Computer-supported collaborative work over networks has become an important research topic over the past few years, including in the Visinet project. The Visinet participants conducted trials of new CSCW methods based on virtual representation and virtual reality techniques over trans-European ATM networks. Designers, architects, city planners, and engineers worked collaboratively with virtual 3D models from locations in the Netherlands, Belgium, UK, Ireland, Portugal, and Switzerland (see the sidebar “List of Visinet Partners”).

The project started in August 1994, but, owing to delays in the availability of the trans-European ATM pilot network, user trials did not begin until January 1995. Trials are still ongoing at the time of this writing, now using the James network.

Visinet is part of the TEN-IBC (Trans-European Networks, Integrated Broadband Communications) program, one of the RACE subprograms (the European Commission’s Fourth Framework R&D program). In TEN-IBC, common-interest groups of users and application developers from different industry sectors explore the potential for using ATM networks to let people located throughout Europe work together on the same design project. Visinet connects partners in the European countries mentioned above via the European ATM network. Using these connections, project members have investigated different scenarios and disseminated the results widely.1,2

**Objectives**

The main objectives of the Visinet trial were to:

- Demonstrate the use of broadband communications
- Provide advanced systems on an “as required” basis, using off-the-shelf applications
- Evaluate the performance of new interactive tools, such as virtual representation in a distributed environment
- Evaluate whether broadband will shorten the design-

**List of Visinet Partners**

Six European countries are represented in the Visinet project:

- The Netherlands—European Design Centre, Eindhoven; City of Eindhoven; Philips Development Workshop, Eindhoven; Plaza Ontwerpers, Eindhoven; Moons & Van Hoof Industrial Design, Eindhoven; PTT Post, the Hague; ElectroGIG, Amsterdam
- Belgium—Limburg University Centre, Diepenbeek; Philips Interactive Media Centre, Hasselt; Androme, Diepenbeek; Brics, Gent; Alcatel Telecom, Antwerpen
- Portugal—Adetti, Lisbon; Oficina de Arquitectura, Lisbon; NovoDesign, Lisbon
- UK—University of Bradford, Bradford; Engineering Technology, Derby; Division, Bristol; Ukerna, Oxford; Analysys, Cambridge
- Ireland—Trinity College Dublin, Dublin
- Switzerland—University of Geneva, Geneva; Ecole Polytechnique Federale de Lausanne, Lausanne
to-product lead times and increase quality through collaborative working
- Identify the commercial benefits of remote CAD over broadband; measure these benefits where possible
- Determine the potential size of the common-interest group
- Increase awareness among potential users of remote CAD and virtual representation
- Identify obstacles to adoption of remote virtual representation
- Stimulate activity of CAD tool vendors and users in broadband communications
- Examine the extent to which use of network-based interactive technologies will result in the reengineering of the entire design and production process
- Disseminate the information on Visinet widely in the community
- Promote discussion and debate, and ensure new users have ready access to the information, such as through workshops and one-day projects with end users
- Examine the integration of heterogeneous networks and platforms
- Integrate ISDN into the Visinet ATM network

Overview of the scenarios

The trial applications fall into four different types, as follows.

Scenario 1: Remote presentation. The client asks the design center to present virtual 3D representations and visualizations over the broadband network. The designers and client then discuss the results on line, using voice and/or video (see Figure 1).

Scenario 2: Remote program execution. The remote execution scenario (see Figure 2) resembles the remote presentation scenario, but the users themselves perform the actions—“treatment” of the virtual model or prototype—rendering the results on the computing center’s machine. No interaction with the designers takes place in this scenario.

Scenario 3: Collaborative work. Different sites work together on the same database to take advantage of each other’s expertise in real time and to allow immediate intervention at any point in the design cycle (see Figure 3).

Scenario 4: Virtual supercomputing. The main purpose of this scenario (see Figure 4) is to provide graphical supercomputer power to users who do not have such equipment, but who benefit from the remote access. Project members are also investigating ways to interconnect homogeneous and heterogeneous sets of supercomputers over ATM, in order to have one virtual supercomputer within the consortium.

Network

The Visinet project depends heavily on the interconnection of the different European sites involved. The main backbone is the European ATM network, which connects the different public network operators (PNOs). Some users without ATM access connect to other sites through ISDN, which has a lower bandwidth.

Figure 5 (next page) depicts the ATM network connections, with the respective line speeds for each interconnection at the maximum rates. In practice, the respective PNOs mostly allocate a lower rate (ranging from 2 to 12 Mbits per second, except between the Dutch sites, where a bandwidth of 155 Mbps is available).

For more information on the SuperJanet network...
used to connect the UK to the rest of the European ATM network, see Clyne’s article. The aggregation of European PNOs that provide the trans-European ATM links is called the James network (formerly the MoU or PNO Pilot).

**Integration of ISDN**

The Visinet network consists of an ATM backbone infrastructure among the main sites in the participating countries. However, not all users have ATM access at their sites. Two different approaches give these users access to the network: For high-bandwidth applications, such as real collaborative work in a 3D environment, users can employ the ATM-connected machines at the main sites; for lower-bandwidth applications, such as teleconferencing with low-quality video and a shared whiteboard, an ISDN connection suffices. For the latter connections, some sites even use PCs to discuss the status of a design or experimental results.

To save on the connection costs when accessing a distant site, an ISDN-connected user will link to the nearest ATM site and use the ATM network as a carrier to go to another ATM site, where a connection to the other end user is made (possibly also via ISDN). Software routing over the ATM network aids this kind of connection (as explained in the next section).

Several possible solutions achieve the ISDN-to-ATM integration, depending on the corresponding projects’ site requirements. Because the applications used are built on TCP/IP, all information (data, voice, images, video) is encapsulated in IP packets. IP routing within the network establishes a gateway between different networks.

Within the Visinet project, associate partners need ISDN access. The principal partners have high-end SGI workstations equipped with Ethernet, ISDN (BRI, or
basic rate interface), and ATM interfaces, letting them establish the following communication paths:

- BRI ISDN users can establish a virtual circuit consisting of one or two B-channels. This path starts directly from their workstation or PC, via a router, or via a terminal adapter (always one B-channel), depending on the end-user equipment's interface. It then goes through the ISDN network to the ISDN board in the SGI machine of their principal site. With a router, data compression is possible. The SGI machine has IP routing functionality, so it can send the data over the ATM network to the destination site (see Figure 6).
- PRI (primary rate interface) ISDN users can establish a virtual circuit consisting of one or more B-channels to a router equipped with a PRI ISDN interface and located at the principal site. This router can transmit the data over Ethernet to the SGI machine, which takes care of the routing over ATM (Figure 7).
- A more project/site independent solution consists of
installing an ATM interface in the router. This router can be placed centrally in the network to give different sites Euro-ISDN connections and let them see their IP traffic being routed on the ATM network. The PNO also proposes this solution, by promoting IP over ATM in favor of VP (virtual path) bearer and by installing routers to access the James network. See Figure 8.

Software routing capabilities

Note that the European ATM network (currently run by the James project) remains experimental. To make this kind of service available on a commercial basis requires addressing some practical deficiencies. One significant shortcoming is the lack of automatic connection. This means that all ATM connections have to be requested quite some time before actual use. Visinet solves the interconnection of distant ISDN users by assigning another partner’s workstation as a software router.

Consider the situation depicted in Figure 9. Suppose sites A and B simultaneously request a logical connection through James to site C, but would benefit from having an occasional connection to each other. In this case, the workstation used at site C can be configured to act as a software router between A and B.

The Visinet trials and workshops have used this solution frequently. It also allows for inclusion of non-ATM hosted workstations in the network. Configuring the ATM workstation at site C as a router between its local (Ethernet) network and the ATM cloud lets any system in the same local network be accessed from other sites through ATM and vice versa. This lets sites invest in only one ATM connection while permitting more users and more workstations in connections over the ATM net-
work. Of course, we must take into account that the end-
to-end bandwidth will be limited by the slowest con-
nection in the network.

**Applications**

The Visinet project used the following applications
environments:

- Videoconferencing with shared whiteboard using
  InPerson’s XTeleScreen (see Figure 10)
- ElectroGIG’s 3D-GO for 3D modeling (see Figure 11)
- Virtual reality using Division’s dVS and dVise
- VLNet, developed jointly by EPFL-LIG and MIRALAB,
  University of Geneva (see Figure 12)
- Virtual supercomputing by remote access (VRnet, see
  Figure 13) and distributed virtual reality

Performance measurements came from a walkthrough
(at a resolution of 640 by 480 pixels) in a 3D scene. The
scene consists of several roads, along which network
equipment appears in different configurations; the end-
user equipment is shown in the building interiors. Figure
13 shows a snapshot of this VRnet
application.

To assess the client-server appli-
cation, we ran the application locally
on an Indy, then remotely between
this Indy and an Onyx RE2. The local
application rendered 0.2 frames per
second (one frame every five sec-
onds), while an ATM connection
(with a real bandwidth of less than
70 Mbps) delivered 5 frames per sec-
ond. This represents a performance
increase by a factor of 25.

Since we did not have more band-
width available, real-time interac-
tion (25 frames per second) was not
possible. Therefore, we must look at
ways to reduce the amount of data
sent over the ATM network connec-
tion. For example, generating only
8 bits per pixel (using dithered
images or black-and-white) reduces
the amount of data by a factor of
three, which yields real-time speed.
We have already used this technique
to reduce the required bandwidth
when running this application over
a frame-relay connection (at 2
Mbps) to a PC. We have yet to inves-
tigate the use of hardware compr.

**Bandwidth and
throughput**

During the trial, project members
measured bandwidth use, which
obviously depends on the applica-
tion used. Table 1 on the next page
shows some typical figures for the
different scenarios.
Remote presentation relies mainly on videoconferencing with the shared whiteboard—the bandwidth use goes to the video and to the transfer of images in the whiteboard. (Please note that the application used is not optimized for the ATM network.)

Remote program execution shows very different bandwidth uses. But since the majority of graphics calls have to be transferred over the connection, all available bandwidth is used.

Collaborative work can use either a single application with replication of the I/O (for example, XTeleScreen plus 3D-GO) or a local application with a local database at each site and exchange of interaction parameters (movement of the user's virtual body or virtual objects, for example). In the former case, just one site should host the shared application (and possibly a powerful computer) while using more bandwidth (typically around 5 Mbps); in the latter case, each site hosts a copy of the application and database (and preferably a powerful computer) while consuming very little bandwidth (typically about 100 Kbps).

The virtual supercomputing application for which we have made measurements, VRnet, uses all available bandwidth. In this application, a remote graphics supercomputer receives navigational parameters from a (low-end) client workstation, generates 3D images in real time, and sends these images to the client workstation. Because of the high volume of data contained in the image sequences, the full bandwidth is used (possibly even filling a full 155-Mbps link, when available).

**Project results**

Within the time frame of the Visinet trial, project members developed and supported a number of real-world projects. We describe the most representative ones here.

**PTT Post**

The PTT Post division of the Dutch PTT requested the European Design Centre in Eindhoven to design two new distribution centers. EDC created the visualizations (see Figures 14 and 15) and used remote presentation to PTT Research's premises in Leidschendam, where they could use equipment with an ATM connection to EDC. The parties used InPerson to discuss the results. This project will continue into the visualization's next phases, consisting of a VR model of the distribution centers and a 3D animation representing the logistics within each distribution center. The VR model and the animation will be created at the EDC and presented in real time over the ATM network. Remote rendering facilities might be used.

**Eindhoven's West Corridor plan**

The city of Eindhoven's West Corridor plan included designing a new train station, creating a large green area in the city center, planning a route for the new public transportation system, and designing a tunnel for the highway. In addition, some of the existing buildings needed restoration. The functional proposal included the following points:

- Restore some of the existing industrial buildings
- Restore the old heating plant as an archaeological asset, perhaps as a museum
- Build a shopping center along the railway, including offices and commercial areas
- Build houses and residential dwellings in the affected area
- Give priority to underground parking, parks and green areas, and houses

Project members used the Visinet network access point at Adetti in Portugal, plus its software and hardware facilities, to translate the geometry and images prepared in AutoCAD into the appropriate data formats for

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Maximum Bandwidth (Mbps)</th>
</tr>
</thead>
</table>
| Remote Presentation | 2.82 (ATM LAN)  
                     | 2.532 (ATM WAN)  
                     | 0.112 (BRI ISDN plus Ethernet plus ATM) |
| Remote Execution    | 9.6 (all available bandwidth) |
| Collaborative Work  | 4.8 (joint editing)  
                     | 0.1 (joint VR-walkthrough design evaluation over ATM)  
                     | 0.064 (joint VR-walkthrough design evaluation over ISDN) |
| Remote Supercomputing | 9.6 (all available—remote use of graphics supercomputing)  
                           | 0.1 (VR for design evaluation) |
dVise. Oficina de Arquitectura (OA) in Lisbon then presented its work to the clients in several virtual meetings over the Visinet network, using both the EDC access point in the Netherlands and the Adetti access point.

For the presentations, project members first set up the audio-video channel between the two parties, permitting some brief conversations with visual feedback. Then a collaborative slide presentation took place, using InPerson’s shared whiteboard as the support tool (see Figure 10). During this session, the OA representatives and the Eindhoven architect jointly discussed several aerial views of the area and images showing the phases of the urban planning project. Finally, the participants engaged in a joint virtual walkthrough of the 3D scenarios for the proposed designs. They used the dVise tool while maintaining the videoconference parallel channel. Since the 3D virtual world includes a representation of each person’s head and hand (two virtual bodies), OA just had to set up a social protocol for the Eindhoven participant to follow the OA representative’s virtual body at all times during the virtual tour.

The city developers used the graphics to evaluate the results of their plans and to present the results to the city council. (For some of the results, see Figures 16 and 17.)

**Philips chip-card terminal**

Philips Development Workshop produces prototypes for other Philips divisions and third-party companies. PDW processed a public-transport chip-card reader into a CAD model, then subsequently sent their CAD data to the European Design Centre. This Pro Engineer model was converted to a 3D-GO readable format. Using InPerson over the ATM network, EDC presented preliminary results to both the designer and the developer of the chip-card reader. After they modified and tuned the material specifications, such as colors, and defined the right camera angles, the final images were ray traced and sent back to PDW (see Figure 18). The same model was used to produce a stereolithography prototype.
This cooperative working method reduces the time needed for prototype modifications. In this project, it also allowed users to use supercomputing performance at a distance and enhanced communication between developers.

**Philips Medical Systems scanner**

For Philips Medical Systems, the Limburg University Centre in Belgium made a virtual model of new medical scanning equipment, starting from an existing design. The virtual model is imported into dVise, which lets the designer walk around the machine, look at the interface and monitors, and take the patient’s position, before a physical model is made. This project aimed to test ergonomic properties of the new equipment, such as the positioning of the monitors, the transport rails, or the patient’s “bed.” The Philips designers and the LUC developers walked through the virtual environment to discuss the results. Project participants next plan to extend the environment to include the operating room where the equipment normally resides.

**Trade Centre Eindhoven**

This project is in the initial definition phase. The “virtual” Trade Centre Eindhoven project was initiated by the Visinet consortium to involve all “user partners” in a single collaborative working project. The TCE project is unique in involving all disciplines within Visinet. The project as formulated will cover the complete development of a new trade center for the city of Eindhoven, including the disciplines of urban development, architecture, industrial design, interior design, and graphic design.

The Eindhoven Urban Planning Department, which handles urban infrastructure and facilities planning, will help organize the TCE’s location in Meerhoven. The Oficina de Arquitectura architects will participate in developing the first architectural concepts with input from the other partners. NovoDesign, Moons & Van Hoof Industrial Design, and Plaza Ontwerpers will provide input from disciplines such as furniture design, interior design of removable or flexible systems for exhibitions and other events, design of high-tech communications, and parking system design.

The basic motivation behind this collaborative working approach arose from the perceived value of having different disciplines collaborate at an early stage. The participants will demonstrate a truly collaborative working project, at the same time demonstrating the four proposed Visinet scenarios and their associated benefits.

**User evaluation**

Consortium partners Analysys, a telecom consultancy firm, and the Telecommunications Users’ Foundation are responsible for the user evaluation. The nature of the technology involved means that researching its effects cannot be confined to technical performance or to the immediate impact on how specific tasks are carried out. They need to measure what effect the project has on business and organizational practices and structures, and determine how to measure this impact in financial and usability terms. If they can provide such measurements, the results of the Visinet trial can serve as a model for assessing the wider potential of the technology.

Objectives in measuring the project’s effects included:

- Assessing trial users’ perceptions of the technology’s impact on their business, both directly and on other aspects of the business and organization;
- Gauging actual use and comparing this with expectations;
- Measuring the predictability of use patterns, to identify where new and unexpected uses occur; and
- Measuring the technology’s performance as an input to the measurement of costs and benefits.

The potential benefits consolidate into several major areas:

- Reduce overall operating costs
- Improve overall product and process quality
- Reduce time to market
- Save time and travel
- Open up new commercial opportunities
- Improve decision making
- Reengineer the organization and its working practices

**Future research**

The Visinet environment has enabled the linking of collaborative 3D design applications over high-speed ATM networks. Results to date, albeit with limited bandwidth on some network links, have demonstrated the advantages of letting multiple users interact in real time and the acceleration of critical parts of the design-to-product cycle. In addition, demonstrations and workshops have highlighted the impact that collaborative design across national boundaries can have on local companies and organizations.

Visinet participants are currently exploring possibilities for further links between new companies. One important issue is to evaluate how far new technologies such as those used in Visinet will change existing practices in companies as the cost of high-speed networks falls. The rapid growth of business use of the Internet for training, retailing, document distribution, market research, and communications has demonstrated that network access changes traditional business methods.

Two additional projects use the Visinet infrastructure. MAID (Multimedia Assets for Industrial Design), supported by the European Commission Information Engineering section of the Telematics Applications program, is developing network-based multimedia databases for designers. Vista (Virtual Interactive Studio Applications using Networked Graphical Supercomputers), supported by the European Commission Esprit High-Performance Computing and Networking program, is an interactive virtual studio for supporting drama scenarios controlled by remote users. We anticipate that developments in both projects will further demonstrate the benefits of distributed collaboration over ATM networks.
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