A Tutorial on Intelligent Systems in Global Network Environment - The Measurement Perspective

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Abstract

The paper presents a review of so called agent systems. Agent is a new paradigm of an intelligent system embedded in the environment of the global computer network. Considering that the fusion of the measurement and the global computer networks became already a reality and that measurement is a knowledge intensive, systems which can realize complicated and distributed metrological tasks are of growing importance.

1. Introduction

Global computer networks (GCN) have evolved in the background of numerous technical, social, scientific, etc. activities into a 'natural' information medium able to store and propagate information [1]. It led in consequence to a shift in the paradigm of what an intelligent system (embedded in the GCN) should be. This new category of systems reveals potential to realize within the GCN also tasks usually not associated with computer networks. Global computer networks can connect related measurement sites increasing greatly the dimensions of the objects measured by distributed measuring systems. Global computer networks can also connect essential processing resources up-grading thus considerably the quality of measurement results available at the measurement site. Whatever is the aim the new medium requires a fresh view and a sound analysis of the concepts and technical means.

2. Global computer networks

Computer networks received a leading role in several areas of our life. Small local area networks where computers share common information and services, and global computer networks (GCN) distributing data among local networks became building blocks of companies' infrastructure. Most of today's computers operate in a networking environment, routinly reaching local and distant resources.

The Internet - the largest global computer network - connects millions of computers allowing tens of millions of people to communicate, find and publish information, socialize in virtual communities, etc. [1]. These numbers increase exponentially every year. Technologies inflating such a fast grow are communication and integrated circuit technology, advances in personal computers, and many others.

In the field of IC technology the Moore-law foresees that the density of integrated circuits doubles in ca. 18 months. This is the reason of the increasing performance of personal computers and workstations. Beside the increasing power of central processing units, today's computers are capable of displaying multimedia animations, 3D virtual models, and playing movies. New communication technologies (ATM, fiber optics, satellite links, etc.) increase rapidly the accessibility of the computer networks and the bandwidth of data transfer. It allows thus new types of networking applications, like establishing audio and video links.

Other new networking technologies are also emerging. Intranets are private networks for corporations, virtual private networking (VPN) delivers methods for creating virtual private networks over the Internet. Virtual meetings, distributed project management, connecting company sites to each other became everyday corporational practice.

Current Internet applications are difficult to operate and access even for experienced users. Current user interfaces force users to adapt to the application rather than adapting themselves to the users' needs. The ease of usage of the Internet is a major issue in several academic research projects and business solutions.

3. Agents - intelligent systems in GCNs

Until recently intelligent systems were built as stand-alone systems, isolated and confined to a short periods of problem solving. Distributed artificial intelligence dealt with cooperating intelligent systems, the number of systemic components was, however, limited, the roles well defined and the connections and interactions sparse.

The World Wide Web brought in something new and different. It introduced an environment where an intelligent system is surrounded by a multitude of other (possibly) intelligent systems with not exactly known or only suspected knowledge content and information processing capacities. In such environment the progress of the problem solving cannot be monitored closely and the control of the user over the system excercised too strictly, Fig. 1.

The design of an intelligent system on the Web requires thus a shift in what should be considered as essential system properties [2, 3, 4]. The new system paradigm - an agent - is in short a system embedded in an environment and acting in a continuous and autonom way. The general idea related to an agent is that of ordering rather the service and delegating any responsibility of direct control than to excercise it. The truth is that an intelligent system embedded in a physical environment of Web dimensions is simply too complicated to be followed by the user in detail [5, 6].

An agent continuously perceives its environment, which is the source of agent's problems and tasks but also the source of information needed to solve them. Agent compares the sensory data with the stored (or predicted) information and after a suitable processing (e.g. knowledge-based reasoning) it decides upon the course of action to be taken next in the environment, Fig. 2. The formulation of actions is influenced by a number of issues. Agent's aims and expected utility of the actions are of course the most essential but e.g. finite resources, like time, memory or energy can also be of considerable consequence. The sequence of actions is a tool of transforming the environment into a state equivalent (for the agent) to the solution of its problems.

Research formulated various notions of agency [7, 8]. Researchers agree, however, that first of all an agent should be:

- persistent (i.e. possesing a consistent state over long period of time),
- autonomous (excercising control over its own states and actions), reactive (perceiving changes in the environment and reacting to them), and
- social (being in contact and communicating with human users or/and other agent systems).

As an interesting development an agent can be also mobile, i.e. it can 'move' over the Web transferring itself from a server to a server [9, 10]. A truly intelligent agent should be pro-active, i.e. actively seeking things to do. This issue is important because even if a particular user task is completed the everchanging Web of information resources which must be mapped and evaluated, creates new configurations to increase the future utility and efficiency of the agent's actions.

The concept of an autonomous, reactive and proactive system is technically appealing. It defines a restless system actively seeking means to fulfill its tasks, cooperating, evading conflicts and generally planning for a balanced provision of services and economical management of its resources.

As an intelligent system an agent may posses also more traditional capabilities of symbolic reasoning, planning, and learning [2]. Of considerable interest to the researchers (but not so much to the measurment technical applications) are properties derived from the human character and complexity of the interactions, like e.g. veritability (communicating only truthful statements), benevolence (being friendly and helpful), and cooperativeness. Such notions, despite their human flavour, are usefull concepts when considered strictly from technical point of view.

Architecturaly an agent can be decomposed into three principal subsystems: communication and cooperation component, task (problem) solving component and an optional user interface, Fig. 3. Problem solving component depends upon the requirements of the task and on limits of implementation. The so-called reflexive agent (viz. reactive property) works with the predesigned perception-action pairs. It can be very fast, but will be brittle when up-scaled to the more complex problems.

Deliberative agent is equipped with the symbolic representation of its environment and develops actions by symbolic reasoning or other symbolic or connectionist techniques. Such agent will never be fast, on the other hand it can be very flexible and adaptive, especially when equipped with learning. Usually a hybrid solution is dictated by the complexity of the task and the environment.

Hybrid agent unifies advantages of both basic types of architectures. It is prepared to react fastly to certain typical events in the environment, the proper handling of the unusual events is worked out in a deliberative way when needed, Fig. 4.

The natural and intensive conectiveness of agent systems brings up the issue of communication and cooperation [11, 12]. The lack of user's direct control over an agent means also lack of the control over its communication efforts. Consequently it is up to the agent to decide when, with whom, what, and via which particular protocol to communicate [13]. To achieve these aims the knowledge base of an agent should contain not only domain models and methods suitable for problem solving but also logical models (believes) about the 'self' and the 'others', and especially methods suitable to judge the utility of cooperation vs. isolated problem solving, [14], Fig. 3. Agent's actions and perceptions are thus not confined only to the problem solving but contribute to the 'cognitive' components of its knowledge, Fig. 5.

Until recently typical agent applications were confined to information management in the so-called Cyberspace (Internet environment), like e.g. [15, 16]:

- data brokers, searching systems, WWW robots, ftp agents, etc. for information retrieval,
- Usenet News, e-mail filters as information filters,
- electronic libraries, databases as information providers, and other categories like system event monitoring agents or electronic secretaries (e.g. in White House).

From a somewhat different perspective, the current applications fall into the following four main categories:

- intelligent partner, that helps in accessing the Internet resources,
- intelligent interface, that helps in using the Internet applications,
- intelligent tutorial system, that helps in the acquisition of knowledge how to utilize the Internet applications,
- intelligent problem solver, that can access Internet resources to solve the user's problem.

Agents had been designed also for a number of challenging problems, like e.g. communication network management, organization of delivery, computer controlled manufacturing, hospital information systems, patient monitoring, air traffic control and the like [1, 15].

4. Practical issues

Designing systems with networking capabilities is already everyday routine in software development. Development systems offer rich set of tools and libraries for building networking applications. There are standards and implementations for data exchange (messaging), remote procedure calls (RPC), network file systems (NFS), distributed object-oriented systems (CORBA, DCOM), etc. [17, 18, 19].

The World Wide Web offers a set of standards for document representation, transferring and displaying [20]. The MIME (Multipurpose Internet Mail Extensions, [RFC 1049, RFC 822, RFC 1896, RFC 2045-2049]) standard makes possible to transfer full-motion video sequences, stereo soundtracks, high-resolution images, texts with layout information, and any other type of media in the Web environment.

Web browsers became de facto user interface standards. Most of today's software systems in networked environments use this kind of interface. The HTML [RFC 1866] became a popular standard for representing text documents with layout and structure information. JPEG and GIF image formats, and the AVI video format are the most common multimedia elements. The Virtual Reality Modeling Language allows the description of three-dimensional objects, interactions and behavior [21]. VRML-aware browsers can display and navigate 3D environments.

With the Java applet technology [22] full-fledged interactive applications can also be embedded in the Web environment. This is the first widespread technology that offers code mobility: the applet program is downloaded from the network first, and then it runs in the browser environment on the user's machine. This eases the communication problem in large computer networks.

Agent systems utilize wide range of these technologies. Agents can run in the Web environment as Java applets; they interact with the user via the Web interface. Code mobility is also a very promising idea in agent systems [9]: mobile agents offer a new software design paradigm. They use a special communication system that is capable of transferring a running program from one network node to another and an agent can decide whether it wants to change its running environment. There are already commercially available systems that support the creation of mobile agent applications.

5. Measuring systems and global networks

In measurement the presence of the global computer networks was until recently difficult to notice (Compare e.g. the references to the Web in [23] and [24]). Worldwide network of informational resources offered nothing serious to the users of specialized measuring equipment. With the increasing number of PC-based measurement controllers, however, computer networks became already a physically existing, real environment, just as real as the instrumentation linked via the GPIB interfaces [25].

Measuring equipment manufacturers began to realize the importance of computer networks and started to offer networking components and solutions. They do not, however, utilize the full potentials of this technology. Simple product monitoring interfaces in local area networks and public domain resources over the Internet are offered, comprising only instrument libraries, ordering information, financial and management press releases, application notes and typically links to related organizations and data banks [26]. Certain vendors act already as clearinghouses for user written toolboxes and other useful applications. Future net resources will possibly develop toward databases of reported measurements, typical set-ups involving vendor's products, interesting border cases, typical test signals, reusable virtual instrument programs, and the like.

To clearify better the relation between the measuring systems and the global computer network it should be noted that the measuring and computer systems are both special cases of general information machines, i.e.

machines or systems of machines performing acquisition, processing, outputting and effectuation of information.

Information machines operate by transforming input symbols into output symbols by defined transformations, where symbols are attributes of physical variables called signals. Consequently there are no conceptual problems with connecting or embed measuring systems into the global network. The only question is whether is it worth doing so ? In the following we will discuss three different aspects of working with a global network when solving measurement problems [27].

5.1 GCN as an extension of the technical means

Global computer network offers excellent possibility to extend traditional programmable measurement set-ups. Instruments locally connected through the GPIB or recently through SCIPI protocols [28], PC based virtual instruments can be easily connected over geographically larger areas [29, 30], Fig. 6.

The primary question is, nevertheless, the character of the measured object. If the object to be measured is already widely distributed, like in environmental measurements, meteorology, marine studies, space research, or large scale industrial measurements, then the sensors must be distributed accordingly and networking technology is a straightforward extension of the GPIB bus topology. If the objects to be measured are geographically localized, distribution applies rather to the information processing and to the presentation of the measurement results, permitting remote experiments or using remote procedure libraries (see a good analysis in [31]).

5.2 GCN as an (expert) support environment

Measurement is knowledge-intensive task. More to the point, it is not merely the amount of knowledge, but rather its variety and interrelations between various aspects of the same problem [32]. Consequently measurement technical expertise is something of real importance.

Instrumentation providers are already present on the Internet, albeit Web technology is only fractionally used to handle corporational information [26]. Such up-to-date top repositories cover mostly marketing information, applications notes and sometimes user developed packages, which altogether cannot yet be called measurement technical expertise.

Collaborative tools on the Net, from e-mail to multi-media conferencing offer possibility for an easy and fast acquisition of the expertise. Measurement data, together with a suitable description of the experiment can be sent to the designated expert individuals for evaluation and opinion. Video-conferencing can be used for remote monitoring of the usage of the instruments and the organization of experiments, providing immediate feedback with expert advice and diagnosis. The research in such measurement-oriented applications is still far from being concluded.

5.3 GCN as an object of measurement

Measuring stand-alone computer systems (e.g. probability of the faults, time span of correct behavior, supported services, etc.) is already well established. What is not realized is that such measurements are governed by the measurement theory like any other. Measurement completes the process of modeling, i.e. of identification, providing us with the model of studied system of required complexity and accuracy. 'Metrology of computer systems' is still a new field, mainly due to the unusual character of the models used to describe such systems.

Global networks can also be 'measured'. Server managers ruinously collect information about the density of the traffic, load upon the servers and the availability of information resources. For a moment, however, such measurements address only very low level features (low-level protocols). Moreover no application dependent information is supported, which would require the identification of the distribution and the availability of information all around the network.

The possible usage of the global network as a widely distributed 'measurement hardware' requires well-defined measurements. The principal difficulty, more easily handled in the 'traditional' measurement problems, is the fact that network nodes participating in the 'measuring system' architecture belong also to the measured global network. Special care should be exercised to make them 'invisible' or to attenuate their load upon the measured network.

6. From GPIB bus to measurement servers.

Measuring equipment belongs obviously to the category of distributed systems. Its architecture is still traditional and stiff with controllers governing over teams of instruments, bringing them into predefined states with relatively low level commands and simple data structures.

These characteristics did not change much despite a steady progress in the communication standards. A recent SCPI protocol offers already a manufacturer-independent set of commands and is based upon an innovative view of the measuring device [28]. Emerging needs to describe more complex (test) situations resulted in the ATLAS language [33].

Increasing demands amplified the computing components of instruments. All this computing power is spent, however, on virtual instrument systems, extensively developed graphical user interfaces (GUI), high level instrument languages (SCPI) and CAD like software support to put signal processing schemes together. Even LAN facilities newly introduced in [24] are foreseen to support primarily hard copying of the measurement graphics and remote storage of the measurement results.

Controllers of today, paradoxally, exceed actually in many aspects (above all in computing resources and computation speed) the average expert system platforms from some years ago. Yet considering the measurement related expertise, these workstation based controllers are not more intelligent than when HP-IB bus was first introduced. Integration of the measuring systems with components representing more involved measurement knowledge, even expertise, already started [34, 35, 36, 37]. Nevertheless, such developments resulted in locally distributed systems not drawing from the resources of the global network. Research in the geographically distributed measurement equipment started for real only recently and in the following we review the mainstream ideas and applications, Fig. 7.

Remote experiment monitoring. In an interesting and pioneer initiative the measurement data of the BETSCE (Brilliant Eyes Ten-Kelvin Sorptin Cryocooler) experiment, taken into orbit on space shuttle 'Endeavour', was downloaded to Houston. It was then relayed to LabView based system run at Measurement Technology Center at NASA's Jet Propulsion Laboratory in California, then sent to a LabView-based server at National Instruments in Austin, Texas. There the flow of the experiment could be followed minute by minute all over the world on the home pages of the National Instruments InstrumentationWeb (see [38] for a post mortem summary).

Remote signal processing. Remote signal processing, albeit not yet via the global networks, is already widely applied. Every large-scale industrial monitoring and control system processes information collected from the distributed network of sensors in a remote centralized way. The question to switch over to the global network is thus solely of technical character, if the unreliable timeliness of the Internet data transfer poses no problems. Another possibility, coming shortly, is the remote specialized post-processing, with e.g. Matlab toolboxes, at sites, where more able specialists are available and the evaluation of the results can be made on the spot.

Distributed laboratories. Distributing virtual instrument over the Net is similarly straightforward. They are nothing else as signal processing packages, they can be made distributed, downloadable, remotely runnable. The only problem in using the remote virtual instrument library is a satisfactory information about their capabilities (virtual instrument manuals). User, building a measurement set-up must know how it will behave and what side effects to expect.

The idea of a distributed laboratory was introduced in [29]. Designer of a distributed measurement system (DMS) can draw from the set of nodes, i.e. DMS activities, like measurement, interface and configuration, connection, and monitoring and diagnostic nodes. The architecture of the virtual instruments is flexibly solved along object-oriented classes. Connection of geographically remote labs specialized in different measuring fields was realized in [30, 39], permitting the concurrent access of more users on the same measurement set-up. Such development serves first of all educational purposes, making well equipped, but specialized laboratories available for a wider set of user.

Laboratory on demand. An opposite approach is not to connect to existing set-ups, but to create them virtually at the user's site from the remote libraries of LabView components [40]. After composing a suitable set-up model client downloads from the measurement server the required LabView components and the simulation engine to run them in place, creating thus an experimental set-up at the site. Similar is the mobile measurement architecture described in [41], realizing 'laboratory on demand'. Users not only can download single instrument components, but full measurement stations, which interact with DUT via GPIB instruments at the user's site.

Using ideas developed until now, expensive, complex, bulky nonportable measurement equipment (like e.g. VLSI measurement stations, biomedical lab equipment) can be made available to a wide and distant group of users. A client-server architecture described in [42] addresses these needs by providing the user with the necessary architecture and communication means. As a result only the target device has to be moved, e.g. by mail, an alternative clearly superior to the installing of the equipment.

7. Measurement expertise as globally distributed resource

That expertise is needed to perform measurements was clear for a long time [32]. As a consequence designing intelligent measuring systems borrowed extensively from the methods of Artificial Intelligence (AI). AI tools accomplished most in the instrumentation design and the system identification problems [34, 35, 36, 37]. On the whole it became clear that measurement is extremely rich in knowledge, and it requires innovative and joint usage of a number of artificial intelligence and traditional methods.

Traditional intelligent measuring systems were self-contained with respect to the involved expertise. Knowledge was introduced in the design phase and any kind of communication and cooperation between such intelligent systems was out of question. Global network opens for the intelligent measuring system vast sources of knowledge. Instrument data and application note repositories at vendor sites, repositories of the user developed software at other places already exist and will develop intensively in the future [26]. Repositories of 'real' expertise, i.e. direct on-line contact with the renowned specialists, advice seeking and providing in a number of measurement related issues belong still to the future. The key issue here is not the willingness of experts to participate in exchange of information, or the lack of technical means. It is rather the lack of portable and suitably abstract knowledge representation to describe measurement problems in a logical and unambiguous way and to serve as a basis for expertise exchange protocols [31]. Consequently it is rather the field of artificial intelligence where the first breakthrough is expected.

Particularly interesting opportunities emerge from the application of multi-media tools and video-conferencing for measurement related problems. This way expert at the vendor's site can monitor closely the usage of the advanced measurement equipment at the user's site and supervise the topology of the measurement set-up. They can warn about possible side effects, help evaluate results of tests and calibrations finally propose the ways to redesign the measurement to serve better results. For lengthy measurements such contact can happen even in the real-time, if geographical factors, like difference of time zones, or the overloading of network in between won't slow the exchange.

8. Conclusions

Global computer networks offer many opportunities in distributing measurement tasks. Yet it should be kept in mind that in measurement the measured object and the user are strictly tied. The object to be measured is designated by user's modelling aims and only that user can utilize fully the measurement results. Consequently it is rather the expertize and processing facilities which can be meaningfully distributed and which are brought together in particular geographic location and time point by the developed tools to serve particular measurement problem.

The majority of distributed measurement schemes mentioned earlier, albeit technically challenging, makes no use of the true global dimensions of the world computer network. The global character of the world computer network, on the other hand, can be utilized fully in experiment monitoring and maintenance. Interestingly the very first trials (see Point 6.) pointed already in this direction.

Monitoring remote experiments (and generally assisting in measurement maintenance tasks) will yield multiple opportunities for both remote experts and users. An expert will be able e.g. to comment on the course of preparation and execution of the measurement. Less knowledgeable users can observe and learn from the demo measurements organized and demonstrated by the experts. Finally potential customers can participate in 'live' measurement demonstrations ('Virtual Fairs') which present far better basis for the purchase than scanning leaflets and manuals.

Such 'focusing expertise' via the GCN applications is emerging already in medical practice and a number of other areas. In our opinion it will be decisive factor in the measurement culture in the future.

References

[1] The National Information Infrastructure: http://www.aaai.org/Policy/Papers/nii.html

[2] S. Russel and P. Norwig, 'Artificial Intelligence. A Modern Approach,' Prentice Hall Series in Artificial Intelligence, Prentice Hall, New Jersey, 1995

[3] M. Knapik and J. Johnson, Developing Intelligent Agents for Distributed Systems, New York, McGraw-Hill, 1997

[4] A. Waern and S. Gala, 'The common KADS agent model,' Tech. Rep. ESPRIT Project KADS II/ M4/ TR/ SICS/ 005/ V.2.0, Swedish Institute of Computer ' Science and ERITEL, Stockholm, Sweden, Madrid, Spain, Dec. 1993.

[5] M. Minsky and D. Riecken, A conversation with Marvin Minsky about agents,' Comm. of the ACM, vol. 37, no.7, July 1994, pp. 22-29.

[6] Agent-Based Engineering: http://cdr.stanford.edu/NextLink/Expert.html

[7] N.R. Jennings and M.J. Wooldrodge (eds.), Agent Technology, Foundations, Applications, and Markets, Berlin, Springer, 1998

[8] M. Wooldrige and N.R. Jennings, 'Intelligent agents - theory and practice,' Knowledge Engineering Review, vol.10, no. 2, Cambridge University Press, June 1995.

[9] D. M. Chess, C. G. Harrison and A. Kershenbaum, 'Mobile Agents: Are they a good idea? Mobile object systems: toward the programmable Internet,' Springer-Verlag, Lecture Notes in Computer Science No. 1222: 25-45, 1997

[10] P. Morreeale, 'Agents on the move,' IEEE Spectrum, April 1998, pp. 34-41.

[11] S. D. Bird and G. M. Kasper, 'Problem formalization techniques for collaborative systems,' IEEE Trans., Vol SMC-25, no.2, pp. 231-242, Feb 1995.

[12] R. Smith and R. Davis, 'Frameworks for cooperation in distributed problem solving,' IEEE Trans., Vol SMC-11, no.1, pp. 61-70, Jan. 1981.

[13] T. Finin, R. Fritzson, D. McKay and R. McEntire, 'KQML - a language and protocol for knowledge and information exchange', Technical Report CS-94-02, Dept of Computer Science, University of Maryland Baltimore County, 1994.

[14] M. Wooldrige, 'The logical modelling of computational multi-agent systems,' Ph.D. Thesis, Dept of Computation, Manchester Metropolitan University, 1992.
[15] O. Etzioni and D. Weld, 'A softbot-based interface to the Internet,' Comm. of the ACM, vol. 37, no.7, July 1994, pp. 72-76.
[16] J.M. Bradshaw (ed.), Software Agents, Menlo Park, AAAI Press/ The MIT Press, 1997
[17] R. Otte, 'Understanding CORBA,' Prentice Hall, 1996.
[18] R. Orfali, D. Harkey and J. Edwards, 'The Essential Distributed Objects Survival Guide,' John Wiley & Sons, Inc., 1996.
[19] R. Orfali, D. Harkey and J. Edwards, 'The Essential Client/Server Survival Guide,' Second Edition, John Wiley & Sons, Inc., 1996.
[20] W. R. Stanek, 'Web Publishing,' Professional Reference Edition, Sams.net Publishing, 1997.
[21] The Virtual Reality Modeling Language, VRML: http://www.vrml.org/vrb/
[22] K. Arnold and J. Gosling, 'The Java™ Programming Language,' Second Edition, Addison Wesley Longman Computer & Engineering Publishing Group, 1998
[23] Hewlett-Packard Test & Measurement Catalog 1995.
[24] Hewlet-Packard HP 54800 Infiniium Oscilloscopes, Test and Measurement Catalog, 1999
[25] T.P. Dobrowiecki, et al., 'Will Measurement Instruments Turn Into Agents?' Proc. of the IMTC/96 Conference, Brussels, June 4-6, 1996, pp. 1365-1368.
[26] Measurement Resources on the Internet (a digest)

http://www.hp.com/	"Hewlett-Packard"
http://www.natinst.com/	"National Instruments"
http://www.keithley.com/	"Keithley, Inc."
http://www.tek.com/	"Tektronix, Inc."

[27] T P. Dobrowiecki and T. Mészáros, 'Measuring Systems in the Age of Global Computer Networks,' Proc. of the VI Int'l Metrological Seminar, Rzeszów, Oct 26-28, 1998, pp. 49-48
[28] Standard Commands for Programmable Instruments - SCPI 1991, Version 1991.0.
[29] P. Arpaia et al., 'A distributed laboratory based on object-oriented measurement systems,' Proc. of the IMTC/96 Conference, Brussels, June 4-6, 1996, pp. 27-32.
[30] F. Cennamo, et al., 'A measurement laboratory on geographic network for remote test experiments,' Proc. of the IMTC/98 Conf., St. Paul, May 18-21, 1998, pp. 206-209.
[31] Z. Papp, H. J. Hoeve and A. Bos, 'A System Architecture for Distributed Implementation of Virtual Measurement System, IEEE Engineering of Computer Based Systems Symposium and Workshop - ECBS'99, March 7-12, 1999, Nashville
[32] G. Zingales and C. Narduzzi, 'The role of artificial intelligence in measurement,' in IMEKO TC7 Int'l Symp. on AIMaC'91, Kyoto, 1991, pp. 3-11.
[33] IEEE Guide to the Use of ATLAS, IEEE Inc., 1980.
[34] S. Gentile, A.Y. Barraud and K. Szafnicki, 'SEXI: an expert identification package,' Automatica, vol. 6, no. 4, pp. 803-809, 1990.
[35] M.Haest, G. Bastin, M. Gevers and V. Wertz, 'ESPION: an expert system for system identification,' Automatica, vol.26, no.1, pp. 85-95, 1990.
[36] F. Louage and T.P. Dobrowiecki, 'An automated measurement and identification environment,' Proc.of the 10th IFAC Symp. on System Ident. - SYSID '94, vol. 2, Copenhagen, July 4-6, 1994, pp. 453-458.
[37] A. Niederlinski, J. Kasprzyk, and J. Figwer, 'A PC Instrument for Process Identification,' Proc. of the 2nd Int'l Sem. MSN'92, Gliwice, Sept 24-25, 1992, pp. 63-79.
[38] BETSCE Experiment: http://www.natinst.com/shuttle/data.htm
[39] Networked Instructional Instrumentation Facility: http://www.mal.eecs.uic.edu/networke.htm
[40] A. Ferrero, V. Piuri, 'A simulation tool for virtual laboratory experiments in a WWW environment,' Proc. of the IMTC/98 Conference, St. Paul, May 18-21, 1998, pp. 102-107.
[41] L. Nigro, G. Fortino, and D. Grimaldi, 'Multicast Mobile Measurement Architecture,' Proc. of the IMTC/98 Conference, St. Paul, May 18-21, 1998, pp. 108-114.
[42] M. Bertocco, C. Offelli, 'A client-server architecture for distributed measurement systems,' Proc. of the IMTC/98 Conference, St. Paul, May 18-21, 1998, pp. 67-72.

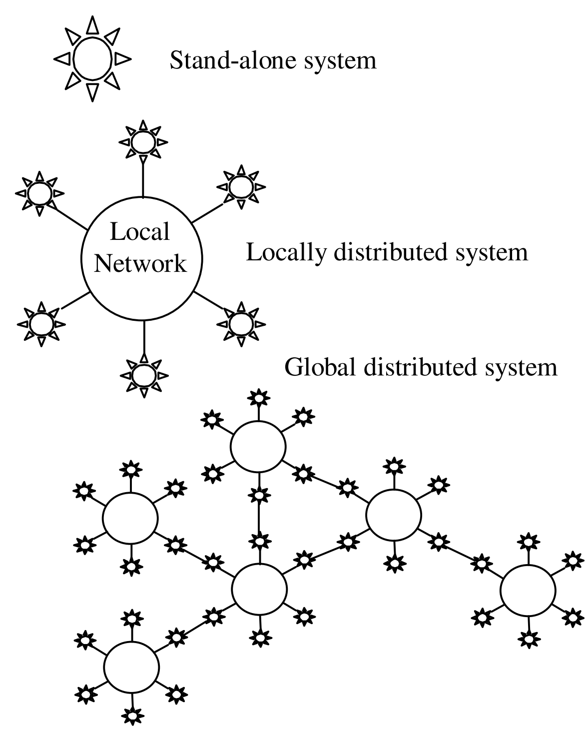

Fig. 1. Qualitative leap in the distributiveness of traditional DAI (Distributed Artificial Intelliegnce) systems vs. systems on the GCN (Global Computer Networks).

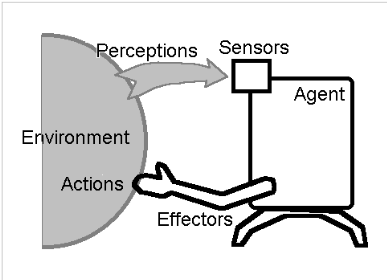

Fig. 2. Agent and its environment (after [2]).

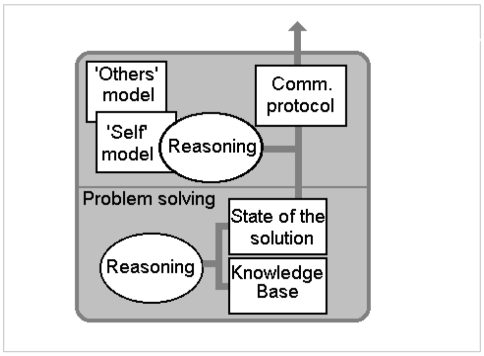

Fig. 3. Components of agent's knowledge.

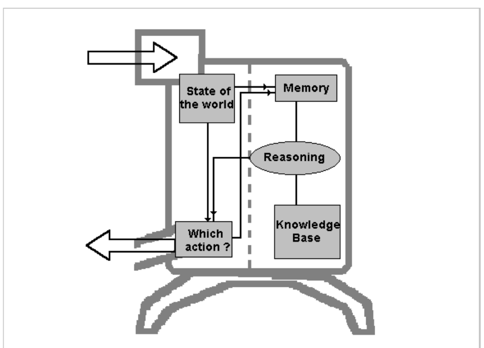

Fig. 4. General architecture of a hybrid agent.

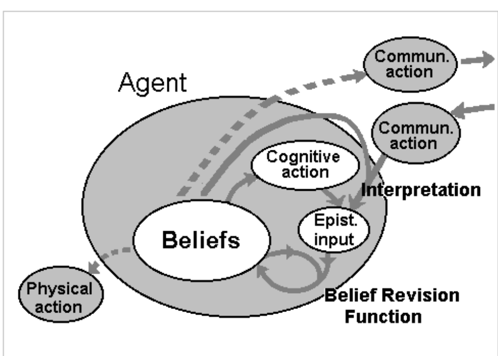

Fig. 5. Effect of agent's actions (after [8]).

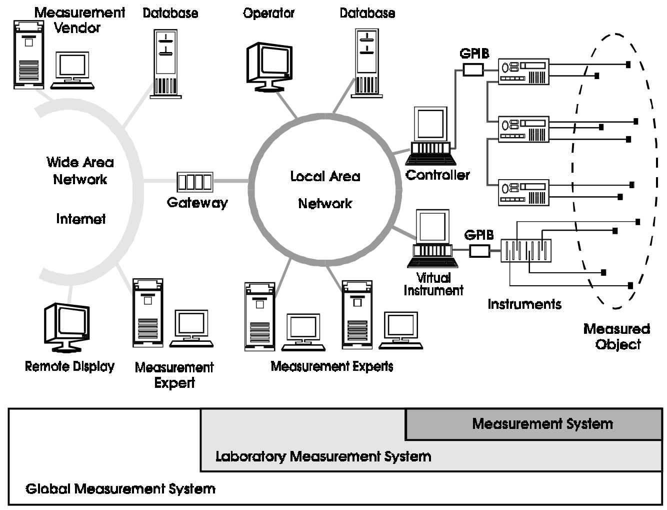

Fig. 6. Global computer network - based hierarchy of measuring systems [25].

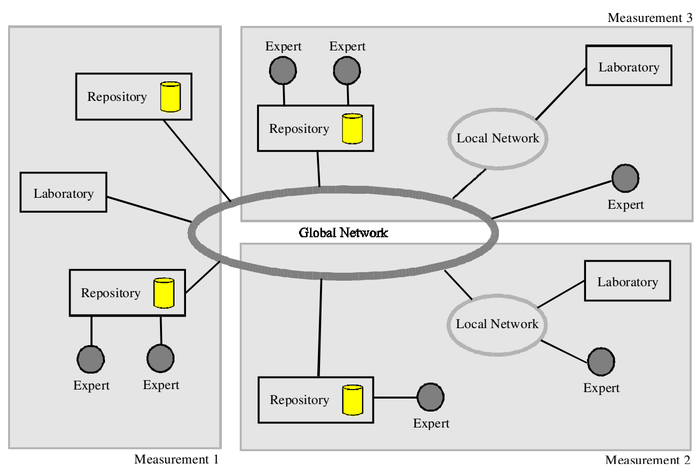

Fig. 7. Various configurations of GCN-based measurement schemes.