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Will Measurement Instruments Turn into Agents ?

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***Abstract* - Authors investigate implications of agent based software engineering and Internet environment in measurement practice. Measurement 'minded' expert agents and instrument-as-agent approach offer numerous advantages. It would require however reconsideration of certain properties of the measuring equipment and the role of the system controller.**

I. MEASUREMENT AND AI·

Advances in both fields suggest that Measurement and Artificial Intelligence (AI) should be in tune with each other, however they are not. Recent results in Distributed Artificial Intelligence (DAI) and shift of perspective regarding the nature of cooperative problem solving add only to the problem [1,20].

Research in measurement culminated in the recognition of its basic role as knowledge acquisition component in modeling. This led consequently to a wider notion of the measurement and to formulation of a formal theory [5]. It became clear that measuring equipment is involved in information processing at various levels of abstraction and that at least from that point of view instruments and computers are alike [5,6].

AI entered the picture when the increasing complexity of problems brought into focus qualitative aspects of measurable objects. Knowledge representation, symbolic signal processing, nonanalytic means of modeling measurement uncertainty, and many other issues received deserved attention and, in certain domains at least, became approved tools of solving measurement problems [6]. AI tools accomplished most in instrumentation design and system identification tasks [7-9,17]. On the whole it became clear that measurement is an extremely knowledge intensive area wich requires innovative and joint usage of a number of AI and traditional methods [22,26].

II. COMMUNICATION AND COOPERATION

Measuring equipment belongs obviously to the category of distributed systems. Sophisticated measurement problems lead to a natural physical or conceptual decomposition of tasks and thus to design of distributed measuring systems. Architecture of such systems is still traditional and stiff. Controllers govern over teams of instruments, bring them with relatively low level commands into predefined states and accept relatively simple data structures.

This characteristics of measuring systems did not change much despite a steady progress in communication standards. Recent SCPI protocol [21] offers already a manufacturer independent set of commands and is based upon an innovative structuring of the measuring device. Emerging need to describe more complex situations resulted in ATLAS language [13], with an interesting period of joint ATLAS / AI development in the 80's [18].

Increasing demands amplified the computing component of instruments. Today it is not uncommon that measuring systems are organized around RISC architecture workstations. Regarding however, how all this computing power is spent the present is dominated by (albeit next generation) virtual instrument systems, extensively developed graphical user interfaces (GUI), high level instrument languages (SCPI) and CAD like software support to put together signal processing schemes [14].

Controllers of today exceed actually in many respects (above all in computing resources and computation speed) average expert system platforms from 5 years ago. Still when it comes to undertake the measurement technical expertise these workstation based controllers are not more intelligent than when HP-IB bus was first introduced.

III. INTERNET AND ITS AGENTS

In measurement presence of Internet was until recently difficult to notice. World-wide network of informational resources offered nothing serious to the users of

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specialized measuring equipment. For Unix or Windows based workstation controllers however Internet, albeit supported with different commands and software packages, means a physically existing, real environment, just as real as their GPIB instruments or signal processing paths realized within a 'custom-designed' virtual measuring system.

Internet environment gave birth to a new category of systems - intelligent agents. Agents are autonomous, cognitive, reasoning and first of all communicating systems [1,4]. General idea is ordering a service and delegating any responsibility of direct control, rather than monitoring closely the progress of the problem solving (as a real agent is authorized to act on another person's behalf). The truth is that an intelligent system embedded in a physical environment of Internet dimensions is simply too difficult to follow. As put by M. Minsky: “You call it an agent when you want to treat it as a black box.” [2].

Until recently typical agent applications were confined to information management in the so called Cyberspace (Internet environment), like e.g. [3]:
- 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,
- other categories like system event monitoring agents or electronic secretaries (e.g. in White House).

Research in agents brought up various notions of agency [24,25]. In technically most appealing weak notion an agent means a system which is [23,24,25]:
- autonomous: operating without direct human control,
- concurrent: executing independently of other agents,
- social: operating in connection to people or other agents,
- reactive: i.e. responsive to the events in its environment,
- proactive: operating purposefully, even if not requested for a particular service.

Interesting secondary characteristics involve being [19]:
- mobile: able to change place physically or virtually,
- friendly: trying to fulfill best external queries,
- rational: intending to fulfill its aims, and
- veritable: intentionally providing true information.

Idea of an autonomous, reactive and above all proactive system is particularly appealing. It defines a ‘restless’ system actively seeking means to fulfill its tasks, entering into cooperation, evading conflicts and generally striving for a balanced providing of services and economically managing its resources.

Strong agency draws more from human properties. It is accepted that an agent can express opinions, have intentions, commitments, desires, obligations or duties. Emotional agents can demonstrate also human like emotions, e.g. irritation, resentment or just contentment. Although unfamiliar to a traditional software engineer this intentional stance is an abstraction tool - a convenient way of talking about complex systems, which allows to predict and explain their behavior without having to understand how the mechanism actually works [24]. Intentional agents did not see yet serious applications, on the other hand ‘weak’ agents had been and are designed already for a number of challenging industrial problems, e.g.: communication network management, computer controlled manufacturing, organization of delivery, air traffic control, hospital information systems, patient monitoring, etc. [12] A separate research topic is the realization of ‘agentized’ versions of existing expert systems.

IV. EXPERT AGENTS IN MEASUREMENT

Controller connected to Internet makes it possible to specify a variety of measurement related agents (Fig. 2). Some of them are direct applications of already clarified ideas, other require deeper analysis and reconsideration of the roles played by the controller and instruments during the measurement.

A. Information Providers and Filters

Year 1995 marked the point when measurement information appeared purposefully and in mass on Internet [10,11] (Fig.1). Public domain resources comprise for a moment only instrument libraries, ordering information, financial and management press releases, application notes and typically links to related organizations and data banks. Certain vendors act already as clearing houses 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.

This kind of information is what searching, mediating and providing agents are about. Client agents (resident on system controllers) will seek solutions to the user’s problems, agents at vendor sites could support measurement “virtual reality”, e.g. distant measurement and instrument training, courses, expert multimedia consultations, or virtual measurement situations.

B. Expertise Retrieval

A truly interesting topic is the retrieval of measurement technical expertise. Agents should be able to inspect description of software packages, applications, compatible data about similar instruments. They would pick problem description (measurement task) at client site and then would start looking for experts, interviewing them for the possible set-ups, flow of control, or interpretation of the data. Another possibility is to circularize measurement results together with the description of measurement itself, to seek help in the interpretation of the data.

Expertise seeking agents exist still only on the paper. The primary bottleneck is not the development of an agent itself, rather portable symbolic formulation of the measurement problem is yet rudimentary.

Strictly related to the previous ideas is the notion of a 'mobile' measurement. Measurement data, obtained already in the past and stored for better signal processing packages, or for a particular development in theory can be dispatched to places of better expertise or better methodological support. There it can be measured with virtual instruments and interpreted on the spot.

C. System-Controller-as-Agent

If the information retrieving agents are within reach, the possible agency of system controller requires deeper consideration. Controller exists at the border of three physical environments - GPIB (SCPI) instrument society, users, and other information systems. Expert user who knows how and would like to exercise direct control over the measurement process does not and possibly never will require any support of agent-like features.

Controller-as-agent idea is promising rather to an interdisciplinary user exploring the possibility of measurement in his research field but not necessarily at home in today's instrumentation. Such controller would accept a problem, discuss it with the user, then would seek via other agents information leading to an adequate specification of the measurement set-up. In consequence it would be up to controller to fetch and adapt or automatically generate control command sequences and interpret the measurement results for possible inconsistencies or signs of trouble.

Much of existing measurement expert systems [6,8,9,17] or also recent development in object-oriented organization of real-time measurement scheduling fit well the above considerations. A real question is a new kind of user interface and a protocol at much more higher level of abstraction. Such protocol must draw from the research on cooperating intelligent systems but it should be also excessively tailored to the specific measurement characteristics.

D. Agent-In-Instrument

Will it be ever needed? Communication with today's instruments is based on the assumption that the controller knows exactly what a particular instrument is able to do. On the other hand, if there is no severe programming error, the instruments will always do as told.

Agent-like instrument would accept description of a task rather than a command. Furthermore being sent a task does not necessarily mean that controller is convinced that it can be done by this particular instrument at all, or perhaps under what kind of additional constraints. Intelligent instrument, being aware of its own functionality, would interpret the problem and evaluate for the controller or similar instruments the prospects of the measurement or the reason why it should refuse the task. In consequence all lower level command sequences would have to be generated within the instrument itself.

Simple instruments do not require this kind of sophisticated design. In complex instrumentation however much of essential know-how is not even contained in manuals. The best place to confine instrument related knowledge would be the instrument itself, able to notify the controller and to influence thus the course of the measurement design. In consequence the highest level of the communication would be based on bid-and-contract, than on present command-and-execute scheme.

In a sense SCPI specification, assuring consistency of the request with the functionality of the instrument rather, than with its particular realization, took step in this direction. Further step exploring the advantages of agency would be a truly programmable instrument equipped with an interface transparent to SCPI commands to assure compatibility, but able also to accept software packages for execusion from the controller. That way another layer of measurement protocol could be easily established and verified.

V. SUMMARY

Communication links in controllers, high level graphics, embedded computers in instruments - all required hardware and much of software is already in place. Intelligent and distributed equipment, aware of its functionality, contracting tasks, communicating, sharing knowledge - is it what we would demand from an instrument in the future? Automated manufacturing processes, space research, unmanned measuring stations, etc. make such development very attractive. Agency is however only one of possible directions. It requires a new view on the information exchange during, but also prior to the measurement and the reconsideration of the role of the system controller.

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http://hpcc998.external.hp.com/pressrel/home.html *"HP Press Releases"*
http://www.natinst.com/Catalog/GPIBcat/4011/4011.htm *"Introduction to GPIB: from 1965 HP-IB to SCIPI and HS488"*
http://www.natinst.com/links.htm *"Internet resources for instrumentation"*
http://www.keithley.com/ *"Keithley, Inc., Home page"*
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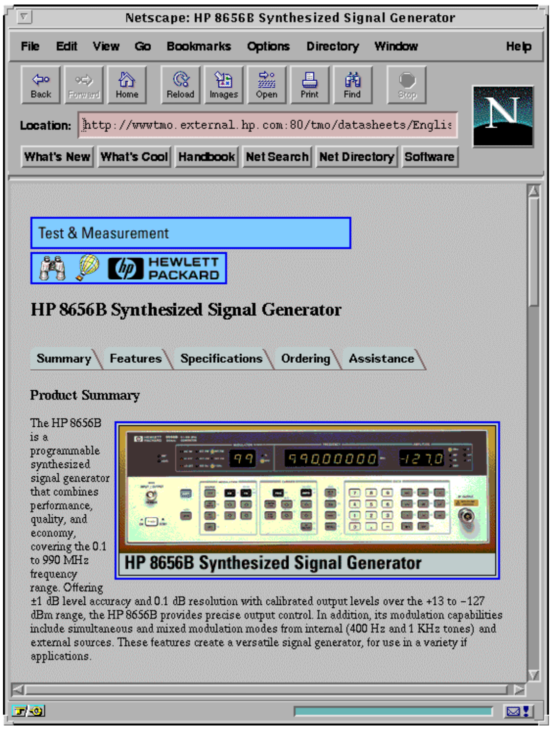

Fig. 1. One of Hewlett-Packard Internet Resources [11]

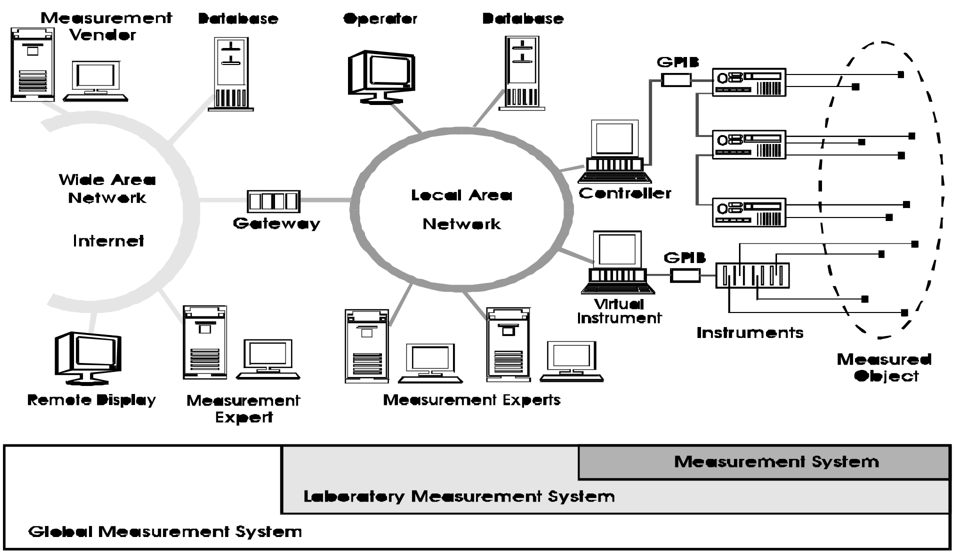

Fig. 2. From instruments global information system