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DEVELOPMENT AND APPLICATION OF VIDEOCONFERENCING SYSTEMS

ABSTRACT

Videoconferencing is the best-known form of teleconferencing. It allows concurrent transmission of images and sound via computer network for the communication of several persons physically distant in real time. The computers are networked and additionally equipped with camera, microphone, voice and video card, and adequate programmes. Video signals are digitized and compressed before network transmission. Students and lecturers may lead discussions and exchange documents and other materials via the computer.

KEY WORDS

videoconference, ISDN, video signal, interactive classroom, types of videoconferences

1. INTRODUCTION

Videoconference is one of the most frequent and best-known forms of teleconferencing. It most often means concurrent transfer of images and sound via computer network. Several users physically distant can see each other and hear each other in real time by means of multimedia-equipped computers linked in a network.

In order to enable such transmission and interactive participation of experts from different centres it is necessary to have certain telecommunication infrastructure, which includes hardware and software support.

For the transmission of images and voice, it is technically justified to use optic fibre network infrastructure, network interfaces, switches (switching field with several possibilities of inputs and outputs at different rates), network cards, PCI adapters, PC Ethernet, ISDN modems, Ethernet connectors, etc. All these represent LAN computer network which should enable transfer of high-quality audio and video signals via LAN network. The software must be based on multimedia solution for the transfer of audio and video signals to different locations via ISDN, in order to be able to see the audio and video recordings in real time at destinations. The possibilities of LAN network infrastructure allow also the transfer of images and voice to external users via the Internet. The technical solution of videoconference transmission via the Internet can be realized via HDSL link[1] per 30 channels of 2 Mbit/s transfer rate to the server and further to several destinations.

2. TYPES OF VIDEOCONFERENCING

2.1. Room videoconference

The videoconference systems have greatly changed during the recent years regarding their first versions. In the beginning there was only the so-called room videoconference. For this type of videoconference, a specialized classroom is necessary, and it accommodates all the necessary equipment for the videoconference and is used only for this purpose. Of course, at least two such classrooms are needed, one in which the lecture is given and the other at the other end of the network where the students listen to it. Usually high-quality audio-visual instruments, sophisticated CODECs and excellent control units are used for room videoconference, creating thus the atmosphere of a full lecture-room. Room videoconference is often used as support to traditional lecture in a classroom which is characterized by:

- interaction between professor / tutor and students, controlled by professor;
- unequal participation of users;
- formal dialogue.

Room videoconference is suitable for individuals or minor groups. Computer is used together with camera and microphone for transfer of video and audio signals from one computer to another. It is a two-way communication, i. e. audio and video signals are sent in both directions. In order to set a videoconference, all computers involved in operation have to have installed a CODEC. CODEC (coder-decoder) is an instrument or programme for digitisation, compression and coding of data for the transmission along the computer network. Videoconference may be limited only to a minor, local network or it may be spread via public networks (e. g. conventional telephone lines) to a wider area. The majority of videoconferences use ISDN (Integrated Services Digital Network). ISDN uses the existing telephone lines, performs transfer at a rate of 128 Kb/s per single line and provides certain throughput capacity of the channel. The result is high-quality audio and video signal. Apart from this method of establishing connections, videoconference can be realized also via the Internet. Two known programmes offering the possibilities of establishing videoconferences are CUSee-Me University of Cornell and Microsoft NetMeeting. In both cases a video camera and digital card for the transfer of video signals, as well as microphones, loudspeakers and audio card for the transfer of audio signals are necessary. The rate and the quality of videoconferencing via the Internet depend primarily on the rate of the Internet connection. In most cases the usual modem is too slow and shares the throughput capacity of the channel with other data, and the result are the standstills, skewed and unclear image, poor sound.

2.2. Desktop videoconference

The advancement in technology and the availability of ISDN as a relatively inexpensive medium for digital data transfer have enabled the appearance of desktop conferences. This type of videoconferencing uses personal computer that has special hardware and software support for signal coding and decoding. These components are cheaper and suitable for individuals and small groups.

The desktop videoconference systems usually contain also one document that may be seen and changed by all the participants during their discussion. Precisely these documents and the relatively low price make the desktop videoconference ideal for communication, cooperation and learning.

Desktop videoconference is characterized by:

- interaction of all the users,
- equal share of participation of all the users,
- simpler control of devices,
- informal conversation.

2.3. Video on Demand

Video on Demand is an asynchronous application. This means that the audio-visual material is recorded in advance, digitised, compressed and saved on a special computer which functions as video server. Such a server can simultaneously respond to the requests of several clients – user computers, and it is possible to have several video-programmes simultaneously in the network.

3. TECHNICAL SUPPORT

During design and realisation of the videoconference systems the specific lecture requirements within the available technology have to be taken into consideration. Generally, the system configuration reflects the needs of lecturers and students, as well as the material that is subject of the lecture.

The videoconference system includes audiovisual equipment (monitor, cameras, microphones, loudspeakers) together with the resource for data transfer between two sites. The broadband satellite connection together with high quality equipment gives best results regarding the quality of video data. However, this method of transmission is very expensive. The advancement in computer and communication technology, and the appearance of the Internet have brought something new to the market, the so-called compressed video system. The system operates so that the data are transmitted via the Internet or telephone network, which greatly reduces the costs.

The videoconference can be restricted to a minor, local network, or can be spread to a wider area by means of public networks (such as e. g. regular telephone lines). The majority of videoconferences use ISDN. ISDN uses the existing telephone lines, performing transfer at a rate of 128 Kb/s per single line and insures certain throughput capacity of the channel. This results in the high quality of the audio and video signal.

ISDN network system features a number of advantages besides other network systems and it is therefore used most frequently for videoconferences:

- ISDN network-based systems comply with all the standards and are linked to other systems by simple, standardized hardware,
- ISDN uses the existing telephone lines and does not need any special cables, so that it is very widespread,
- for switching ISDN uses the channel switching technique which establishes the physical path between the caller and the called, and once the connection is established it exists until the end of communication.

ISDN is based on two main types of communication channels: channel B, for transfer of data at a rate of 64 Kb/s and channel D for the transfer of management information at 16 or 64 Kb/s.

The technology used with ISDN, which allows very high-quality data transfer, is the ATM (Asynchronous Transfer Mode). The basic idea of ATM is the transfer of data in small packages of the same size - – by ATM cells.

The operation principle of videoconferencing is very simple: CODEC at one side of the network compresses all the video and audio data into the digital form which is then by means of digital telephone lines transmitted to another end of the network, where another CODEC processes the data in the precisely opposite way and forwards them to the peripheral output units for reproduction. The process of data transfer results in slight delay in transfer and decompression of images and voice, which is caused by imperfection of the transfer medium, which is a disadvantage of the ISDN transfer. Therefore it is necessary to increase the transfer rate.

Depending on the type of connection used in certain cases, room videoconference services can be divided into:

- point-to-point conferences,
- point-to-multipoint conferences.

Point-to-point conference is the type of connection which involves only two parties, with equal or compatible equipment. The connection can be set up by any party. Subsequent addition of new members in the conference is not possible.

Point-to-multipoint conference is the type of connection which involves more than two locations. Central control device establishes the connection by calling and connecting certain members into the system. Such method of operation is significantly more complicated and requires engagement of many more resources.

3.1. Video signal transmission

In video signal transmission the compressed video signal is transmitted. The compressing methods can be different. Video signal compression according to the standard H. 261, H. 263 and H. 263+ [18] establishes the video flow that features almost constant rate *(CBR - Constant Bit Rate).* These compressing methods have been developed with the original purpose of applying the ISDN lines (B - channels) of the basic rate of 64 Kbit/s. Constant output rate in this standard of video signal compressing is realised by the change of quantification factor, which in greater shifts in the image significantly deteriorates the image resolution and does not give constant visual quality of the video sequence. Constant transfer rate can be different depending on the available scope of transmission. Video signal compressions according to the MPEG-2 and MPEG-4 standards give a variable bit rate *(VBR - Variable Bit Rate)*, but a uniform quality.

In the video signal decompression process the error has the tendency of spatial and time spread per video sequence, so that the transmission forecasts special video signal processing (packaging of the video signal, division of data in the package into segments that describe the vectors of shift and fill the segments). In video signal transmission in order to realise the services in real time the methods used for transmission security are the FEC methods *(FEC - Forward Error Correction*). In video signal transmission which does not require real-time transfer (checking of video contents) it is also possible to use the method of repeating the incorrectly received packages (*ARQ – Automatic Repeat Request*).

The problem resulting from the multimedia service transmission, and that refers to the selection of code and the degree of code diffusion or greater number of codes with maximal degree of code diffusion, is dominantly connected to the bit flow rate R_f and the required signal/noise (E_b/N_0) ratio.

If, in general, the maximal degree of code diffusion is m and if at the level of code tree, K=0, which matches the maximal degree of code diffusion, the system supports the basic rate in the transmission of service of R bit/s, and if the system receives a request for the transmission of service at a rate of R_f, the transmission can be done by reducing the code diffusion degree or by using a greater number of codes without reducing the code diffusion degree.

In reducing the code diffusion degree which goes on in steps defined by equation (1) there is an increase in rate in relation to the basic rate R in steps described in Table 1.

$$\text{Diffusion factor} = \frac{m}{2^k} \tag{1}$$

where:

m – maximal degree of code diffusion at the level K=0,

K – level of code tree.

With the increase in the code tree level by one step, the diffusion factor is reduced by half, and the transfer rate is doubled. For the service transfer which requires transfer rate R_f the applied level of code tree has to satisfy equation 2.

$$K \geq \log_2\left(\frac{R_f}{R}\right) \tag{2}$$

Table 1 – Increase of rate with reduction of code diffusion degree

Level of code tree K	$K=0$	$K=1$	$K=2$	$K=3$	....	$K=\log_2 m$
Diffusion factor	m	$\frac{m}{2}$	$\frac{m}{2^2}$	$\frac{m}{2^3}$	....	1
Transfer rate	R	$2R$	$4R$	$8R$	....	mR

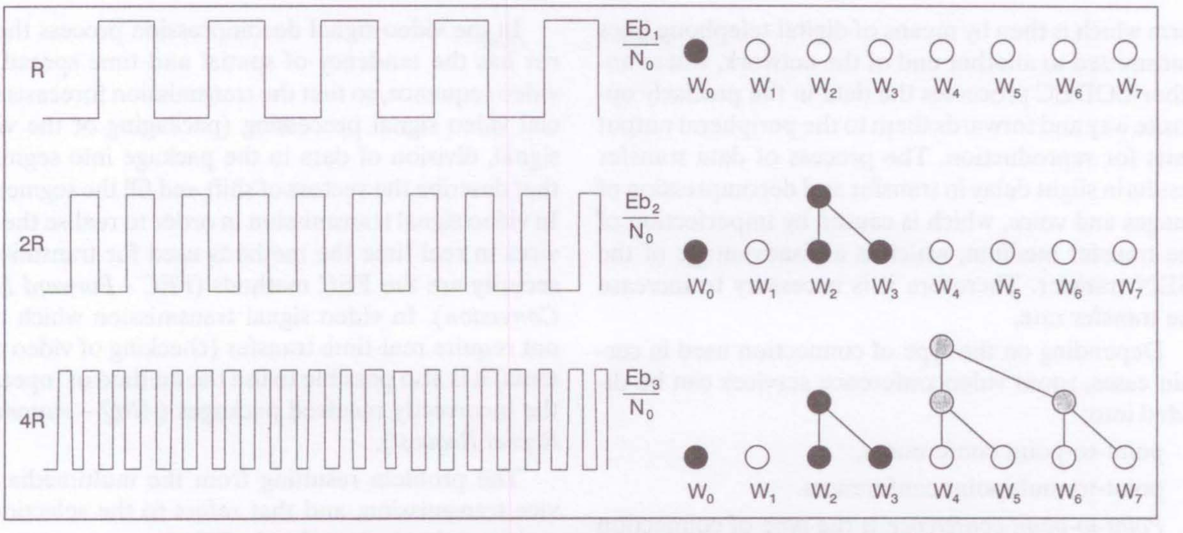

Figure 1 – Signal transmission at higher rate with decrease in the code diffusion level

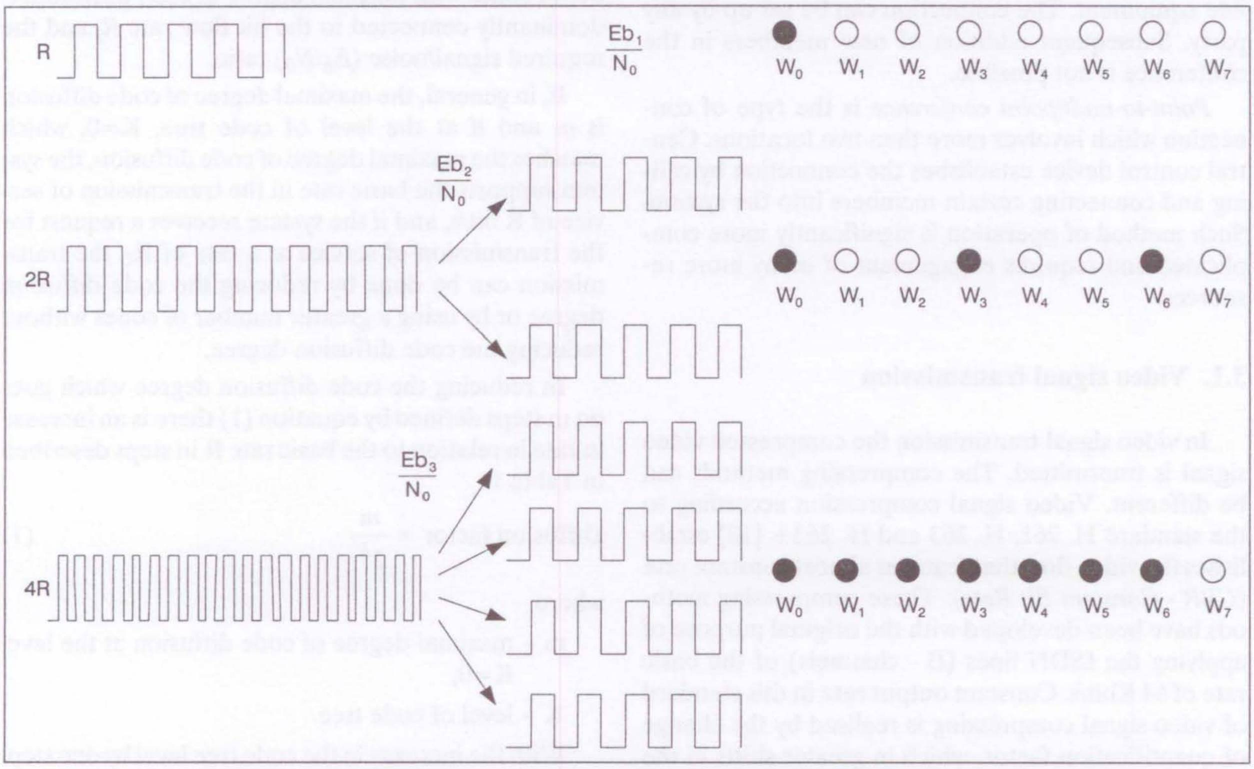

Figure 2 – Signal transfer of higher rate with multiple codes without reducing the code diffusion level

The reduction of code diffusion by one step leads to the doubling of the rate of the signal that can be transmitted. Also, the reduction of code diffusion results in the reduction of the number of available codes.

In multi-code operation there is no change in the code diffusion degree, and the rate of the multimedia signal can be increased in gradual steps that are multiple rate R at the lowest level of the code tree. In multi-code operation the serial bit flow is split into several parallel flows, each of which has the rate R, and on each of these code diffusion is performed with the maximum diffusion factor, which at the same time regarding the signal/noise relation gives maximal code retrieval.

4. INTERACTIVE CLASSROOM

The size of the classroom depends on the needs and the average number of students who will attend the lectures. The optimal size of the classroom would be approximately 10x8 metres, not more than 3.5 m. Such a classroom would accommodate 20-30 persons. However, the usage of ATM technology (high-quality voice and image transfer), as well as big projection systems (separate for the lecturer and separate for the computer data) allow also a larger auditorium. Depending on the needs, also big TCRs (Teleconference-rooms) can be built for the auditorium of some hundred attendants. Insulation is welcome or a location further away from stronger external noise sources (traffic, lifts, water installations, ventilation channels, boiler rooms, workshops, etc.), which at the same time minimizes the need for sound insulation of the premises. The control room can be located next to the classroom or may be obtained by partitioning a part of the classroom. Good acoustic insulation of the control room is recommended. It is good to locate the control room in the back of the classroom, which enables the operator to have good overview of the classroom, as well as physical contact if necessary. An ideal TCR classroom has no windows, since they create the problems with acoustics and light. Camera and the display/monitor have to be located as near as possible to each other, because of the minimal eye shifts. Thus, everyone looking at the monitor looks at the same time at the camera. The classroom should not be overcrowded. Every attendant should clearly see the lecturer and the monitors, without having to stand up, turn the head or move. The walls should not be built of permeable materials, installation of classical panels and glass windows. It is recommended to put carpets or such other soft bases, thus reducing the noise and echo in the room.

4.1. Technical support in the room

- The TCR classroom audio equipment depends on the size and properties of the classroom, and various other factors. The basic and necessary parts for all the systems are:
- wireless microphone for the lecturer,
- microphones for the audience set on the desks,
- ambient microphone receiving sounds from the whole auditorium,
- audio mixer for control, tuning and combination of signals from various sound sources,
- amplifier and respective loudspeakers for the reproduction of audio signals from the remote classrooms.

Sound processing often includes combining of signals from two or more locations, so that great attention should be paid to the feedback, noise and sound echo. The accommodation of loudspeakers and microphones can also increase or reduce the acoustic problems in the room. The loudspeakers should be located as close as possible to the monitors or projection screens, in order to achieve a feeling of communication as natural as possible. The microphone has to be as close as possible to the person who will use it. The distance from the microphone has direct influence on the feedback and the feeling of sound lag (related to the level of the sound produced by the person speaking into the microphone and the entire level of sound in the room produced by the loudspeaker, critical distance for the majority of classrooms is between 0.5 and 1.5 m). The objective is to reduce the noise level in the room. This is not possible without a special control system with headphones. If the microphone is near the loudspeakers, its sensitivity should be reduced. Therefore, it is important to consider the minimal distance between the microphone and the loudspeakers (about 2-3m). In the majority of rooms the distance between the microphone and the speaker is less than half a meter, so that directed microphones have to be used, which are less sensitive to the ambient sound in the room.

The quality of video signals depends on the type and method of lighting installation. The used video signal format is e. g. composite analogue PAL video signal.

The lecture is best followed by two cameras: one for the lecturer and the other for the auditorium. The ideal position of the camera is at the average eye level of the observers, but in practice they are regularly set somewhat higher. In order to watch the picture in the control room there should be at least as many control monitors as there are active sources of the video signals, but, often, due to saving, one monitor is used with the device for simultaneous presentation of several video signals on one monitor. The lecturer needs to have the possibility of controlling the presentation on the computer (by means of remote computer mouse). The cameras should certainly be controlled by remote control from the directing premises. The number of cameras depends also on the room layout.

The presentation equipment usually requires two monitors or two projectors with adequate projection screen (one for the presentation display – local or split, the second one for the presentation of the remote lecturer or audience). The projectors of more intensive beam are recommended (from 1200 ANSI luminance and more). Almost all the modern projectors support such requirements. Projection screens should have minimal dimensions of 2x1.2 m, and the size depends on the size of the room.

It is also necessary to have one or two PC compatible computers, which are, apart from their own monitors, connected to light projectors. It is necessary to insure also adequate network equipment for the connection to the IP network: Ethernet network cards on computers, network concentrator or switch. Depending on the type of transfer technology for videoconference transfers, ATM-suitable CODECs are necessary – IP, ISDN or ATM. Also routers or switches are necessary for the connection with IP and ATM networks, as well as minimally two UTP ports and one optical pair.

4.2. Technical characteristics of the room

The influence that each room has on the sound in it is determined by the acoustic properties of the room. The acoustic properties of the room determine the sound characteristics and the characteristic of the room. Some rooms can have excellent acoustic properties and natural sound, but when this sound is presented in another environment, it may sound unnatural. Therefore, in designing two-way communication systems it is necessary to reduce the influence of the room on the sound in it.

Noise is defined as any sound except for the lecturer's voice, voice of the audience or additional sounds used in teaching. Such sounds are generated by various sources: air-conditioning devices, street traffic, aircraft, and trains, etc. If special attention is paid to the room acoustics, very satisfactory results can be achieved. Unlike human ear, the microphone has no possibility of selective listening, i. e. ignoring of noises and unwanted sounds from the environment, so that acoustic technical requirements are much stricter than in case of regular lecture-rooms and classrooms.

The external noise, such as aircraft noise, traffic and industrial noise, can be reduced by the increase of the sound transmission coefficient in the room (STC - Sound Transmission Coefficient). Harmful sound can reach through walls, floor or ceiling. External walls reduce sound by upholstered doors, installation of good sound insulating material into the walls, by insulation of windows or by using curtains.

Internal noise is a completely different problem. The equipment that produces noise should be removed from the room or located in the sound insulated boxes. Fluorescent lighting that produces a zooming sound has to be replaced.

Echo shows how sound behaves within the room. The room with all hard surfaces reflects sound. Thus the lag or thudding effect is created, which deforms the sound and makes listening difficult. The objective here is to "soften" the walls and thus absorb part of the sound. Natural wall fabrics such as velvet help at high frequencies, but have little influence overall. Greater effect is achieved by multi-corner walls and thin, soft and spongy materials. The best combination of sound insulators is dense mass (concrete, stone tiles, gypsum etc.) and multiple air pockets (of glass wool or sponge rubber). Concrete is the optimal solution for new constructions, whereas the combination with gypsum or sound insulators, as well as the treatment of walls represent the best solution in refurbishing. The usual solution is 10-15 cm wide wall facing filled with insulation of glass wool and coated by 2 cm thick gypsum panels. The windows represent a problem due to external noise. If these cannot be removed, additional panelling will reduce the problem. These additions have to be made of Plexiglas, by no means of glass. The quality of the used materials is measured by the Noise Reduction Coefficient - NRC. The higher the coefficient, the more the material absorbs the sound (the material with NRC=1 absorbs the sound completely). The values of NRC =0.65 – 0.85 are considered very good. Although NRC is a good indicator, it may be misleading. Its value, namely, represents the average value for a group of frequencies. Thus, a material may be excellent at high frequencies, but completely useless in case of low frequencies, although having a good NRC.

Lighting is a very serious problem: the front (lecturer) and back (the auditorium) have to be illuminated, which represents a problem in accommodating darker zones required by monitors or projectors. Therefore it is necessary to use projectors with more intense beam, suitable for operation with more light. Besides, the camera yields best results with intense lighting, which is again in conflict with the monitors and projectors, which require low level of lighting.

Camera has to see uniformly lighted objects of recording, which means that most of the light has to be directed towards the objects seen by the camera. If the light comes above the head of the person being recorded, hair will be very light, and eyes and the neck will be in deep shadow. Thus, the light coming from the ceiling has to be mildly and uniformly distributed over the whole area of recording. Side-lights and lights illuminating the front part of the room and the lecturer very easily cause eye fatigue.

A good solution of the lighting problem at the remote side which is observed by monitors or projectors, is a large source of soft light at the front of the room (on the ceiling) directed towards the back of the room. The light surfaces of desks and boards may be well used for the reflection of light to the parts in the shadow. The use of mixed sources of light (fluorescent and regular light-bulbs) yield dim light and poor image quality. For the same reason, the external light must be eliminated, and thus the light in the room can be best controlled.

Special attention should be paid to the colour temperature of the light source and their mutual balance. The best is the temperature of the sun-lamp or metal-halogen study lamps (3200-3400 K) which produce white light. Other sources of light can be also used (e. g. neon lamps), but exclusively with satisfactory colour temperature. Then, fluorescent tubes with colour temperature greater than 3100 K should be used, with electronic mufflers that operate at frequencies from 40 kHz or more. The illumination by halogen lamps is acceptable but the consumption of electricity is significantly higher for the same level of illumination.

5. CONCLUSION

Video technologies provide also the possibility of audio communications. Personality is added to communication – the students and professor can see reactions, face and body expressions which are very important for the communication. High level of interaction is insured. Quite a lot of additional equipment is required which may be very expensive. A lot of planning and preparation is needed. The majority of videoconferences are not spontaneous, but have to be agreed in advance. Due to complexity, a team of experts is needed to follow the entire process, from the recording and broadcasting of signals, to equipment maintenance. When the classroom changes the form, and the lecturer is located at the place which is physically at a distance from the students, the dynamics and the teaching method change. The traditional teaching methods are adapted to the newly created conditions. Successful usage of videoconferencing systems for interactive learning requires practice and planning, as well as several important instruction strategies. The lecturer in the videoconference classroom must know how to use the equipment, control the local and remote classroom, how to establish contact and cooperation with the remote lecturer. The learning process needs to be in the focus and expectations determined. Besides, additional materials used need to be prepared in advance, as well as diverse, interactive activities for students, thus stimulating them for intercommunication. When the conference is over, its success needs to be evaluated, possible faults identified, they need to be registered and efforts invested to avoid them in the future conferences.

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SAŽETAK

RAZVOJ I PRIMJENA VIDEOKONFERENCIJSKIH SUSTAVA

Videokonferencija je najpoznatiji oblik telekonferencije. Omogućava istodobni prijenos slike i zvuka računalnom mrežom za komuniciranje više osoba koje su prostorno udaljene u realnom vremenu. Računala su povezana u mrežu i dodatno opremljena kamerom, mikrofonom, zvučnom i video karticom, te odgovarajućim programima. Video signali se digitaliziraju i komprimiraju prije prenošenja mrežom. Učenici i nastavnici mogu diskutirati i razmjenjivati dokumente i ostale materijale na računalu.

KLJUČNE RIJEČI

videokonferencija, ISDN, video signal, interaktivna učionica, tipovi videokonferencije

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