWW. Standard HTML, scripting languages like JavaScript, various Java technologies, CGI, Active X, and other technologies are already utilised by organisations within the countries towards which these systems are directed, and already for a variety of purposes: the experience and knowledge is already present locally. Once again, there is a great variety of Customer Relationship Management (CRM) tools available on the market that might conceivably be adapted to the present purposes. The same applies to ERP and EAM applications. It is not at all clear at present, however, whether or to what extent these tools can be so adapted advantageously.

One of the more important aspects for the successful exchange of data and knowledge between the inner periphery and the knowledge centre will be the WWW–GIS platform which will enable quick and reliable retrieval of the requested data at the inner periphery as these are delivered by the knowledge centre. The retrieved data can then enter as inputs to the judgement engine applications and combined with the user profile and request in order to provide the necessary advice. At the same time, the retrieved data can be easily visualised at the inner periphery through a browser environment.

For this purpose, a full utilisation of the recent technologies for deploying GIS on WWW, such as the Open Geospatial Datastore Interface (OGDI), which uses a Geographic Library Transfer Protocol (gltp), seems appropriate. This interface provides standardised methods through which software packages can access, 'on the fly', a variety of geospatial data products. OGDI uses a client/server architecture to facilitate the dissemination of geospatial data products both locally and over any TCP/IP network, and a driver-orientated approach to provide access to many geospatial data products and formats. There are many advantages to OGDI, as set out on (*http://www.globalgeo.com/*):

The role of the WWW–GIS platform is stressed here because most of the data will be geospatial and this approach is then most suitable on the side of the working of the inner periphery together with the centre. At the centre, for its part, the Web Server will also be connected to the various fact engines in the knowledge centre itself and at the separate external knowledge providers. These external sources will also provide non-geospatial data and will translate the requested facts in Web-compatible format so that they can be received at the inner periphery. Some of these other data will as well be necessary inputs for the judgement engine applications, but they can in addition carry descriptive information, which may be directly transferred to the outer periphery so as to support the recommended advice.

At the knowledge centre itself, the WWW–GIS platform, which will enable the communication between the knowledge centre and the inner periphery, will depend on the fact-gathering tasks that are carried out by the service agents. The main problems related to these tasks are those of efficient interoperability of different fact engines. Some of the fact engines will be available at the system intranet, and relatively easily integrated with the WWW–GIS platform. However, as mentioned earlier, the role of the knowledge centre will be more determined by its tasks of 'knowledge brokering', when fact engines located outside the system intranet in various existing external organisations are employed. The issue of software interoperability then becomes more complex, as it relates to integrating legacy software, which is commonly software developed by different people in different languages and for different platforms.

The software interoperability problem has been already addressed by several existing technologies. The integration of the client-server model, which underlies the communication and computation over electronic networks, with the object oriented technologies, has resulted in a variety of developments, all of which may be gathered under the topic of 'distributed objects'. The best known of these are Microsoft's DCOM (Distributed Component Object Model), CORBA (Common Object Request Broker Architecture), developed by the consortium OMG (Object Management Group), and Java's RMI (Remote Method Invocation) (see Yan *et al*. 1999). All of these technologies have their advantages and disadvantages, but the basic idea behind all these approaches is to package software into components (objects), with well-defined interfaces through which they can inter-operate and invoke each other's methods. This interoperability can be achieved in different client-server modes, and, with some technologies, even across different operating systems. In order to extend this software interoperability to the existing legacy applications, these will have to be provided with the appropriate interfaces.

Any of the above mentioned 'distributed objects' technologies may be used for the development of a framework for integrated operation of the service agents with the various fact engines. However, the task of equipping the 'legacy' fact engines with the appropriate interfaces for operating in such a framework remains extremely difficult, because it requires a lot of low-level interventions in these applications. This task is complicated even more when these fact engines are coming from different knowledge providers. An alternative approach to this problem is to adopt an implementation framework that will closely follow the Agent Orientation Programming (AOP) approach (Shoham 1997) and link the service agents and the fact engines with a highly expressive, specially developed Agent Communication Language (ACL). The ACL that has already emerged as a standard for this purpose is the Knowledge Query and Manipulation Language (KQLM), developed at Stanford University, USA (Finin *et al*. 1997). This approach although advocated by many developers of so-called Multi-Agent Systems (MAS), has still many unresolved problems (see especially Nwana & Ndumu 1999). The most limiting one is certainly the so-called 'ontology' problem, which is related to the need to have specifications of conceptualisations (*ontologies* in MAS terminology) of the problem domain, which are common to, and shared by, all the agents in the framework. Another alternative, which has appeared recently, is to provide the service agents with a linking framework by, again, using XML technologies. XML is designed as a metalanguage for describing data and documents, thereby providing a framework for easier interoperability of various applications. Future research will be very much orientated towards investigating these alternatives.

As for the choice of a particular technology for the technical implementation of the agents associated with all three components, it may be expected that many possibilities will be considered and the final choices will have to be made during the phase of the system design. The most recommended choice from the beginning however, is to make use as much as possible of the various Java technologies. Java was designed from the outset with network programming in mind, and nowadays is probably the best choice for programming distributed applications.

CONCLUSIONS

The rapidly advancing storm of public opinion that threatens water professionals is in many cases justified by events, and the water professionals themselves cannot avoid much of the blame that now increasingly rains down upon them. In this situation these professionals must seek ways to better satisfy the needs of the societies that they serve. To the extent that these societies now pass increasingly into postmodern conditions, where knowledge becomes a central value and the population as a whole becomes 'consumers of knowledge', this response of the water professionals must be in the direction of providing knowledge to the general population. This knowledge provision must then serve the interests of the population as a whole, empowering the individuals, families and other social groups within this population as genuine stakeholders in water resources, while also enhancing their awareness of their environmental responsibilities. This can lead to more equitable and sustainable distributions and uses of water. To the extent that so-called 'third-world' societies move in this direction, such as through introducing knowledge intensive agricultures, knowledge-intensive aquacultures, knowledge-intensive health service provisions and other such services, so they will have to apply knowledge management systems of the type that has been introduced here by way of a possible prototype. Clearly, the realisation of these systems will require new institutional structures, necessitating the disaggregation and re-aggregation of existing social, including agricultural and industrial structures, and this has also to be researched. The realisation of this new paradigm now appears as the greatest challenge facing hydroinformatics on its sociotechnical side.

The sustainability of systems of this kind clearly necessitates another level of coexistence, and even in some cases co-operation, between different end users. This necessitates that there is at least some understanding of the judgements and actions of others and, beyond this again, that there is at some stage a change of attitude towards 'the others' in a society. Both of these developments can be considered in relation to the dual of the category shown in Equation 1:

$$\text{action}\rightarrow\text{decision}\rightarrow\text{judgements}\rightarrow\text{positions}\rightarrow\text{attitudes}\rightarrow(\text{beliefs (facts)}) \quad (2)$$

where now actions and facts are observables. In the first case this represents the process of understanding why a neighbour or some other such person of influence in the life-world of the individual end-user behaved in the way that he or she did in a given instance. In the second case it has the interpretation that the performing of actions increases the awareness of the consequences of an own decision-making and judgemental process, thus providing *experience*. Connecting back experiences to the judgements that produced those experiences, the positions and thus attitudes may be brought into question and, under the influence of repeated experience, the attitudes themselves, and thence the belief system, may change (see, especially, Husserl 1948//1973). The first of these interpretations can be realised using logical discourse, while the second is usually supposed to proceed at the level of the pre-linguistic and pre-predicative, so that it is largely the product of a more extended, personal, experience of using such a system in the manner of a tool.

It is a basic tenet of hydroinformatics that every new development must not only provide ameliorations in the life of people and their natural environment, and these inseparably, but it must also provide business opportunities. In the present case these opportunities appear as accruing to what is often called the 'New Economy', of the information and communication technologies, and in many cases in opposition to the 'Old Economy', associated here with genetically modified crops, agro-chemicals, and to some extent also with mechanisation. The new paradigm that is advanced here may then be envisaged, at least on the surface of things, as a confrontation between the 'Old' and the 'New' economies, where it is to be expected that the 'Old' economy will try to take on many of the clothes of the 'New', as already exemplified by the 'new rhetoric' of the World Bank and other such organisations. This then constitutes a further part of the 'business challenge' of this initiative. Although the business development of the present initiative is also essential to its practical realisation, it does not seem appropriate to introduce this aspect at this juncture.

As is usual in all sociotechnological studies, there is a synergy here between technical advances that appear to be very new, even as their roots run far back into the past, and the underlying current of ideas, which is often very old but which carries its message with undiminished, and indeed amplified, relevance into the present time. Here, as in so many other places, the past is not only irrevocable; it is also irreplaceable.

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