Software Technology for Distributed Multimedia Systems: Can AI help?

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Abstract

A look at current trends in information technology, in telecommunication and in consumer electronics shows that *distributed multimedia systems (DMS)* are a common and very fast-growing domain of all three markets. Appropriate *software technology*, especially for the development of *applications* of such DMS, can easily be identified to be crucial for the speed of this development.

The presentation is drawing from many years of experience in software technology for distributed applications, and from some two years of experience with multimedia support software. Based on this experience, the major requirements and coarse architectural considerations for a *software engineering environment and programming paradigm for DMS applications* are developed.

The proposed point of discussion for the workshop is the question: where can AI help in this context? As a basis, we first try to point out areas in the above described architecture where we see AI technology and DMS software technology to *come 'naturally' together*; in addition, fields are described where current approaches seem to be insufficient for solving the problems of DMS software technology; these are the areas where we seek *help* from AI.

The presentation can roughly be outlined as follows:

1. DMS as a logical consequence of the developments in IT, Telecommunication, and consumer electronics.
2. Requirements and concepts for a software engineering environment and programming paradigm for DMS applications.
3. Limits of current approaches, relations to AI; open issues.

Multimedia and Communication: Fields of Research

Max Mühlhäuser

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1 Overview

Future communication networks are largely impacted by the integration of information technology, telecommunication, and multimedia aspects, the latter traditionally being a domain of consumer electronics.

In the remainder, a "network vision" is developed first. Fields of research in information technology are extracted from this vision. These fields are considered crucial on the path towards "intelligent" multimedia networks with value added services and complex applications.

2 Background

Visionary workstation technicians have long recognized the development towards multimedia workstations. Visionary networkers have also long recognized the need to adapt communication protocols to the requirements of multimedia traffic. We believe, however, that those lines of thoughts are too narrowminded to serve as a design centre for an enterprise computing vision of the nineties. We therefore want to lean back a bit further and take a more general view as follows:

The 80es were marked by the breathtaking micro-electronics development where cost reduction and scale-down enabled the introduction of information technology into virtually every market segment.

The 90es will be marked by the seamless integration of three domains - or branches of the industry - which are up to now considered largely separate:

- information technology,
- telecommunication, and
- consumer electronics.

As an example, let us look at and extrapolate the development of integrated services digital networks (ISDN), considered as a major industry promoter in Europe.

1. Narrow-band ISDN integrates mainly existing telematic services (phone, fax, VTX etc.) and introduces the "communication socket on the wall" for multiple or multi-functional terminal equipment.
2. Broadband ISDN (B-ISDN) enables the general introduction and integration of high-quality individualized video-communication. It has been recognized that the successful integration of information technology and video communication depends heavily on the use of parts from the consumer electronics industry. Only the vast consumer electronics market has a learning curve steep enough to make high quality digital video equipment easily affordable. In other words, only a co-ordinated development in the three domains "HDTV", "Workstations" and "B-ISDN" can create an attractive multimedia market. [1]
3. The extrapolation of this development beyond the current B-ISDN plans leads us to value-added services and networks in the multimedia context. This means that in addition to multimedia transport, the network now offers multimedia information processing and storage. On one hand, very generic services can be imagined, like network transparent supercomputer access. On the other hand, very specialised services can be imagined like - to cite an arbitrary example - a press agency service. (Such an agency service could accept video news from individual journalists, could process digitized video information for quality enhancement, could compress the digitized video for efficient transmission, store and classify news for easy retrieval, and offer it to TV-stations or even end-users. Being "value-added," the service would be offered by the network provider). Along with the introduction of multimedia value-added services, the transport characteristics of the network would have to change, too: the current point-to-point traffic pattern of distributed applications and the current uni-directional broadcast pattern of TV and radio would be replaced by, or become a special case of, a generic n-to-m cooperation pattern (see below).
   This kind of value-added ISDN shall be called V-ISDN in the remainder.

Instead of extrapolating the ISDN (Telecommunication) development, we could have extrapolated the TV (consumer electronics) development - towards digitized video, intelligent terminal equipment, interactive video and on-line storage - or that of workstations (information technology) - towards multimedia and integrated network solutions - all leading to the same vision.

[1] In order to fully exploit video transmission and display technology, it has to be accompanied by affordable storage technology; this area might in analogy be covered by consumer electronics developments like CD-I with an ISO compression standard according to MPEC plus writeable CD technology.

ion patterns (the characteristic of current TV and radio broadcast facilities) will evolve into general n <-> m-communication patterns. But cooperation also means that the view of isolated interaction points - which were regarded independent of other actions of the communicating parties - are no more sufficient to describe complex interactions between many parties; cooperation services will therefore be introduced, capable of understanding and supporting whole sequences of interactions between different parties; cooperation services will somewhat resemble current communication protocols, but they will be more flexible (n<->m-communication, dynamic changes of topology etc.) and they will be able to depend on actions of the parties involved.

- "Intelligence" will be introduced into cooperation services in two ways:
  - Expert system technology will be used to help develop and optimize cooperation services (e.g. for transforming high-level interaction-facilities into efficient realizations on a given physical topology).
  - Cooperating instances will themselves be expert systems in part, to be loosely coupled with other instances. This means that cooperation services will have to be prepared for cooperation with and among expert systems.

- The assignment of end-users <-> terminal equipment <-> service access points will be much more flexible. V-ISDN will allow, for example, to plug in portable terminal equipment at every "place in the world" or to assign terminal equipment to an end-user and its accounting flexibly.

- The meaning of an "addressable item" or "service user" has to change: neither terminal equipment (like with the telephone system) nor todays operating system processes (as with present communication protocols) are sufficient in a V-ISDN scenario. Instead, the primary addressable object will be a mobile autonomous entity, more precisely a "mobile autonomous multimedia persistent object", for which we want to define the term **item**. Some desirable characteristics of **items** are as follows: **items** can be hierarchically structured with the finest granularity resembling that of small procedures. **Items** contain descriptions about their behaviour (dynamics, "code") plus their state (statics, persistence) plus their appearance (user interaction). **Items** are very mobile: within a single session they can migrate and replicate between terminal equipment (regarding the network as a cooperation facility) or between terminal equipment and the network (regarding the value added functionality of the network). Modern network services require a degree of reliability and efficiency which can hardly be reached without such a kind of mobile **items**.
  Items will inherit some of the findings of current research on distributed object-oriented systems: encapsulation, class-hierarchy, mobility, fine granularity, and inheritance. They will also inherit some of the research findings of hypermedia systems: persistency, hierarchy, and multimedia aspects.

- The spectrum of service providers and service users in a V-ISDN network will comprise terminal equipment with the most varying functionality (and thereby most different **items**, too) and the functionality of a single service will evolve over its lifetime. This means that services and terminal equipment will be developed at a much faster rate than the current standardization process for communication serv-

3 Implications for Software Technology

If an organisational or political entity wants to take part in the V-ISDN development as sketched, the primary concern should be that of the "critical path", i.e. the most relevant research and development domains to concentrate on and invest in.

In order to find these domains, we have to look at the three industry segments which influence the V-ISDN development (whatever its real name will be). Consumer electronics does not seem to be the most critical domain, since - despite all political issues - HDTV and individualized digital TV are already today to considerably extend technically sound. The European ISDN initiatives show that telecommunication is not the critical path either. Remains information technology. As far as hardware is concerned, the workstation market is uncritical due to its extremely fast innovation cycles.[1] The real critical domain is therefore support software: multimedia services and applications, especially architectures, concepts, and development methods and tools. We will see that even new ways for the *standardization* of such applications and services are necessary. The long unresolved software crisis, being aggravated in the area of parallel and distributed software, makes it obvious that appropriate software technology is a major requirement for V-ISDN and the dominating factor in the competition about the distributed multimedia processing market of the nineties.

It seems that Europe, with its traditional strength in conceptional research and method development, may play a very important role in this domain where new concepts and methods are lacking most. In order to discuss the necessary developments in more detail, we want to make our V-ISDN vision a bit more concrete.

4 Scenario

There are natural analogies between a) the network and the terminal equipment of V-ISDN and b) the network and terminal equipment of our present telephone system:

- every standard end-user can have access to (in essence) the identical network functionality;
- transport services and value added services are offered within one single network;
- larger organisational entities may dispose of autonomous subnetworks, maybe with enhanced functionality (telephone: PBX-systems; V-ISDN: merging of LAN-technology and PABX-technology into future V-ISDN-PABX systems)

But there are also formerly unknown developments and evolutions in the characteristics of future V-ISDN-systems:

- The interaction patterns of the transport infrastructure will evolve from what can be called "communication patterns" to "cooperation patterns". This term means on one hand that, as mentioned above, point-to-point communication (as offered presently by typical telephone and telecommunication services) and 1->n-communicat-

[1] Despite the fact that the current "MIPS-boost" will have to be replaced by balanced processing / storage / network / graphics performance of future workstation generations

ices would allow. As a consequence a small number of thoroughly defined service interfaces, controlled by a large standardization body, is no more sufficient. Flexible and extendable interfaces and protocols will be necessary, even dynamically defined protocols. But if extendability shall not mean underspecification of the service ("too many things cannot yet be precisely defined"), then the semantics of the cooperation (e.g., document exchange) and the (up to now strictly transparent) user data have to be reflected in the service specification. First tiny steps of moving from communication to cooperation and of reflecting cooperation and user data semantics have been done in the standardization bodies (cf. X. 400 series). However, it will become clear in the remainder that significant steps towards greater flexibility and extendibility are needed in order to prepare for V-ISDN.

The characteristics of a visionary V-ISDN network are illustrated in a scenario called "remote control" according to figure 1. Imagine a non-specified number of pairs of digital video cameras and process control devices on one side and a process monitoring system on the other side. The digital video information shall first be processed in an **item** "event filter", automatically recognizing and extracting relevant events. Those relevant events are then processed in a **item** "quality enhancement/compression" for better visibility of the information and more efficient transmission. From this **item**, the digital video information is transmitted in parallel to an archive and to the multimedia process monitoring system. The users of this system can zoom or pan the cameras (**item** "camera control"). In addition to the digital video information, they can see a graphical display of the measurements and influence the controlled technical process (**item** "process control").

Note the following relevant aspects of the scenario described:

- Separation and encapsulation of a (long-living, cooperative multimedia) communication,
- Unique semantics for the description of and easy transition between distributed applications, application services and value-added services, depending only on the "border lines" defined (closed vs. open vs. public & open),
- Handling of dynamics and asynchrony (Imagine, e.g. a dynamically changing number of pairs "camera/control device"),
- Introduction of "mobile sub-items" (at deeper abstraction levels, cf. figure 2 and description below).

Those aspects become evident through the following trends which our scenario helps to motivate:

- The "internal wiring" of **items**, (cf. "wiring" of "control" **items** and external devices) is long living, complex and dynamic and requires a sophisticated concept "cooperation" for an integrated treatment.
- Apart from their being rather open or rather closed systems, respectively, services and applications do not differ drastically any more. In the scenario for instance, it is largely a business decision whether or not to transform the (non-public) *service* "remote control" into a general *value-added service* to be used in object supervi-

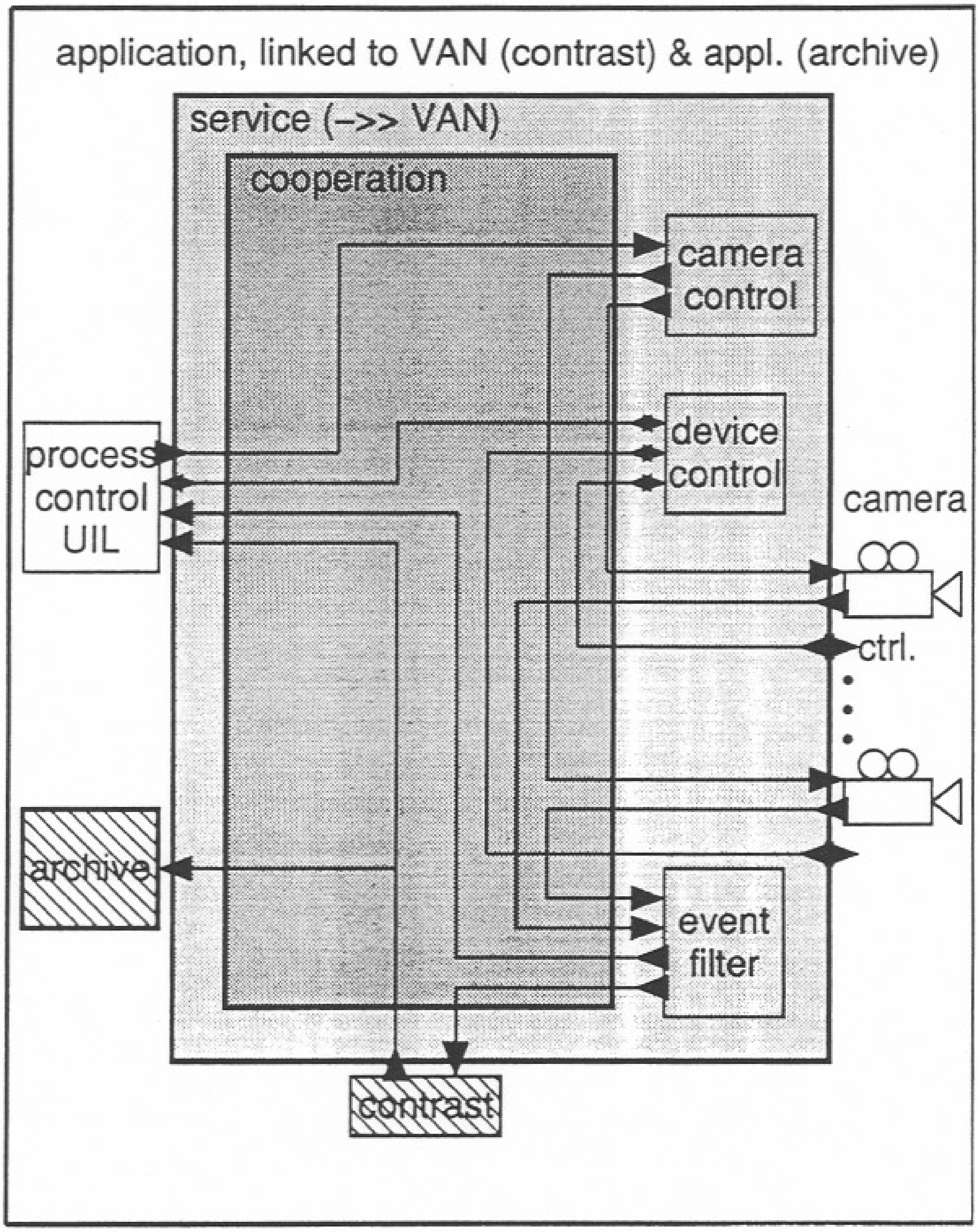

Figure 1: cooperation in distributed application & V.A.N.

sion / security control contexts. It it obvious that such a service cannot be subject of nowadays long-term standardization processes. On the other hand, interoperability among different services and between services and application has to be

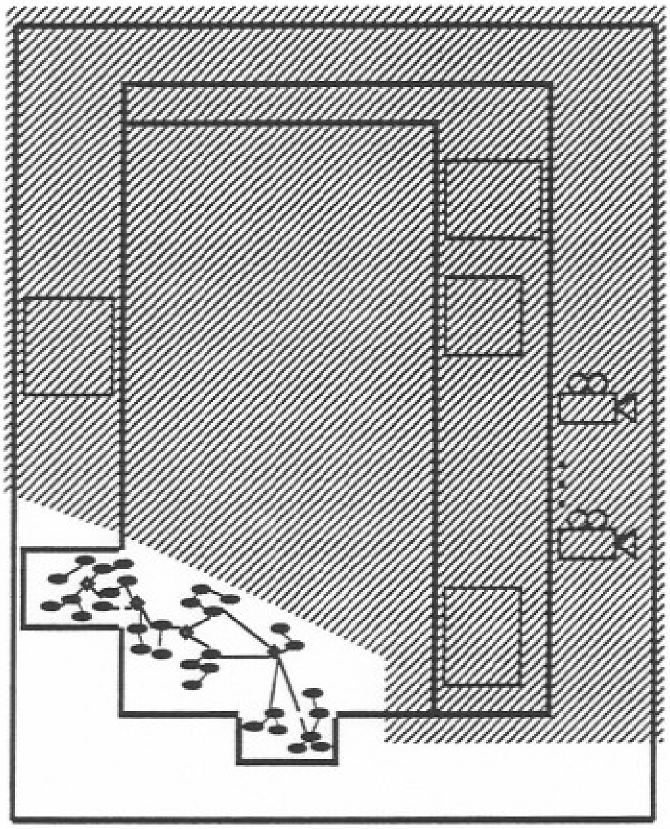

Figure 2: items on abstraction level 2, partial display

assured. This underlines our requirement for new ways of dynamic protocol specifications.

- The "long-living" character of a session in a service like "remote control" does not allow fixed assignment of items to physial equipment (network notes). Replicability and migratability are obviously essential requirements.
- item "event filter" can only be defined as part of a general (value-added) service when the semantis of the scenes (captured by the cameras) and of the relevant events can be defined flexibly and different for each kind for application. The same is true for item "control".

Figure 2 shows the same application as figure 1, in part one abstraction level deeper; it illustrates the fact that items (sub-items) as well as cooperations (cf. the small diamonds) exist on different levels of abstraction. It also motivates migratability and replication of small, mobile items.

5 Summary of Requirements

The following list of requirements can be extracted from the chapters before. They represent at the same time a list of relevant research domains which form a critical path on the way to the technology argued about in chapter 2:

1. Generic semantics of multimedia cooperation
    1. Atomic cooperation primitives
    2. Hierarchical description of complex n-party cooperations and of their relations to the controll flow of autonomous entities.
    3. Semantics of multimedia information (Relations to up-coming multimedia document standards)
    4. Semantics of distributed multimedia information processing
    5. Configuration of terminal equipment with variable functionality
    6. Extendability of the functionality of terminal equipment
    7. Integration of the above points into a generic semantical framework, and into-concepts and architecture for tools for definition and generation of cooperations
2. Intelligent cooperation
    1. "Intelligent" transformation of high-level cooperation definition into efficient implementation
    2. Extension of the cooperation semantics for consideration of expert systems as instances
3. Methodology and development support for **items**
    1. Conceptual modelling of present hypermedia and object-oriented systems with the goal of a synthesis and extension towards **items**
    2. Semantics for multimedia mobile autonomous persistent objects (**items**)
    3. Syntactic and linguistic support for (hierarchies of) **items**
    4. Architecture and concepts for software engineering environments on the basis of **items**
    5. Runtime support for **items**
    6. Tool support for the development and runtime support of **items**
4. Extension of layer 7 of the reference model "open systems"
    1. Introduction of **items**
    2. Flexible addressing and naming capable to support replication and migration. Dynamic assignment of service users (accounting, authentification), terminal equipment (identification, quality of service) and value-added services
    3. Dynamic definition and extension of protocols on the basis of the semantics for cooperation and **items** according to main points 1 and 2 as above

Towards Item-Oriented Programming:

Developing Distributed Multimedia Applications in Intelligent Networks

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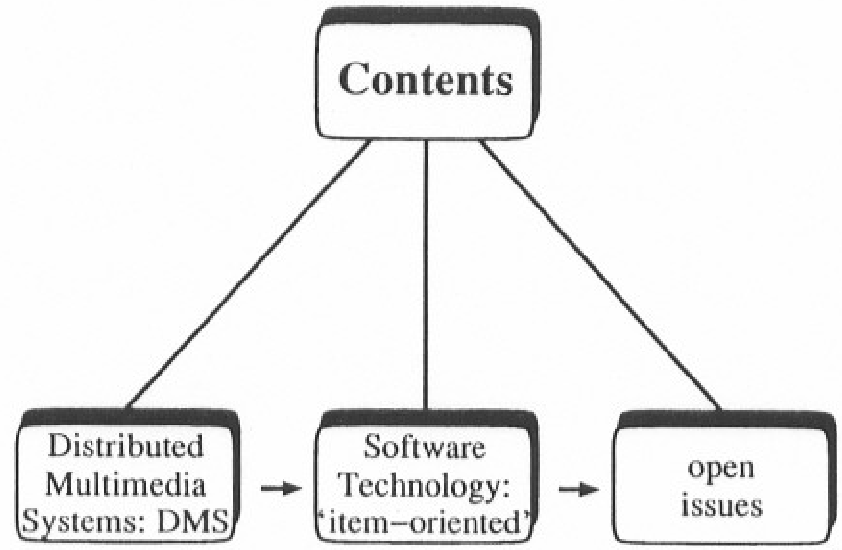
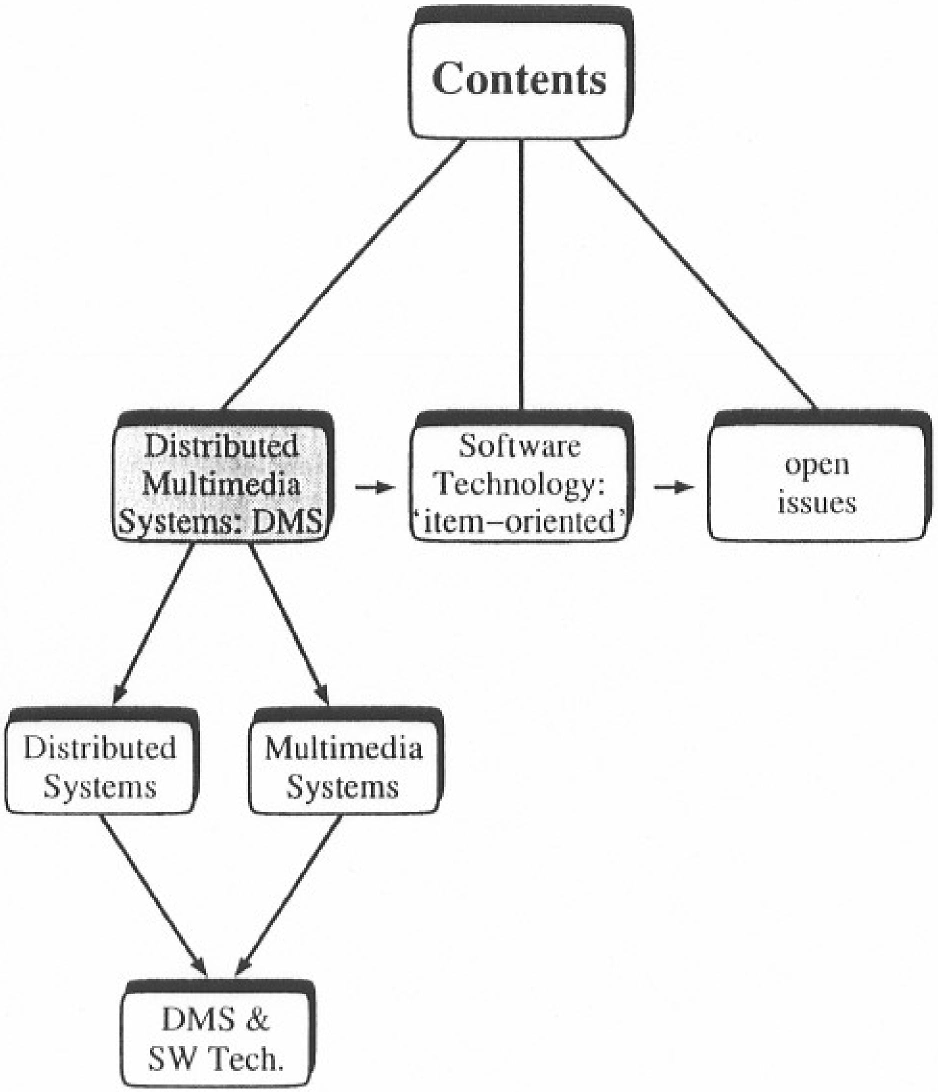


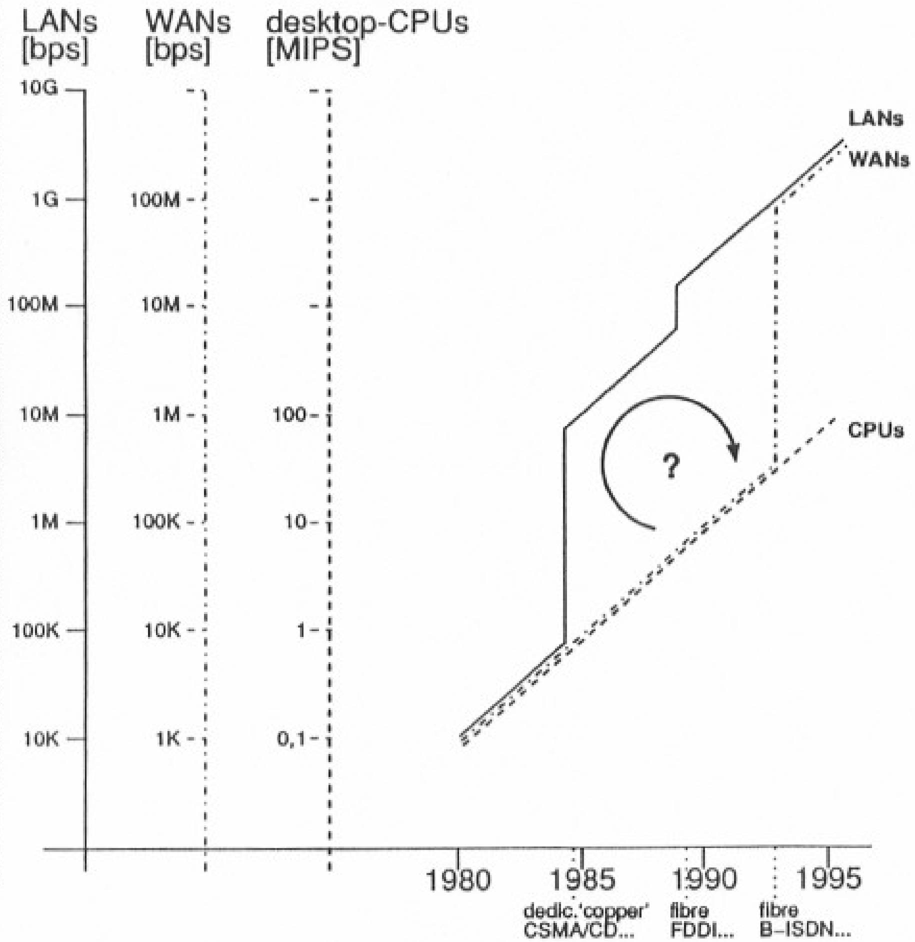


Distributed Systems

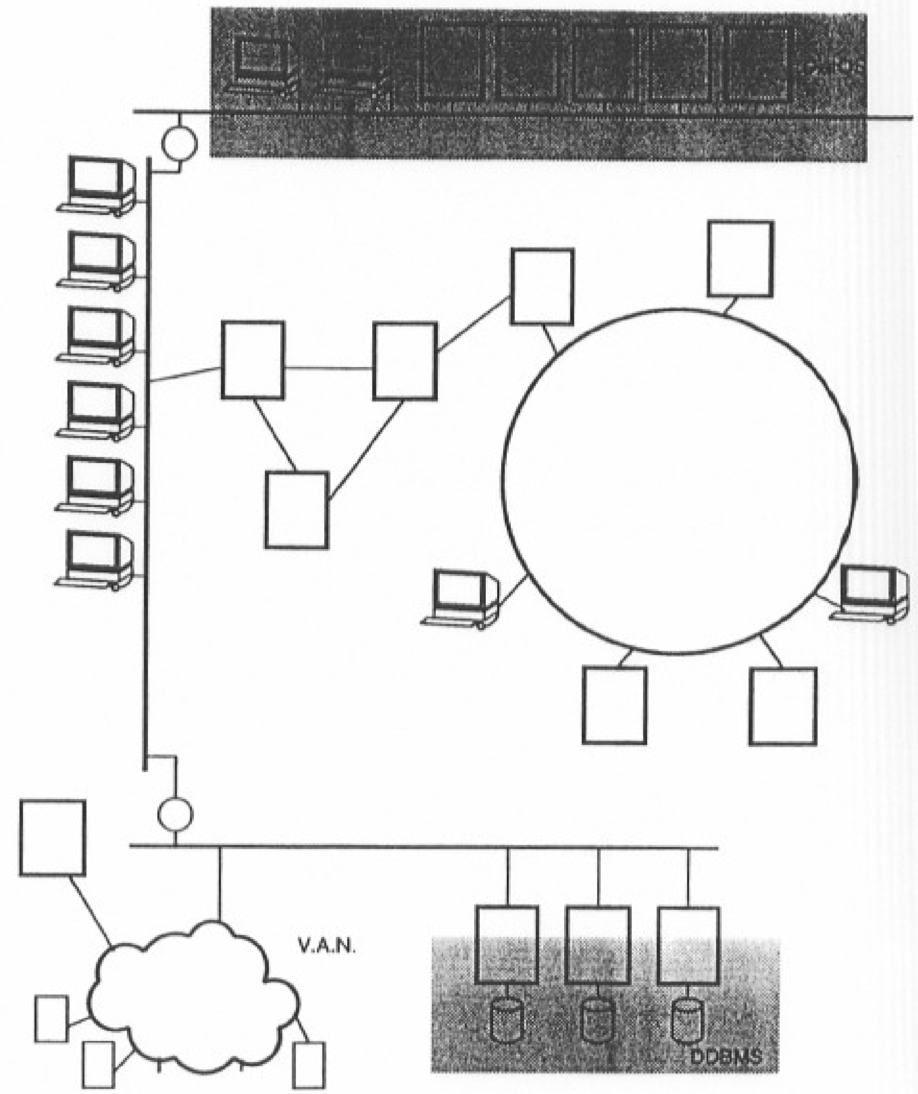
- Technology Push:
  - » communication 'bandwidth leaps': cheap distr. processing
  - » workstations replace PCs: integrated desktop computing
  - » 'the network is the system': very large networks VLNs
- Application Pull:
  - » 'integrating the enterprise' (data *and* work flow)
    -> integrated distributed applications
  - » 'global economy'
    -> telecooperation (distributed CSCW [cooperative work])
- Software Gap: *distributed applications*
  - » *linguistic support* (design, programming)
  - » *development support* (environments, toolsets)
  - » *system support* (very large networks, operating systems...)

Communication Bandwidth Leaps

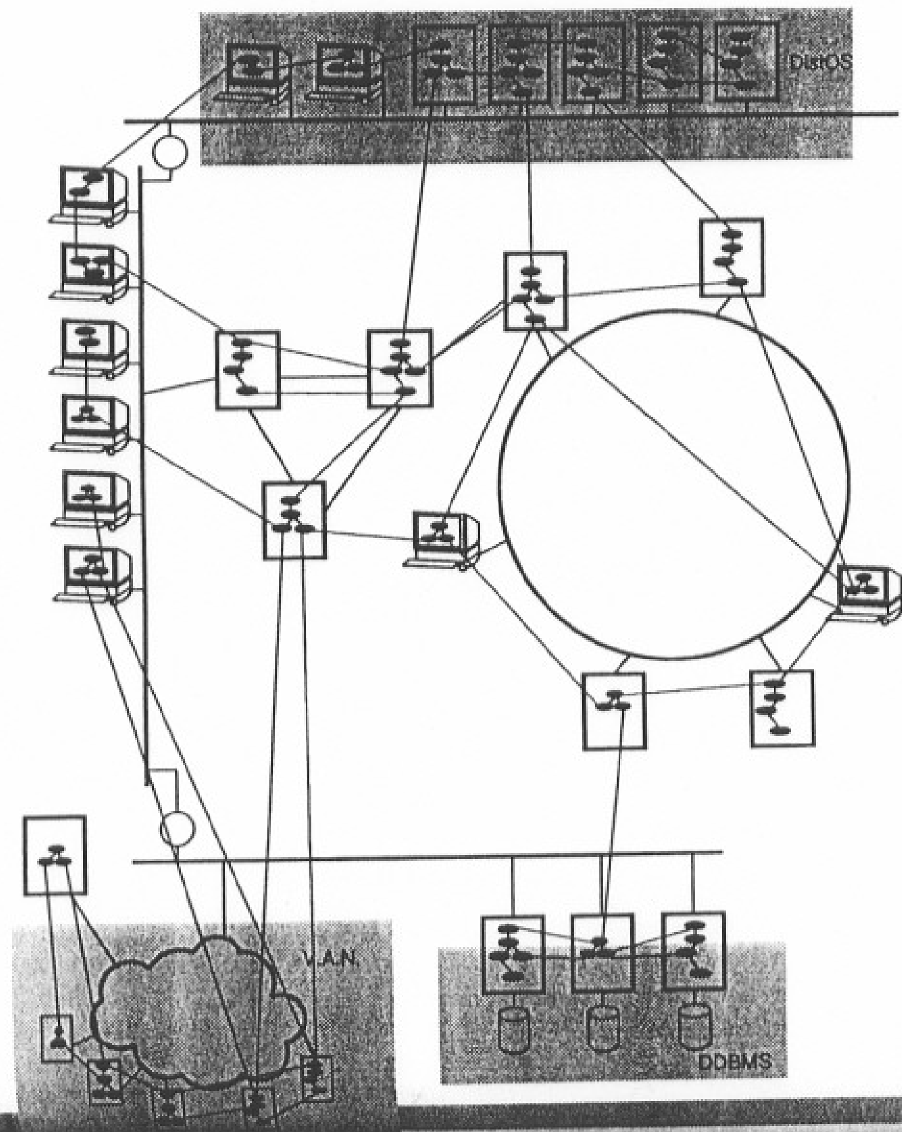
desktop power vs. communication bandwidths



Simple Distributed System



Simple Distributed Application

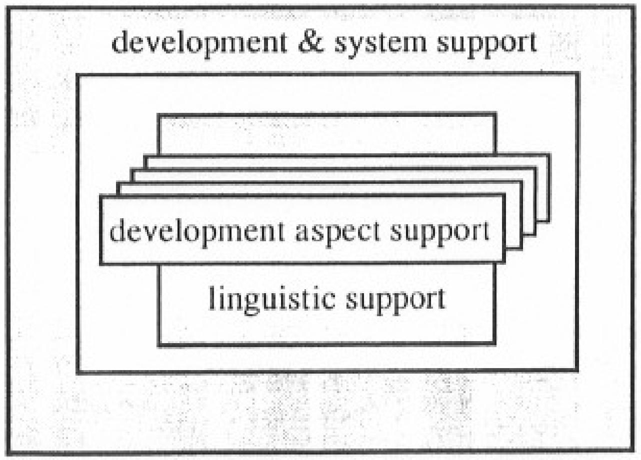


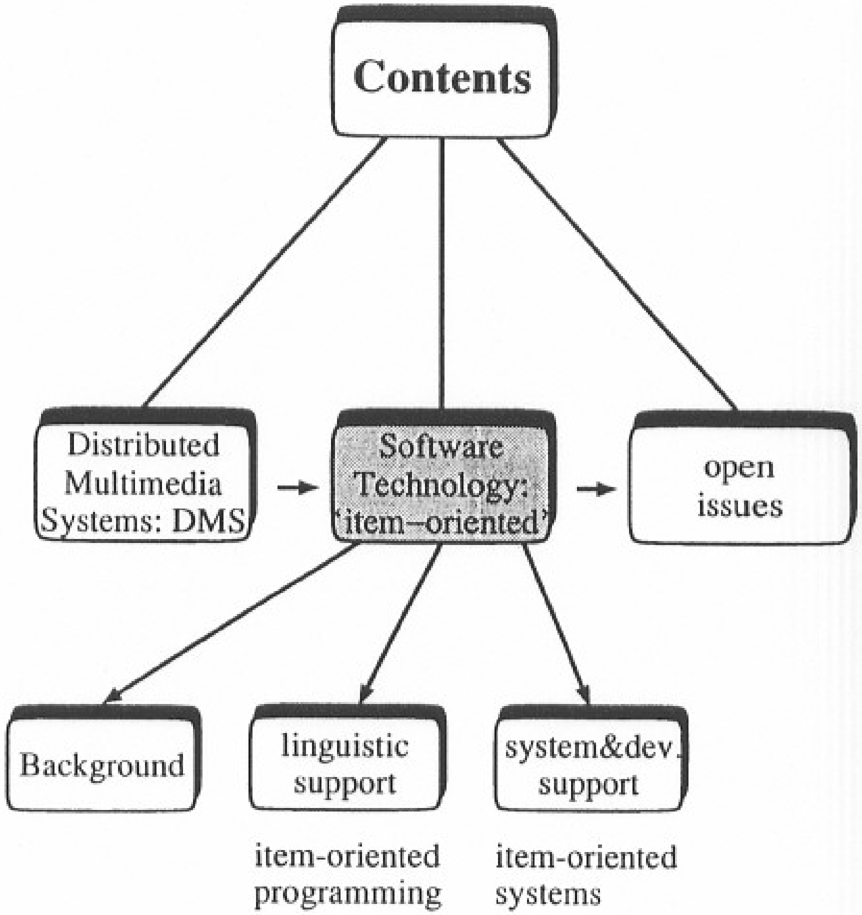
Multimedia Systems

- Technology Push: *three merging markets*
  - » consumer electronics: digital/computerized (HDTV, CDxx)
  - » telecom: digital/computerized (ISDN, B-ISDN, VANs)
  - » information technology: c.e. peripherals, telecom net's
- Application Pull:
  - » human-computer bandwidth: type → talk, describe → show
  - » 'real world' <-> computer bandwidth: direct i/o of 'non computerized' data
  - » 'natural' human-computer interface → vast user market
- Software Gap:
  - » media digitalization/computerization? → 'processible data
  - » media integration? → intra/inter media relations
  - » media communication? → distributed multimedia systems

DMS & Software Technology

- Fast innovation in consumer electronics, telecom, hardware
  → *software technology for DMS is 'critical path'*
- complexity problem! integration vs. modularization
- flexibility problem! standardization vs. innovation
- in search for new software technology:
  - » linguistic support
  - » development support
  - » system support
- coarse architectural sketch:





Background

Telematics Group major projects:

- Project DOCASE:
  - » software engineering for distributed applications
  - » linguistics: object-oriented + ... + ...
  - » programming support: dedicated tools, environment
- Project NESTOR:
  - » networked multimedia workstations
  - » application area: computer aided instruction
  - » digitalization, integration, synchronization of media
  - » hypermedia, navigation
  - » CSCW support
  - » 'transparent' media object support
  - » ('tangible' instructional design)

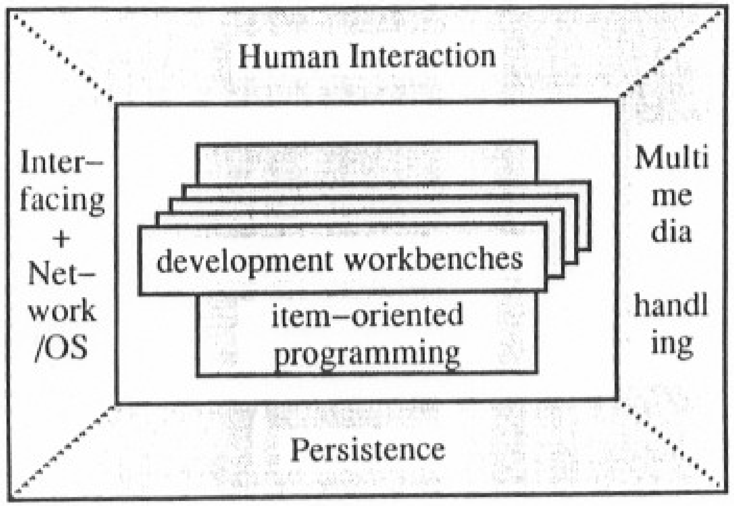
Linguistic Support: item-oriented "programming"

ingredients:

1. object-oriented (oo) paradigm: distribution-proof, modular
2. hypermedia (hm) paradigm (converges with oo!)
3. 'static' ***and*** 'dynamic' nodes / links (hm+oo)
4. highlevel protocol human <-> interaction service:
5. 1-4 → node/link has: state, behaviour, appearance
6. hierarchy/overlap decomposition (node / link aggregates)
7. object mobility (oo): objects move freely around in network
8. new modularization concept (oo): algorithm 'superimposition'
9. navigation support (hm): reusable 'guided tour' algorithms
10. CSCW -> 'telecooperation' support
11. reflectiveness (oo): objects adapt to environment ('intelligent')
12. media type support (understanding, conversion, processing)

item: *i*ntelligent *te*lecooperating *m*obile *m*ultimedia object

Item-Oriented System (I): Overview



Item-Oriented System (II): Workbenches

Problem:

- numerous *development aspects*
  (reliability, performance modeling, mobility, security, media handling, fine-grain parallelization, target system adaption...)
- development aspects
  - » mixed with main functional development
    (e.g. mobility statements <-> functional algorithm)
  - » or totally decoupled (e.g. performance simulation system)
- various tools / human interfaces per aspect

Workbench solution:

- 1 workbench per aspect, single human interface, multiple tools
- coupling via superimposition of algorithms, reflective objects

Item-Oriented System (III): Human Interaction

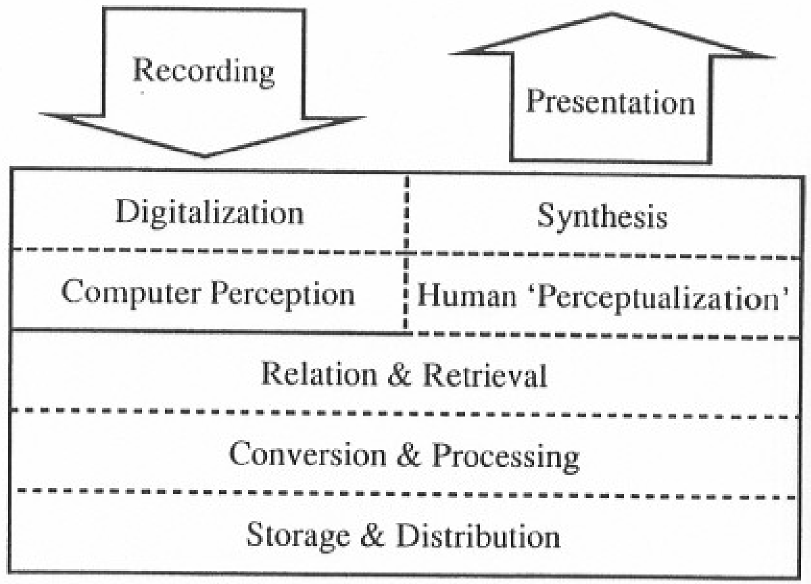
today:

- window / icon / menu / scrollbar (wims) - interfaces
- 'network' (user interaction) protocol = graphics primitives
- toolkits: graphics manipulation

required:

- user interaction protocol & toolkit
  - » independent from graphics metaphor (wims or other)
  - » → independent from media & capabilities used on workstation
  - » based on application object semantics ('choice', ...) instead of graphics object semantics (shape, size,...)
- tool building tools with decoupled (standardized) method description interface (generic graphics editors → generic [media] editors)
- switch between media types: cf. multimedia handling

Item-Oriented System (IV): Multimedia Handling



Computer Perception: e.g.
- voice / character / handwriting / drawing recognition
- video scene analysis

Relation / Retrieval: e.g.
- automatic indexing, document/media description/retrieval
- hypermedia link generation

Storage / Distribution: e.g.
- time-based media cash/prefetch
- tradeoff heuristics: bandwidth/memory/cost/access_pattern

Item-Oriented System (V): Persistence

Contradictory trends:

- persistent programming: break down process / storage wall (requires simple database interface for performance reasons)
- new challenges for database / persistent storage research:
  - » scalability in VLNs
  - » concurrency control -> CSCW access
  - » non-standard use (transactions) in databases
  - » hypertext, -media information structures & contents
  - » object-oriented databases (OODB)
  - » OODB standards for SW development lifecycle

all of the above important for item-oriented systems!

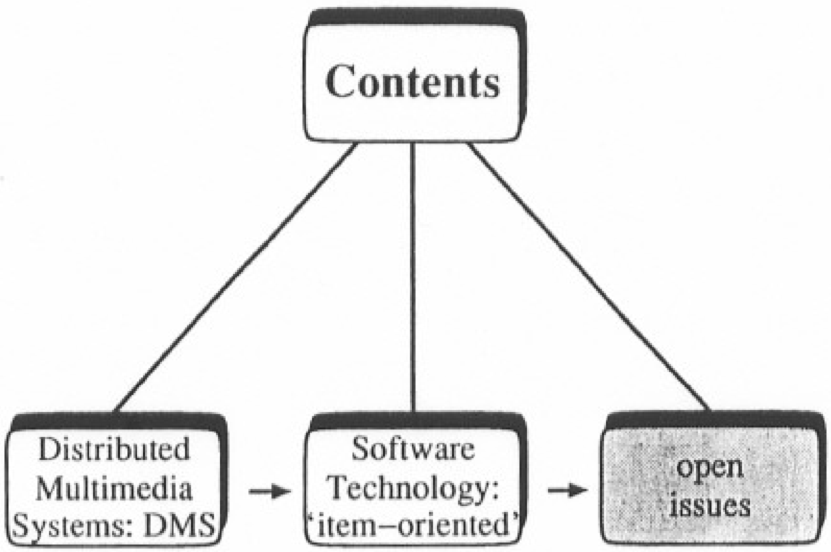
Item-Oriented System (VI): Interfacing+Network/OS

Interfacing challenges:

- 'integrating the enterprise' → interfacing existing applications
- VLN use comprises access to value added network services & L.5/6/7 services: clash of SW engineering and OSI 'worlds'
- required: dynamic definition of interface protocols to L.5/6/7 protocols, VANs, ex. applications (cf. HITS?, ASN?)

network / operating system challenges:

- heterogeneous networks → more/less language specific support on 'old'/'new' operating systems
- breaking old boundaries (process, session, node...)
- VLNs vs. security, autonomous entities, scalability
- distributed OS vs. heterogeneous systems, autonomous entities
- network protocols / performance vs. multimedia requirements
- network transparency vs. efficient mapping items <-> network
- required: abstract models of item characteristics -> optimization independent of application specific knowledge (hints for approaches: 'virtual memory', MUSE ooNOS)



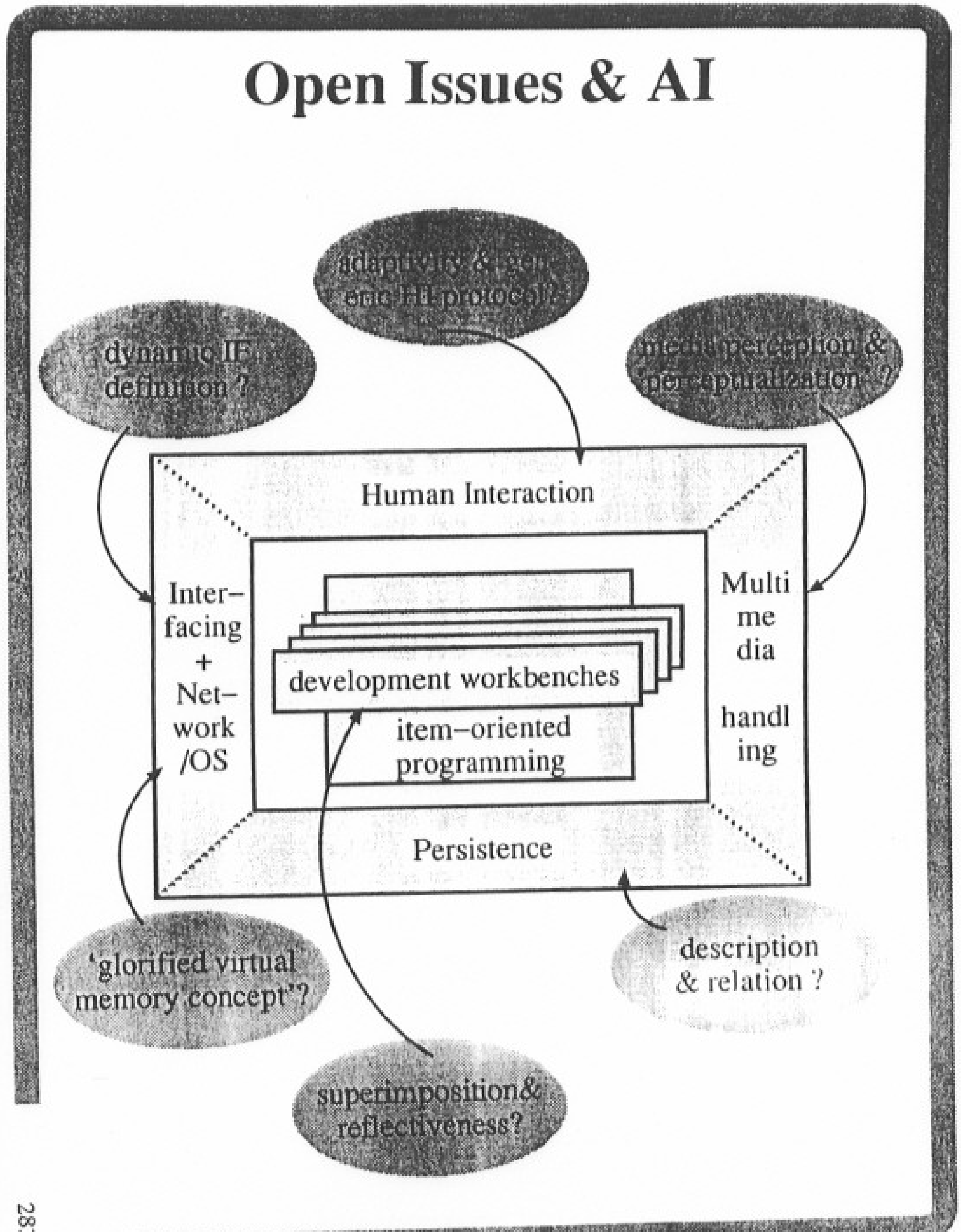
Open Issues

- telematics group investigates:
  + oo & hm & distribution
  + hm navigation
  + object mobility, non abstract model
  · superimposition
  · multimedia object distribution services
  · CSCW + distribution
  (- multimedia digitalization, integration, synchronization?)
  (- human interaction protocols?)

- other groups investigate:
  · object mobility, abstract model
  · VLNs (different aspects)
  · oo & networks / operating systems
  (- most aspects mentioned?)

- AI investigates:
  · image, speech, handwriting recognition, media perception
  · building systems that manage adaptivity & complexity
  (- automatic indexing / description / relation?)

- comparatively little progress - can AI help?
  · integrating the above aspects
  · dynamic interface / protocol specification
  · better 'computerized' media
  · abstract model f. DMS computing (item-based programming)
  · heuristics for support based on this model (cf. virt. memory)
  · flexible human interaction



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