Likewise, no missed alarm occurred over a sample of about 100 incidents: all the persons who entered the covered area were detected as they entered and as they left (cf. figure 31 & figure 32 above). In some tests, during which they were asked to stand still in front of the door, they remained undetected for a few video frames (cf figure 33 & figure 34 below), but were detected as soon as they started moving again.

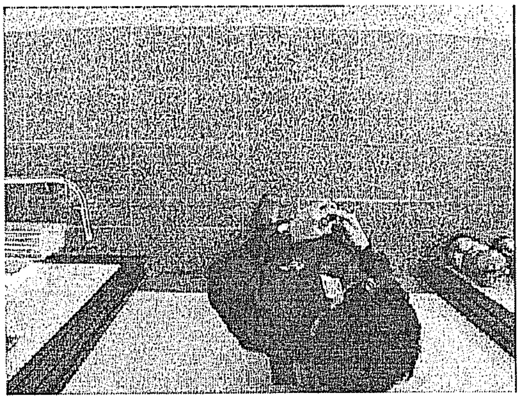


figure 33 : An intruder, standing motionless in front of the door.

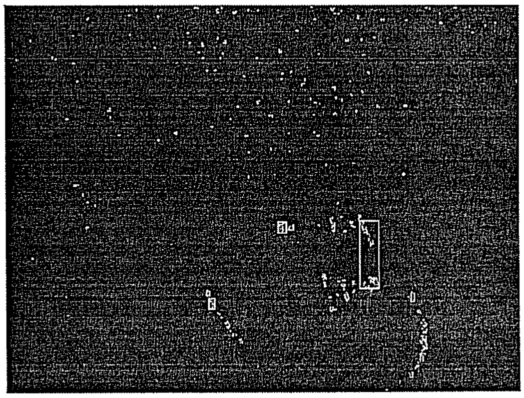


figure 34: The processed image does show some moving areas, but too small to raise an alarm.

Implications and Future Developments

The intrusion function was successfully assessed, showing a very good robustness and reliability. It appears that the future developments should be to industrialise it as a part of a complete operation & surveillance system, in order to integrate it properly with existing equipment.

The remaining identified cause of false alarms is the passing of authorised members of the staff through the covered areas. Much thinking had been given, in Cromatica, to the problem of distinguishing automatically between authorised (trains) and forbidden (the general public) traffic. In the context of Prismatica at NIAL, it seems that a more ordinary passcard access scheme, and a better integration of the Intrusion Detection function in the operation room's equipment, would be a straightforward solution to eliminate false alarms caused by the passing of staff.

Abnormal stationarity detection

Description of Evaluation Activity

A camera was installed in the access corridor to the planes, and shot images of passengers. The "normal situation" is when no object is left in the corridor, and the "real life" sequences show this situation. The false alarms were defined as alarms triggered in this situation.

Then members of INRETS/ILA crew left pieces of unattended luggage in the corridor, and/or stopped and remained motionless for a few minutes, in order to act potentially hazardous situations. The rate of missed alarms was then measured as the number of undetected left luggage or motionless persons in the surveyed area. The rate of missed alarm was defined as the proportion of people who entered and left the frame without having raised an alarm.

It must be emphasised here that the abnormal stationarity detector has one critical parameter, which is the time during which stationarity remains "normal". For instance, it is considered safe for a passenger to stop and check his plane ticket. A passenger doing so should not raise an alarm. On the other hand, stopping for several minutes is most likely to indicate an unattended luggage, a health condition, or other potentially harmful situations. This time parameter is supposed to be set once for all, and not changed during normal operation.

Results and Key findings

The function did not raise any false alarm during the trials.

About 100 incidents involving left luggage and/or motionless passengers were acted. The images below show the original images from the video tapes (on the left) , and the processed results (on the right). The grids of red points roughly delineate the shape of the detected "offenders".

The first image shows a black bag left by its owner two minutes earlier (this is a user-selectable threshold). At this point, the function has gradually accumulated the stationary time of this object, until the threshold is reached to raise an alarm. This alarm remains on for about 5 minutes (another selectable threshold), after which the software considers the bag to be part of the background, and the alarm stops. This is, however, not an inconvenience since the alarm *has* been raised, and for a normally sufficient time for the operation staff to notice and process it.

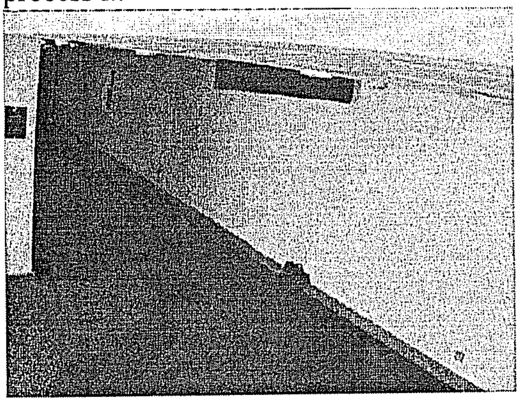


figure 35 : A bag left unattended for 2 minutes.

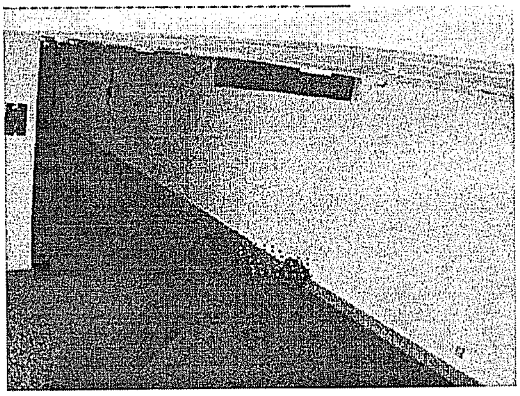


figure 39 : Processing results of figure 38. A detected area larger than the object is common, and not considered an inconvenience.

Other trials were made with people staying motionless while other passengers were passing in front of them. The behaviour of the system remained the same as in the precedent case, although the occlusions of the "offender" by other people did somewhat increase the time before raising an alarm. The stationarity is, however, kept in the memory even in this case, so an alarm was still raised in every case.

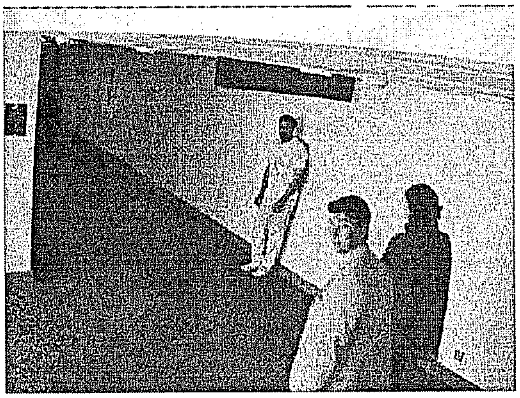


figure 40 : A passenger, standing motionless for 2 minutes.

figure 41: Processing results for figure 40. Alarm has been raised and the cause is correctly highlighted by the red dots.

The image below shows another scene obtained by panning the camera by 90° to the left, to a glass-made wall that lights the corridor the bag already shown on the 1st image above lies slightly on the right of the glass . This trial showed that very poor imaging conditions caused for instance by heavy backlighting do not prevent the system from working correctly.

Overall, no missed detection was noticed during the trials.

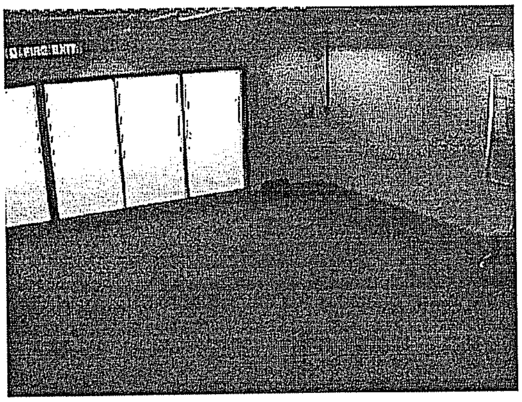


figure 42 : The "offender" is a bag left close to the centre of the image.

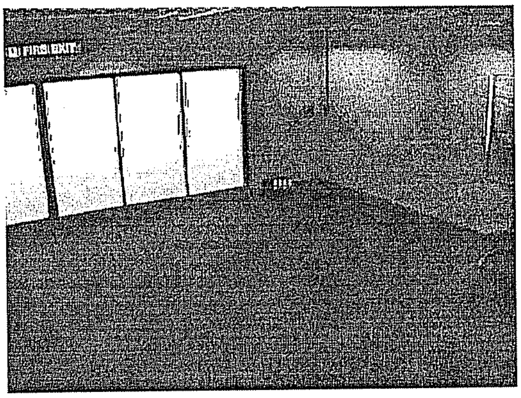


figure 43 : Despite very poor contrast, the bag is detected and located correctly.

Other lighting conditions such as sudden changes caused by alternances of sun and clouds could not be assessed in our trials because the weather did not allow it.

Implications and Future Developments

The system appears to work in a satisfactory way, and shows a good, robustness to both false alarms and missed alarms. The very small number of adjustable (and physically understandable by the user!) parameters is also a good thing in the context of routine daily use.

The only limit of this test was that we could not have access to a proper operator HMI, so no user feedback is available on this point.

Counterflow detection

Description of Evaluation Activity

The site chosen for counterflow detection was the CTA corridor through which people walked to go the boarding lounges. This is the same site that was used for the stationarity trials.

The trials were timed to coincide with passengers having just disembarked from a plane and moving through the corridor, in the direction toward the camera. The counterflow events were simulated by INRETS / ILA staff moving in the direction opposite to that of the passengers, i.e. away from the camera, at chosen times and for different passenger flows.

The evaluation was conducted on sequences of between 30 seconds and 2 minutes in length, extracted from the captured video footage.

The main parameters set by the operator are the direction of counterflow detection, expressed as an angle, and the detection tolerance, set as an angular sector also expressed in degrees.

Lower level configuration parameters that need to be set for the particular scene being monitored are:

- Maximum admissible counterflow velocity, measured from frame to frame.
- Minimum number of pixels where counterflow is detected: if the number of counterflow pixels detected is below this threshold, then it is considered that there is no real counterflow event in the scene and no alarm is triggered.
- Background noise thresholds.

When a significant – i.e. above threshold - counterflow event is detected, a message is sent to the operator and the counterflow event is highlighted in the image for as long as it lasts.

On evaluating this functionality on the data collected at NIAL, we found that provided the low level parameters listed above were set up correctly for the frame rate of the camera and the optical magnification of the scene, no false detections were observed.

Results and Key findings

Once the initial adjustments were made, no false detection was observed on all the sequences extracted from the captured video footage. It has to be noted however that the algorithm used is designed to work in relatively well controlled light conditions.

Limb motion in people or image noise, among others, can create localised counterflow conditions (for instance, somebody swinging their arms) so it was necessary to add a "minimum size of event" criterion to allow the system to discriminate between these and a real counterflow situation.

Although the system is usually tested on relatively near scenes, experiments were also conducted on image sequences captured in the airport check-in area, where passengers were viewed from a much longer distance. The system performed well in both cases, but performance was sensitive to low-level parameter adjustment, each scene requiring a different set of parameters.

Areas of the image with temporal illumination gradients did not cause particular difficulties analysis, as long as the variations were not too fast. The overwhelming majority of practical situations would fit this constraint.

The three detections below in figure 44 and 45 and 46 are examples of counterflow detection with an average optical magnification. The detection is successful, and no false alert is generated in the absence of counterflow event.

The software used for this function had been originally designed to cope with smaller amounts of data than that used in the present experiments. We observed that current processing speeds were not sufficient to produce detection results at the standard camera frame rate of 25 images per second, but nevertheless fast enough to respond adequately to the characteristic time scales of a counterflow event.

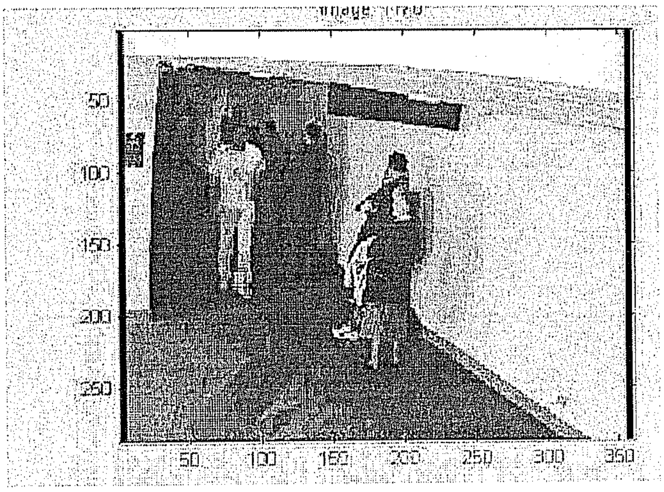


figure 44 : arrival of a person moving opposite the normal direction of travel. Start of detection (left foot)

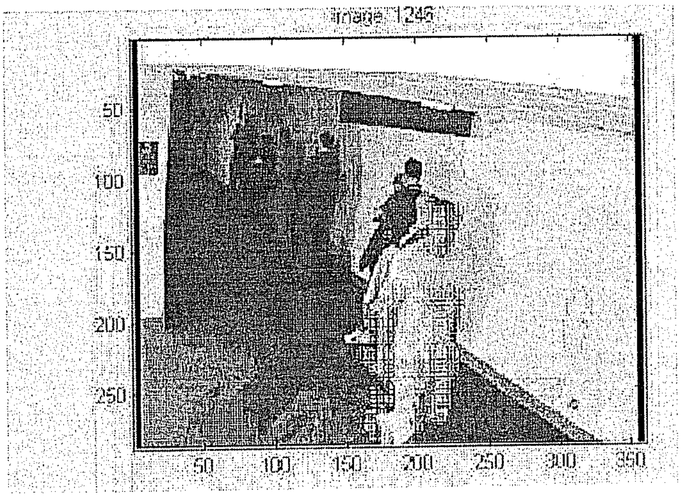


figure 45: counterflow event detected and highlighted to the operator

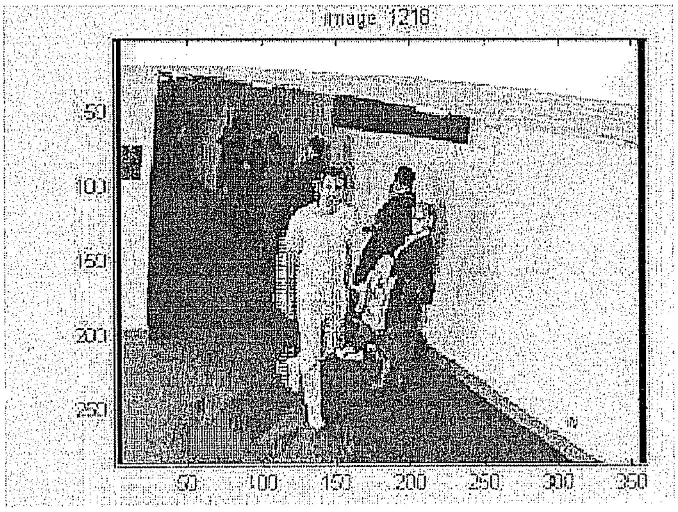


figure 46: counterflow detection continues as the person moves closer to the camera.

Implications and Future Developments

The counterflow functionality worked well and did not produce false alarms on the data collected on the test site. As with stationarity, no user feedback is available at the time of writing on system operation and on the presentation of the analysed data through a user interface, but it can be said that the results of the analysis are quite easy to interpret visually, and that once set up, the system does not require online adjustments.

Future developments should concentrate on reducing the number of low-level parameters that have to be adjusted and optimising the code for speed so that online analysis is possible on live sequences at higher image resolutions.

Passenger counting

Description of Evaluation Activity

Images of the passengers on arrival, leaving the airport through the international arrival gate, were recorded both on the counting processor's hard disk, and through a regular video camera as reference sequences. The two series of sequences were synchronised by matching the time-code (on the video recorder) and the start time of the files (on the image processor).

Back at INRETS, manual counting was performed on the video tapes, using several operators for accuracy, and taken as a reference. The automatic counting process, running on the image processor on the corresponding image files, was thus adjusted to give the smallest global error (the figure on the bottom right end of the table below). Then the whole set of sequences was processed again to fill in the whole table.

Results and Key findings

All the recorded sequences were processed using the same parameters (chosen as described above), and the resulting counts were compared to the results of manual counting taken as a reference. The resulting global error, over a sample of about 2,500 passengers, was an underestimation by 5.66%. It must be noted here that this figure did not change over a fairly wide range of the tested processing parameters, which indicates a good robustness to the parameters – in other words, the operators will not need to adjust the system all the time, which would prevent convenient operation of the counting device.

Seq. #	Duration (h:mm:ss:ff)	Manual count			Automatic count			Error (%)
		From planes	To planes	Total	From planes	To planes	Total	
1	1:21:19:01	201	3	204	200	2	202	-0,98
2	0:43:28:04	216	1	217	188	9	197	-9,22
3	0:06:12:10	25	7	32	21	8	29	-9,38
4	0:49:08:19	400	3	403	358	22	380	-5,71
5	0:21:09:18	54	0	54	52	1	53	-1,85
6	0:45:48:23	139	0	139	124	4	128	-7,91
7	0:45:39:22	191	1	192	184	2	186	-3,13
8	0:15:49:11	64	4	68	64	3	67	-1,47
9	0:20:37:21	157	4	161	139	9	148	-8,07
10	0:48:13:13	576	7	583	520	26	546	-6,35
11	0:05:21:23	4	0	4	4	0	4	0,00
12	0:23:19:07	86	0	86	82	3	85	-1,16
13	0:23:19:07	397	2	399	354	19	373	-6,52
			TOTAL =	**2542**		TOTAL =	**2398**	**-5,66**

Study of individual sequences showed that the systematic underestimation of the automatic counting was related not to the processing parameters, but essentially to a large number of people crossing the gate very close to each other, which may yield several passengers to be counted as a single one (cf. Figure below). Other, much less frequent causes of people not being counted are cases two passengers pushing the same luggage trolley, or children sitting on it.

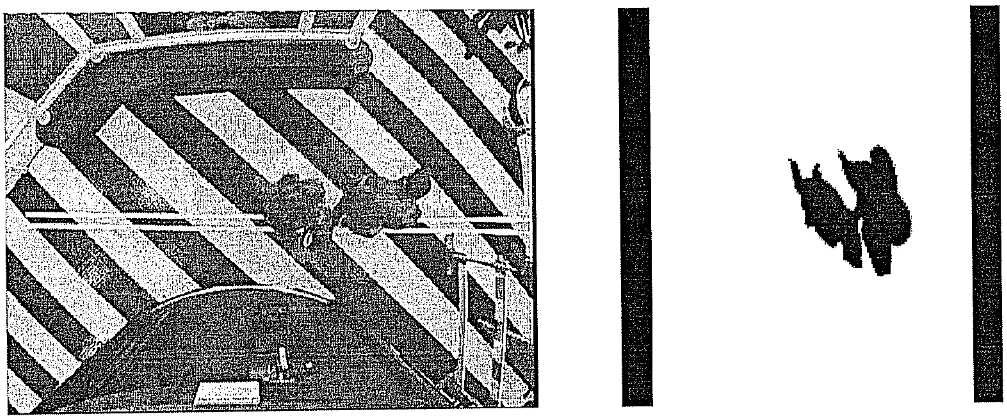


Figure 47: Two passengers very close to each other can be "merged" (cf. right image) and counted as one.

These effects are partly compensated by other issues that tend to yield *over*counting. The most common of these, in the framework of an airport, is the widespread use of wheeled suitcases, which have a thin handle that the system cannot see. As a result, the suitcase can be counted as a passenger due to the difficulty to distinguish between the shape of the suitcase and the shape of a "real" person (cf. Figure below).

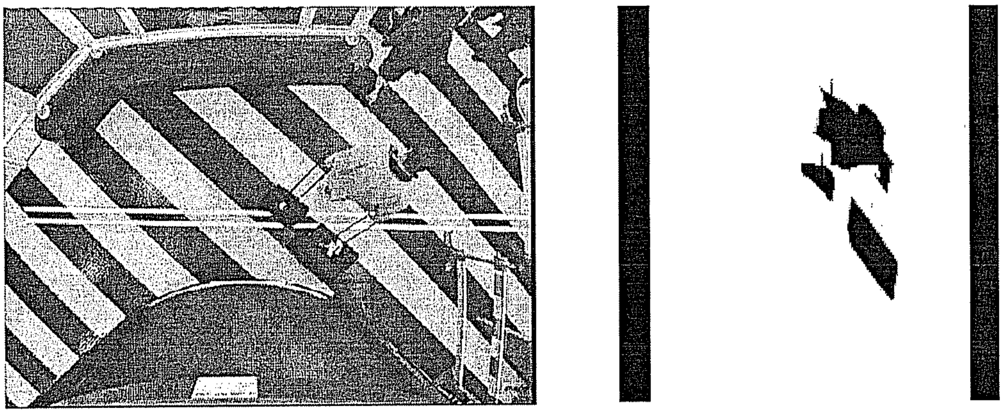


Figure 48: Suitcases can be seen "detached" from the passenger (cf. right image), and mistakenly added to the count.

The same problem can arise, in a very few instances, when a luggage trolley is held at the end of the arms. Then the shapes of both the trolley and the passenger can occasionally be seen as completely unrelated, and mistakenly counted as two passengers (cf. Figure below).

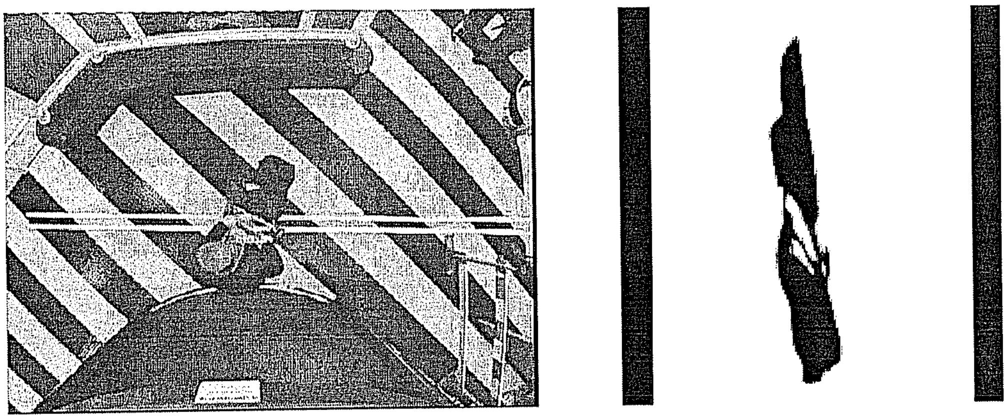


Figure 49: This trolley might be seen separately from the passenger, and mistakenly added to the count.

Finally, we met an regular family meeting, right on the retroreflective stripes of the counting device. Although we could not find out the exact effect of this on the counting (our software only gives the count for the whole sequence), and such instances appear much too uncommon to cause significant errors on a large scale, we feel this shows the importance of choosing the right place to install the cameras : apparently, this one was not extremely good, and should have been chosen closer to the revolving door where such events are unlikely due to the proximity to moving parts and people coming out.

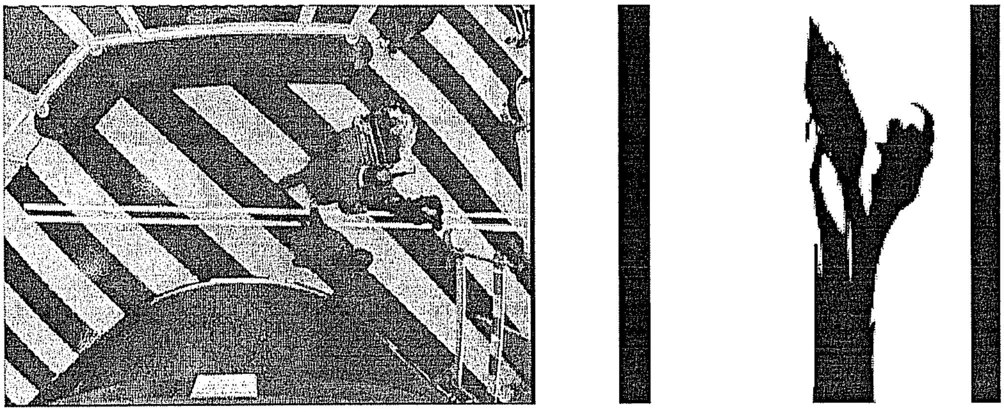


Figure 50: People going back and forth around the retroreflective strips might fool the system and cause counting errors.

Implications and Future Developments

The accuracy found here is noticeably better than what is generally offered by existing systems (which are more in the 10-20% range). It is also comforting that the whole system, when used on the field, could be installed in a matter of minutes despite the need to stick retroreflective stripes on the floor, and proved remarkably insensitive to the processing and imaging parameters.

An most important parameter here is the huge quantity of parasitic light that reaches the camera in direct sunlight. The design of the system must take this issue into account, by using the following steps :

- The integrated lighting system, which provides the light to the retroreflective system, must be powerful enough to compete with direct sunlight (during the first trials, clear clothes were not seen when lit directly by the sun), and have enough angular coverage to cover the whole length of the retroreflective stripe.
- Infrared LEDs (850nm here) must be used in the lighting system, and a matched IR-pass filter (Wratten 89B) must be placed in front of the camera's lens. This allows to reject most of the daylight, which is the visible part of it.

Another important point is the relatively good mechanical robustness of the retroreflective material, which was left in place from July through November without any specific protection, and was not noticeably damaged by the passing of several tens of thousands of passengers (a lowest-case figure, estimated from the traffic figures provided by NIAL). Only the part of it that was lying under the brush of the revolving door was torn away by the friction. Some manufacturers offer protected material though, intended to withstand such abuse, at an obviously increased cost, and with the requirement to "bury" it into the floor, so mounting is more lengthy and expensive. However we did not have the opportunity to actually test such material.

The only aspect still unassessed, although some thinking has been done on it, is the best way to integrate the counting results in the daily management of the airport. The system was originally designed to transmit, via the Ethernet network of the airport, timely statistics to the operation manager's PC, in order to store and process them in the way he finds most convenient. The later events, which led to give up the initially planned installation, did not allow the assessment of this part.

Queue length measurement

Description of Evaluation Activity

Due to the unavailability of the "local camera network" version of the software at the time of the trial, we used the version already running on the intelligent camera system, fed by the video tapes recorded at NIAL.

Images of queues were recorded at different moments of the day and of the year, to estimate both the robustness of the function to lighting conditions (uneven lighting, direct sunlight, poor lighting, etc.), and to various queue configurations (short or long, straight or curved, mixed with the passing passengers in the background, etc.). Although we did not go as far as to measure the actual length of the queues in the hall, we did check that the lengths "seen" by the system (shown as colored solid lines in the processed images below) did match the queues as we saw them on the original video sequences.

Results and Key findings

The first sequence (cf. Figure below) is representative of almost every sequence recorded during the trials. It shows two queues evolving beneath the camera, one (green, centre right) that is already well established, and one (centre left) on a check-in desk which has opened just a minute ago or so. Other passengers are walking in the hall of the airport, or standing to look up at the information panel that lies on the wall, just under the camera.

On the first sequence, the function has found a queue at the first opened chek-in desk, and approximated its shape and length with a good accuracy. Since the processing takes some time to build up a model of each queue, the other queue is only in the course of being detected (which is shown by the grid of white dots displayed over a group of waiting passengers). The red rectangles, in the bottom of the processed image, delineate the "starting pad" of a queue, which is the place where the first passenger in line is expected to stand, and from where the system will search a queue.

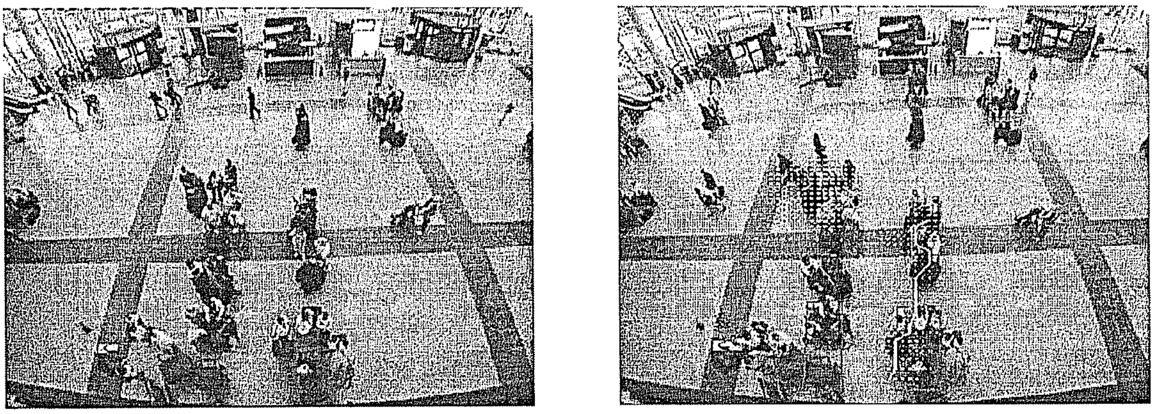


Figure 51: Two queues (1). The queue on the left is still in the build-up stage.

A few minutes later, both queues have evolved. On the left, the queue is now well detected and its length is approximated by the red solid line. On the right, the other queue has also evolved, and new passengers have just arrived, which explains why the approximation of the length appears shortened : these new passengers are not yet considered to be in the queue. As a result there is usually some "lag" between the actual queue and the representation given by the system, due to the time the latter takes to consider the evolution in time.

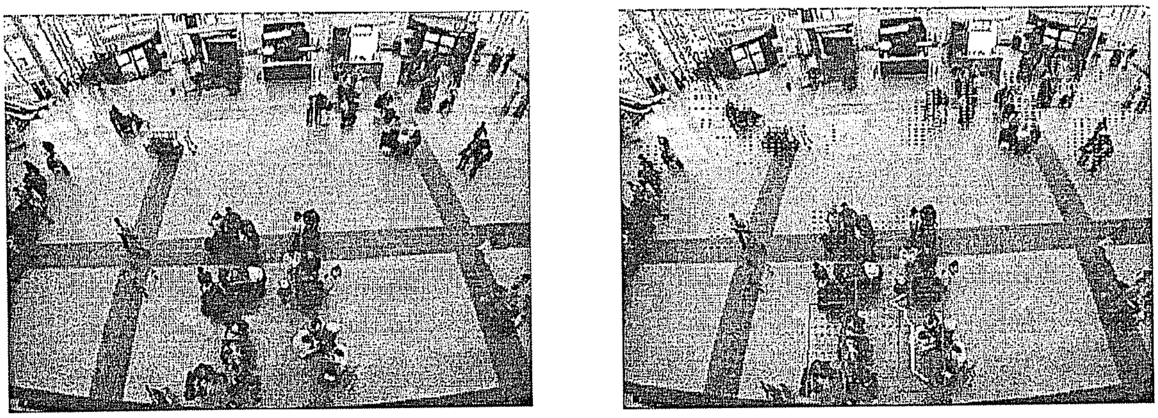


Figure 52: Two queues (2). The left queue is now detected.

The next sequence shows a possible error caused by passengers looking at the information panel. These are standing close to the end of a queue, but have not been mistakenly merged because they are too motionless. We have to stress out that, as a human observer, it is mostly because we know there *is* an information panel, those people are looking up, and they will not be following the queue *afterwards*, that we know that they are not part of it. It really is a difficult case to cope with.

N.B. : the third queue, on the right, has not been detected because the user has not defined a "starting pad" for it, so the system does not look for a queue at this place.

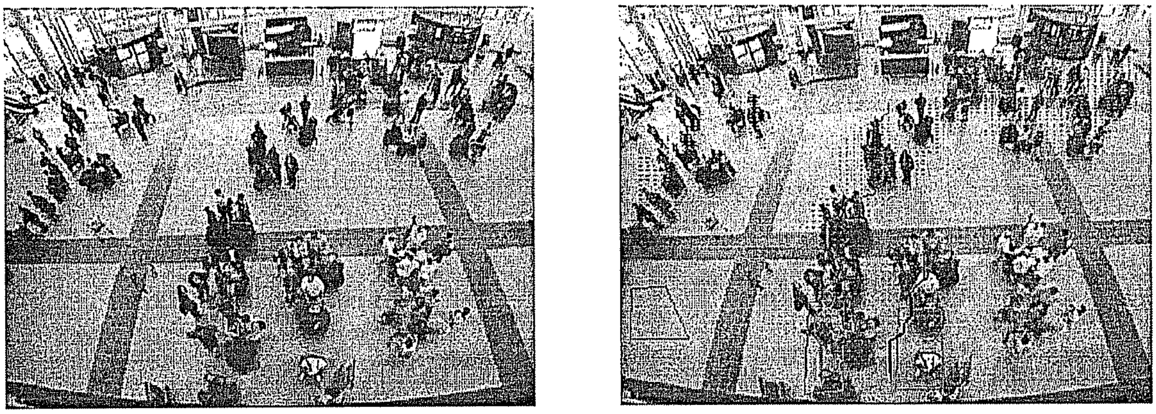


Figure 53: A tricky case. The people in the background have been correctly recognized as not being in the queue.

The last example, below, is one of the very few errors that we met during the trials. The queue on the centre left (red solid line) has been detected, but its direction and length are not accurate. This seems to be a likely behaviour when queues are too short (kind of "round-shape") to follow. Fortunately such issues are solved as soon as more passengers come in line, so actual (i.e. lengthy) queues never have this problem.

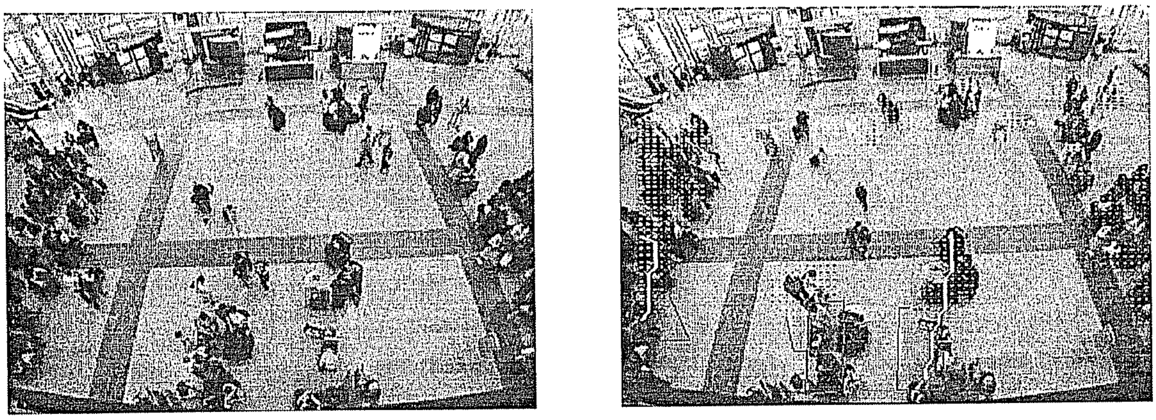


Figure 54: An error of the algorithm. The left queue is too short enough to be tracked properly.

Implications and Future Developments

The current queue length algorithm performed well in most of the situations met during the trials. From inquiries into other airports however, we know that queue geometry cannot always be considered as having a single direction. This is particularly true in the nowadays common situation where the queue is guided by a barrier system. As a result the queue takes a convoluted "snaking" shape. In this case, the combination of poor visual clues concerning the barrier system and oblique view angle make it virtually impossible for the system to correctly detect and follow the queue. Starting with this observation, we undertook to modify the queue construction technique used in the queue length to make it more versatile, using a "floodfill" technique combined with morphological operations. To avoid problems in determining the queue axis in cases where the direction of the queue is ambiguous, as in figure 54 shown above, a simpler but more robust queue length estimator was also tried.

Figure 55 below shows an example of the output produced by the modified function. The representation of the queue is correct, and matches what an observer with no a priori knowledge of the scene would consider as the queue.

The advantage of the modified scheme is to allow the operator to draw so-called cutlines in the observation window. Queue regions separated by cutlines cannot be merged together, and as a result the analysis scheme can cope with convoluted queue shapes more easily. This scheme is under further investigation with the aim of combining its strongest features with that of the current algorithm.

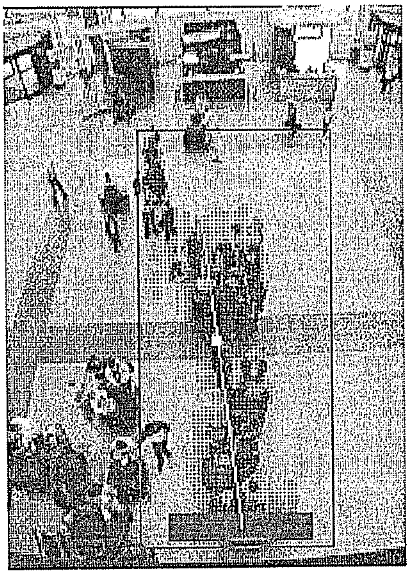


Figure 55: queue detection using alternative algorithm

Crowd density measurement

Description of Evaluation Activity

The density was estimated using the Intelligent Camera System version of the software, fed from the video tapes shot at Newcastle Airport. The video sequences (left) were processed and the resulting estimated crowd density provided by the system was superimposed to the original sequence (right) in order to be able to compare visually the densities estimated by the eye and by the system. As was said in Deliverable 12, it is difficult to find an objective assessment criterion for this function : the only one we could use would be its effectiveness if added to the airport's management system in order to take proper steps to reduce the crowding during peak hours. But only off-line trials could be done, so the only usable criterion would be the number of times the eye-based and system-based estimated densities agree to say "the place is overcrowded, something should be done about it".

Results and Key findings

Below are two processed results from the video sequences shot at NIAL. The crowd density is shown as a grid of colour dots on the right image. Red indicates that the corresponding area has been occupied since more than 3 minutes, whereas blue indicates less than a minute. No density at all is represented as no dots. The density is averaged over time over time, which is why some fairly high densities are occasionally shown where nobody is (there *was* someone a few seconds ago).

On all the sequences, the system matches well the density estimated by the human eye.

Figure 56 : Case 1. Density is high in the centre of the hall, and low on the sides.

Figure 57: Density map calculated for case 1.

Figure 58: Case 2. Density is highest on the edges, and null in the centre.

Figure 59: Density map calculated for case 2.

4.4.3 Conclusion and Summary

The results of the trials show that the output of the algorithms implemented on the local camera network meet the expectations, with in particular a good robustness to lighting conditions (except the aforementioned case of alternating sun/cloud in the case of abnormal stationarity, which could not be tested), and to the processing parameters, which do not seem to need adjustments during normal operation.

It must be mentioned, however, that although HMI was implemented, it could not be properly tested, due to the constraints mentioned in the introduction. The outputs shown here are "technical" displays, not intended to be watched by the operation staff, but for evaluation purpose only.

As a research institute, what we propose is mainly detection algorithms. Our domain is to use cameras and computers to perform the desired detection functions. So, at the end of PRISMATICA, what we propose is a laboratory version of the demonstrators. The degree of industrialisation cannot be much higher than this, because we do not have the knowledge on industrialisation, and moreover we do not have the connections with the companies that make integrated control & operation rooms, as required for smooth integration with existing equipment.

For this purpose we, at INRETS, are used to making an industrial transfer to a private company in the field, which will be able to modify the system in order to make it smaller, more integrable and cost-effective. In this case, market surveys would be under the responsibility of this company. Licensing arrangements will be made.

4.5 Audio Surveillance (Paris)

4.5.1 Description of evaluation activity

As explained in the previous documents, audio information may complement efficiently the use of the video information in order to handle security-related problems. The audio surveillance device has thus been designed as a pre-alert and cueing system that automatically detects loud and stressed human voice such as occurs in aggression situations. It is able to adapt to very different background noises both in level and in content.

The evaluation activity has both taken place in the Gare de Lyon RATP station for actual experiments and in TUS facilities for performance assessments.

Description of the evaluation equipment

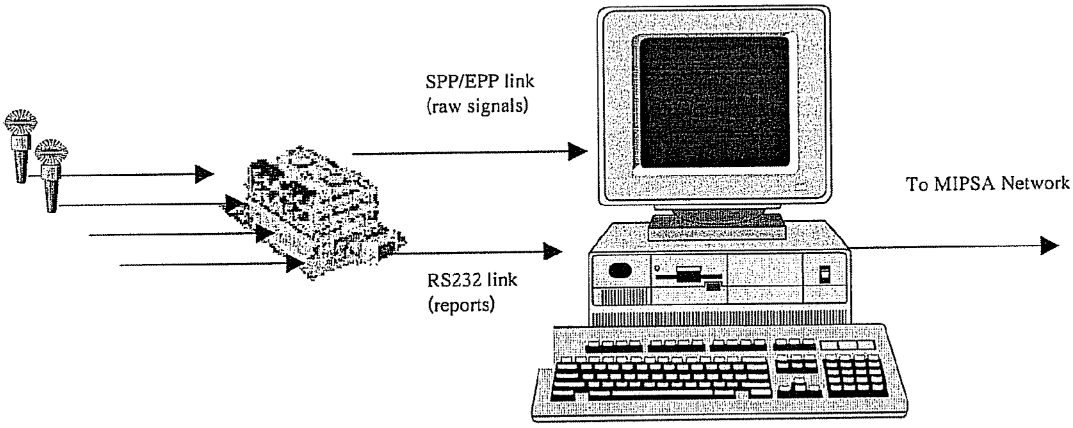
One elementary audio surveillance device consists of a set of microphones units (up to 4 per device) connected through shielded cables to a DSP board (actually located in the technical room).

Though sufficient for stand alone operation, the DSP board is connected to a PC which provides:

- Visualisation of real-time internal behaviour of the audio surveillance software through a technical MMI (serial/com link),
- Storage of detected audio events for off-line analysis and post-processing (parallel EPP/SPP link),
- Interface with the MIPSA through TAO/CORBA dlls.

Actual display of the event to the operator is achieved through the MIPSA MMI.

The overall audio surveillance structure implemented in Gare de Lyon is thus:



The operational function provided by the audio surveillance device is thus the detection and time stamping of unusual cries, potentially related to security problems. An audio feed back is provided at the DSP level (though in Gare de Lyon, this audio output is not relayed to the control room).

Initially, Paris tests were to be conducted in Havre Caumartin where four existing microphones were already installed and connected to a technical room. As the PRISMATICA Paris test site moved from Havre Caumartin to Gare de Lyon, microphones had to be provided and installed. The decided workshare was that TUS was to design and provide the microphones, and RATP was to install them.

The monitored zone in Gare de Lyon consists of two different zones where one microphone has been installed:

- the first is located immediately in front of the ticket line of Metro “line one” in order to be associated with existing cameras. The microphone is placed between a power line guiding (for neon lights) and the roof, and is completely invisible at the ground level. This microphone monitors the ticket hall as well as part of corridors leading to this ticket hall.
- the second is installed on the platform of “line one” at a height of 2.5 meters, at the top of a glass plane located behind a row of seats. This microphone is visible, as no convenient hiding place has been found nearby. This microphone monitors about half of the platforms as well as part of the corridor leading from ticket hall to “line one” platforms.

NB: Detection range of the sensors should be considered with caution. Due to the adaptive characteristics of the processing relative to the background noise, monitored area may vary widely from quiet to noisy acoustic environment both in space (eg microphone 1 is located near a fashion store with constant musical background) and in time (night/day). It obviously also depends upon the radiated sound level of the detection (the loudness of the cry/shout).

Elements of context which can have an influence on the response of the system are mainly related to background noise both in its level and in its content. Three main classes of situation may arise, thus defining the associated experimental contexts :

- The first situation is associated with low level constant background noise. This context corresponds to isolated corridors or slow hour/night-time conditions. This environment is liable to yield the best detection ranges.
- The second situation is associated with potentially high level, but slowly evolving, background noise. This is the standard daytime environment.
- The third environment is a particular case of the second, where specific ambiguous sound sources may be present. This include zones where musicians are playing, workers using circular saws,....

In order to gather data that is representative of the various conditions met on location, we carried out different tests and data collection between June and November 2002, both during daytime and slow hours. Actual operation of the device took place between mid-December 2002 and mid January 2003. All kinds of spurious sound sources were present such as saxophone and accordion players in corridor, Eastern Europe player band (near ticket hall), trains tyre/break screeches on platforms,...

4.5.2 Results and Key Findings

Detection performances

Evaluation description

As it is obviously difficult to obtain audio recordings of actual aggression, realistic simulated events have been recorded using actors through 116 scenarios. These records involved 6 actors (three male and three female) and were collected during night-time at Havre Caumartin Station. Scenarios were defined according to their operational import. Three classes of scenarios were thus obtained:

- "Snatch Robbery": the thief grabs an object and runs away. The victim calls for help.
- Pick-pocketing: As a successful theft involves no sound, it is assumed that the victim is aware of having been robbed, and either calls for help or argues with the thief.
- Robbery under threat: both he victim and the robber shout/argue.

These scenarios included some shouts, but mainly small shouted phrases (such as Help! Thief!...) and even sentences building up the stress of the situation (these records have been described in detail in previous deliverables). Some discrepancies may occur in data recorded in a deserted station at night-time due to an unusually high reverberation level that is naturally damped when many passengers occupies the monitored area. These effects have been neglected because they are not likely to occur with a high level background noise which tends to mask them.

The overall reference case was obtained in mixing both simulated events and actual background noise at different signal to noise ratios. It has been seen that there is no other practical way to define a reference case for detection, as actually shouting at a calibrated level in exploitation is extremely disturbing for both the experimenter and the passengers. The reference background noise was recorded in Havre Caumartin during daytime at different hours (rush hour/slow hour) and places (in isolated corridors, on platforms, near shops, in halls....).

As expected, low background noise level has the main effect to improve the detection rate (or to increase the detection range, at the same detection rate). A reference signal to noise ratio has been defined according to actual live record at Gare de Lyon in order to obtain a realistic situation awareness (i.e. should a scenario occurs within the range of the sensor, an unalerted observer would be aware that a crisis situation is happening). An event is said to be detected if an alarm is sent by the device during verbal exchanges

Performances

It is reminded that the processing scheme involved three successive steps in order to validate an alarm.

The three steps are:

1. Primary detection (signal to noise ratio estimated on adaptive short time window exceeding a given threshold)
2. Characterisation: automatic extraction of features (criteria) significant of an alarm
3. Validation: rule based system for validating alarms and rejection of false alarms

Using the above defined signal to noise ration between scenarios records and ambient noise, the whole base of 106 scenarios led to:

- 4 scenarios that did not lead to a primary detection (step 1): this is completely dependent upon the choice of noise level in the mixing of actual event and ambient noise. Increasing the level of signal (i.e. reducing the detection range or having a quieter environment such as in low activity times of the day), leads to correct detection of the event.
- 3 scenarios that did not enable to extract the necessary criteria for alarm characterisation: these are mainly related to scenario involving a specific female actor. In these scenarios, the combination of nearly pure tonal shout and masking noise prevented the processing from extracting the necessary feature for the characterisation process.
- 4 scenarios that did not pass the set of rules used for alarm validation. These are mainly associated with shouts too short (such as Oh! Ah!) for which signal to noise ratio didn't exceed the threshold long enough, triggering the rule about minimum duration of an alarm.
- 95 scenarios that led to a validated alarm (90% of the total number of detections).

These results are strongly dependent upon the level of ambient noise for a given distance to the sensor. Nevertheless, some scenarios are not detected even in a high signal to noise ratio configuration due to the structure of the device software and the basic hypothesis underlying the processing: 5 scenarios are still not associated with an alarm, even with the raw records involving no additive noise apart from the night-time ambient noise. It thus should be understood that the audio surveillance device is not suited to the detection of very short duration shouts, and in some cases, to nearly pure tonal sounds (vocalisations of some female voices).

False alarms

Evaluation description

Concerning the false alarms, performances of the audio surveillance system have been evaluated on actual ambient noise recorded or processed on-line in various configurations. Records from two sites have been used: Havre Caumartin Station and Gare de Lyon station. Contrary to the simulated scenarios where the actual time of occurrence is fully controlled, the problem with false alarm is to analyse large amounts of data where spurious events could occur anytime, but also where actual events may lead to correct detections. In order to sort out what is really a false alarm, it is obviously not practical to have a permanent audio operator listening to the raw signal, and annotating each detection. It is also difficult to store raw signals over long periods of time either on DAT tapes (which need to be swapped every 4 hours) or on a hard disk (1 Gbytes per 2 hours).

A specific add-on has thus been designed and integrated into both the audio device DSP board and in the PC used for technical display and communication with the MIPSA. A local memory of all raw channel signals is continuously updated for a maximum of 66 seconds per channel. If a detection occurs, the corresponding time slice (with an extension of 0.5s before the event and 0.5s after the event) is extracted from this local memory and transferred to the PC. As the usual serial link is unable to cope simultaneously with both normal report transfer and signal transfer, an adaptation to drive the parallel port of the PC in either EPP/SPP mode has been designed to store the raw sound as a wave signal (*.wav) associated with the time stamp and technical characteristics that led to this alarm. This enables to only store the alarms on the hard disk of the PC.

Actual comparison is done through individual audio analysis of detected events (the only way to validate a posterior a detection or recognise a false alarm). The phenomena to be detected are then defined relatively to the general characteristics of the noisy simulated events: in particular, relevant events explicitly exclude isolated very short cries as these rarely occur in interesting situations.

Apart from the precise description of the nature of the detected signal, three broad classes of detected events have been defined:

1. Actual detections: These real alarms have been caused by actual shouts (children, teenagers making a din, calls between friends, drunks,...) or unusually loud speech (animated talks, quarrels,...). These are obviously not aggression situation, but they cannot be considered as false alarms as they meet the selected criterions. From a system point of view, they would lead to the possible cueing of another sensor such as a camera in order to discard or confirm the alarm.
2. "Known" false alarms: these false alarms are related to acoustic sound sources that have been previously identified as difficult to reject by the system. Four such types of sound have been observed to have both temporal and spectral characteristics that led to ambiguous decision from the device. They are:

    - Loudspeaker announcements: Loud announcements obviously meet the detection criterion. These alarms can be detected everywhere. It must be noted that from a system point of view, the false alarm could be quite easily cancelled as their activation is controlled by the PTO.
    - Screeching tyres/breaks: this alarm is detected on platforms where train arrivals sometime come with a screech-like sound which origin is unclear (tyres or break). It was not possible to cancel this type of false alarm without rejecting many shouts from scenarios (mostly with female actors).
    - Door buzzers: these buzzers warn passengers that the train doors are about to close. This false alarm has been seen to occur only when the buzzer sound has a low signal to noise ratio (e.g. it rings while many passengers are walking on the platform). It is obviously encountered only near platforms.
    - Musicians: Apart actual songs (or shouts such as used by Eastern Europe bands) that meet the detection criterions, some instruments have been seen to have acoustical properties (time/frequency) very close to human voice. It is the case for some wind instruments (such as saxophone) or low frequency string instruments such as the cello. Other instruments such as accordion are correctly rejected.

3. "Unknown" false alarms: this class is related to any detected events that do not belong to the previous classes.

The next chapter deals with the actual performance assessment of the audio surveillance processing

Havre Caumartin recordings

Six test records of ambient noise were selected to reflect different recording conditions and environment. The location were the main hall, a platform, a corridor and the ticket hall and recording times span a full day of activity from 8h00 to 21h30. We present hereafter the results obtained by the device as number and origin of the alarm (as analysed from hearing stored raw signal around the detection).

- Test n°1 : duration = 1h10

Origin	Number
Loudspeaker announcement	2
Mixed speech and door buzzer	1
Incoming train /Tyre/break screech	1

3 detections are related to "known" false alarms. The detection of door buzzer may have been in fact triggered by the speech.

- Test n°2 : duration = 1h05

Origin	Number
Incoming train/ Tyre/break screech	1
Departing train	1
Unusually loud speech	2

1 detection is related to "known" false alarms. The detection of the departing train is unusual and processed as a "unknown" false alarm.

- Test n°3 : duration = 0h55

Origin	Number
Unusually loud speech	1
Incoming train Tyre/break screech	2
Departing train	1

2 detections are related to "known" false alarms. The detection of the departing train is unusual and processed as a "unknown" false alarm.

- Test n°4 : duration = 1h10

Origin	Number
Creaking noise of unknown origin	1

- Test n°5 : duration = 1h30

Origin	Number
Shouts	1
Door buzzer	1
Departing train	1

1 detection is related to "known" false alarms. The detection of the departing train is processed as a "unknown" false alarm.

- Test n°6 : duration = 1h15

Origin	Number
Singer vocalisations	2
Door buzzer	1
Unusually loud speech	3
Saxophone	2
Tyre/break screech	1

4 detections can be associated with "known" false alarms.

Gare de Lyon Recordings

Two test records have been made during July and October 2002 that sample a day of the week in Gare de Lyon. The presented results combine detections made both on the platform and in the ticket hall by the microphone deployed there.

- Test n°7 : duration = 1h50 *2 (independent microphones)

Origin	Number
Simultaneous door buzzer and tyre/break screech	1
Door buzzer	1
Unusually loud speech	1

In this configuration, all false alarms fall into the "known" false alarm category. These false alarms are all located on the platform microphone and no false alarm occurred in the ticket hall.

- Test n°8 : duration = 2h00 *2 (independent microphones)

Origin	Number
Shouts	5
tyre/break screeches	2
Unusually loud speech	3

In this configuration, all false alarms fall into the "known" false alarm category (more precisely the screeches generated by tyres/breaks). These false alarms are all located on the platform microphone and no false alarm occurred in the ticket hall.

We also get detected alarms from some sequences recorded during the system exploitation between December 2002 and January 2003.

- Test n°9 : duration = 17h30 *2 (independent microphones)

The next test was preceding the actual long duration test with full interface with the MIPSA. It spans nearly a full day beginning at 17h00 and ending at 11h30. It thus covers two rush hour periods as well as a night and low-activity periods.

Origin	Number
Unusually loud speech	1
Shouts	1
Loudspeaker announcement	19
Door buzzer	2
Tyre/break screeches	2
Train klaxon	1
Musicians	2
Unknown origin	1

Most of the false alarms correspond to loudspeaker announcements and except one noise of unknown origin (possibly power interference), all false alarms are associated with the "known" false alarms category.

- Test n°10 : duration = 1h00 *2 (independent microphones)

This test was conducted on the 18th of December 2003, immediately before the long term evaluation test.

Origin	Number
Loudspeaker announcement	2
Unusually loud speech	2
Loud speech	2
Tyre/break screeches	1
Door buzzer	1

All 4 false alarms are associated with the "known" false alarms category.

- Unfortunately, no result is available for the actual long term test where the full system was left unattended between the 18th of December 2002 and the 8th of January 2003. Though the audio surveillance device was still operating after these three weeks, detection results were not stored on the PC as the technical software necessary for both transmitting event to the MIPSA and storing the results crashed. A latter analysis seemed to indicate that a flaw in the TAO/CORBA software backbone generated unhanded Windows NT exceptions on devices connected to the network. As no one restarted the storage and communication software on the PC, all alarms transmitted by the audio surveillance device were lost.

- Test n°11 : duration = 1h30 *2 (independent microphones)

This last test was conducted just before a presentation of the device at the test site on the 10th of January.

Origin	Number
Loudspeaker announcement	1
Shouts	3
Train klaxon	1
Loud speech	3
Tyre/break screeches	2

All alarms can be associated with the "known" false alarms category.

False alarm global results

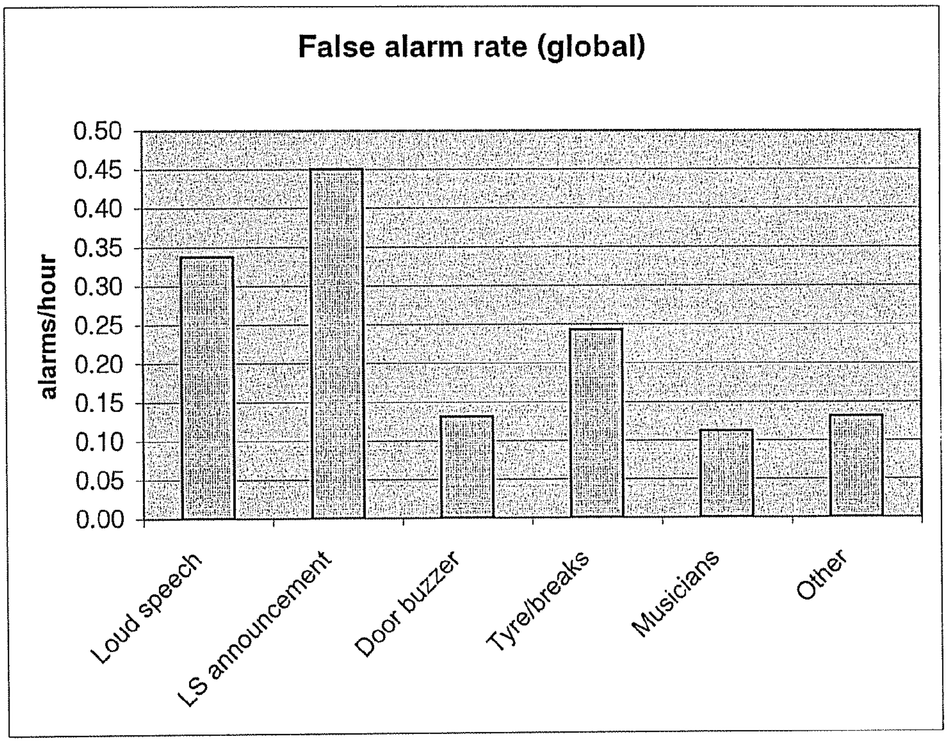
Global results may be presented in different ways: for example, in radar, the false alarm rate is computed relatively to the total number of decision taken by the processing. This is useful to assess the false alarm performance when dealing with random noise, but quite impractical to understand when the major source of false alarm are actual sound sources. Every single one false alarm observed during the tests has been associated with a real sound source (sometime of unknown origin), but never with random noise.

As described in D12, the indicator to be used is the number of false alarms per hour, which is a more "operational" notion. One must also understand that contrary to random noise, the results are highly dependent upon the actual occurrence of those spurious sound sources. It is obvious that the false alarm rate for musicians will increase for a microphone placed around their favourite spot, as well as tyre/break screeches and door buzzers will decrease far from the platforms.

Nevertheless, global indicators have been computed from all the tests conducted above.

Test	Duration (in mn)	Shouts	Loud Speech (all)	Loudspeaker announcements	Door buzzer	Tyre/breaks	Musicians	Other
1	70			2	1	1		
2	65		2			1		1
3	55		1			2		1
4	70							1
5	90	1			1			1
6	75		3		1	1	4	
7	220		1		1	1		
8	240	5	3			2		
9	2100	1	1	19	2	2	2	2
10	120		4	2	1	1		
11	90	3	3	1		2		1
Total	3195	10	18	24	7	13	6	7
Number of events per hour per sensor		0.19	0.34	0.45	0.13	0.24	0.11	0.13

The system being correct in detecting actual shouts, they are not taken into account in false alarm indicators.



Loudspeaker announcements are the main source of false alarms of the system, with an average false alarm rate of one event every 2h10 (of course depending upon the frequency of such announcements). As this can be controlled at the system level (inhibition of alarm display during loudspeaker announcements), this should be managed without impairing too much the system efficiency. The main effect would be to have no audio surveillance during the announcements, but it should be noted that it is already the case. For the sake of precision, it is technically possible to maintain detection capability during announcements, provided that an analog feedback of the loudspeaker could be redirected into the audio device DSP board (noise cancellation techniques), but it would obviously increase both algorithmic and installation constraints.

Detecting unusually loud speech is more subject to argument, because in many scenarios designed for the detection scheme, no shouts are issued but there is a loud verbal exchange. On the other hand, it is expected that some passengers may have animated discussions or expansive behaviours. Reducing the detection rate of otherwise normal discussion would considerably impair the detection of actual stressful situations. They globally contribute at a level of one false alarm every 3 hours and may appear at any location inside the station area.

Tyre/break screeches are the third most important origin of false alarms, with an average of one every 4 hours. In fact, as this kind of alarm may only occur near platforms, the actual figure is nearer one every 2 hours for these locations. As explained in previous documents, these false alarms should be very difficult to cancel as it can sometimes give a fair imitation of a human screech. Fortunately, it seems to appear on only a few trains.

Door buzzers are also alarms that only appear on platforms. As they need rather specific acoustic condition to trigger the device (usually that many people are walking on the platform), they don't generate alarms at every train. They still are responsible of a false alarm every 7 hours, that should be corrected to 3h30 to take into account the fact that it only appears on platform.. It can be noted that a more efficient rejection of door buzzer could be achieved by incorporating very precise decision rules involving the design of the buzzer. The main drawback of this approach is that the device must be tuned to the buzzers used by the trains of a given network or even a given line. Within this constraint, significant improvements could be achieved for this false alarm category.

From the raw figures, musicians seem to be only responsible of a average rate of one false alarm every 9 hours. This figure masks a highly contrasted situation depending (obviously) upon the presence of a musician, but mostly of the type of instrument. It should be noted that in Gare de Lyon, the musician located nearer the two microphones was playing accordion, which is well rejected by the system. Should a saxophonist take its place, the false alarm rate would have been much higher.

To summarise further, and supposing that loudspeaker announcement can be managed at the system level, it is possible to classify these results in 3 main categories.

Events nature	Mean time between false alarm per category (in hours)	Mean time between false alarm for previous categories (in hours)
Random events	26.5 hours	26.5 hours
Loud speech Loud speech +random events	3 hours (1)	2.7 hours
Musicians False alarm outside of platforms	8.9 hours (2)	2 hours
Train noises (on platform only) False alarm on platforms	1.2 hours (3)	0.75 hours

(1) may include actual events

(2) highly dependent upon the musician activity and instrument

(3) can be improved by tuning the system to reject door buzzer for a specific type of train

One must stress the fact that these figures should be taken with caution, as the long term experiment didn't lead to a large amount of data.

4.5.3 Implications and Future Developments

Implications

Analysis of the previous results shows that if the system exhibits a good behaviour versus random acoustic events (even in severe environments such as in halls and near shopping mails), some classes of sound will generate spurious alarms. Reflecting the structure of the software, these sounds are closely related to human voice and thus ambiguous with the events to be detected. Loud speech is a very good example of the difficulty that this implies, as there is no clear boundary between a lively argument between passengers and an actual aggression situation.

The obvious countermeasure to such false alarms is to raise detection thresholds at the cost of a smaller detection range, but it will not be enough for intrinsically loud spurious sounds such as the screeching noise of train brakes/tyres, or some musical instruments such as the saxophone.

Another (obvious) implication of the previous figures is that the place chosen for placing the microphone has a high impact on false alarm performances.

- As trains are a major source of ambiguous sounds (breaks/doors buzzers), microphones located on platforms will generate far more false alarms that one located in a ticket hall.
- On the contrary, corridors and halls are quite suitable for microphone deployment, whenever places favoured by musicians could be avoided. Though quiet locations are to be preferred for detection range/ coverage , the system can also operate in busy environments.

Globally, these results thus confirm that the audio surveillance system is not suited for a stand-alone application, but may well be useful as a cueing system for selecting cameras to be process either automatically or by a dedicated operator. Thus a MIPSA architecture managing this association and prioritisation between heterogeneous sensors and the operator is completely justified as far as the audio surveillance system is concerned.

Future Developments

Though the audio surveillance device developed in PRISMATICA has enabled to assess the utility of an acoustic surveillance component in the detection of unusual acoustic situations, it appears that complementary study and development work are needed before being used in operation and industrialised. These complementary works include:

- Further reduction of the false alarm rate: though it has been stated that the most annoying false alarm sound source are intrinsically ambiguous with the interesting events, it is probable that dedicated work would provide further performance improvement. This could be obtained through two main leads:
  - By tuning classification to a specific environment: So far, a general solution has been looked for, trying to meet the most general requirements: a single device could be used in all PTO networks and lines without adaptations. If this constraint is not maintained, it is possible to tune the devices to a given environment (for example, adapted to a given door buzzer or break/tyre resonance).
  - By relaxing constraints in the type of event to be detected: it should be possible to improve false alarm rejection, if the specification of interesting events was slightly modified. For example, it could be decided that isolated shouts are of little interest, and that a actual event should involve at least two short phrases. In the same way, specific study of ambiguous musical instrument such as the saxophone or the cello should lead to the detection of musical phrases which frequency spans too different from human voice.

  All these studies should be validated on the existing prototype and MIPSA environment.

- Extension to 8 microphones per DSP: Software optimisation should enable the system to cope with its full 8 microphones capability.

- Hardware improvement:
  - Integration of interface with MIPSA: the purpose would be to add an Ethernet capability to the audio device base board, and cancel the need of an local PC. This could also be tackled differently by enabling to concentrate the DSP serial link to the MIPSA computer, thus reducing hardware costs.

All these developments should be validated by long term testing in different stations before industrialisation.

4.6 Contactless-Passcard System (Paris)

4.6.1 Introduction

The pass-card system has been developed in 3 steps

- a preliminary step , before PRISMATICA , where some trials ere performed and the needs specified progressively,

- a second step, within PRISMATICA, has allowed to test the various components of the system, to improve their efficiency /performance and to test the system in the metro station of "Gare de Lyon " researches carried-out through WP4, tests through WP5 and evaluation through WP6. At the end of WP6 , the evaluation process of the pass-card system has been performed within the evaluation of the whole system , i.e. MIPSA + the other systems developed through PRISMATICA. This evaluation has been concluded by a report providing the opinion of the RATP staff in charge of the operation and security of the GARE de Lyon /line 1 station (see below).

- a third step has been undertaken by RATP in parallel to he works/tests performed through PRISMATICA in order to check the pass-card system in actual "operating " conditions. The pass-card system has been installed in 8 stations of the line 4 and Gare de Lyon. This project has been scheduled in order to complete the setting-up before the International conference of March 12 &13 the 2003 which has highlighted the outputs of PRISMATICA. The participants to the said conference had the liberty to pay a visit to the a.m. stations and to see and test by themselves the pass-card in site conditions. The first remarks we got at this occasion were very positive. Of course , RATP has taken the opportunity of this step to bring some improvements to the system. They are described in the related technical note.

4.6.2 Project Description: Portable Emergency Call Device Line 4 (B.A.P.)

Context of the Project

Goal of the project

The project consists in securing the exploitation agent during his/her various assignments, opening and closing of the grids and/or visit of his station and of his/her installations.

The securing of eight stations on line 4, North sector is schemed.

Château Rouge, Porte de Clignancourt, Simplon, Marcadet, Barbès, Gare du Nord, Gare de l'Est and Château d'Eau.

General description of the project

This deals with enabling the exploitation agent to emit an "EMERGENCY SIGNAL" to the Connection Centre, located in Gare de Lyon, at anytime.

The System Operation

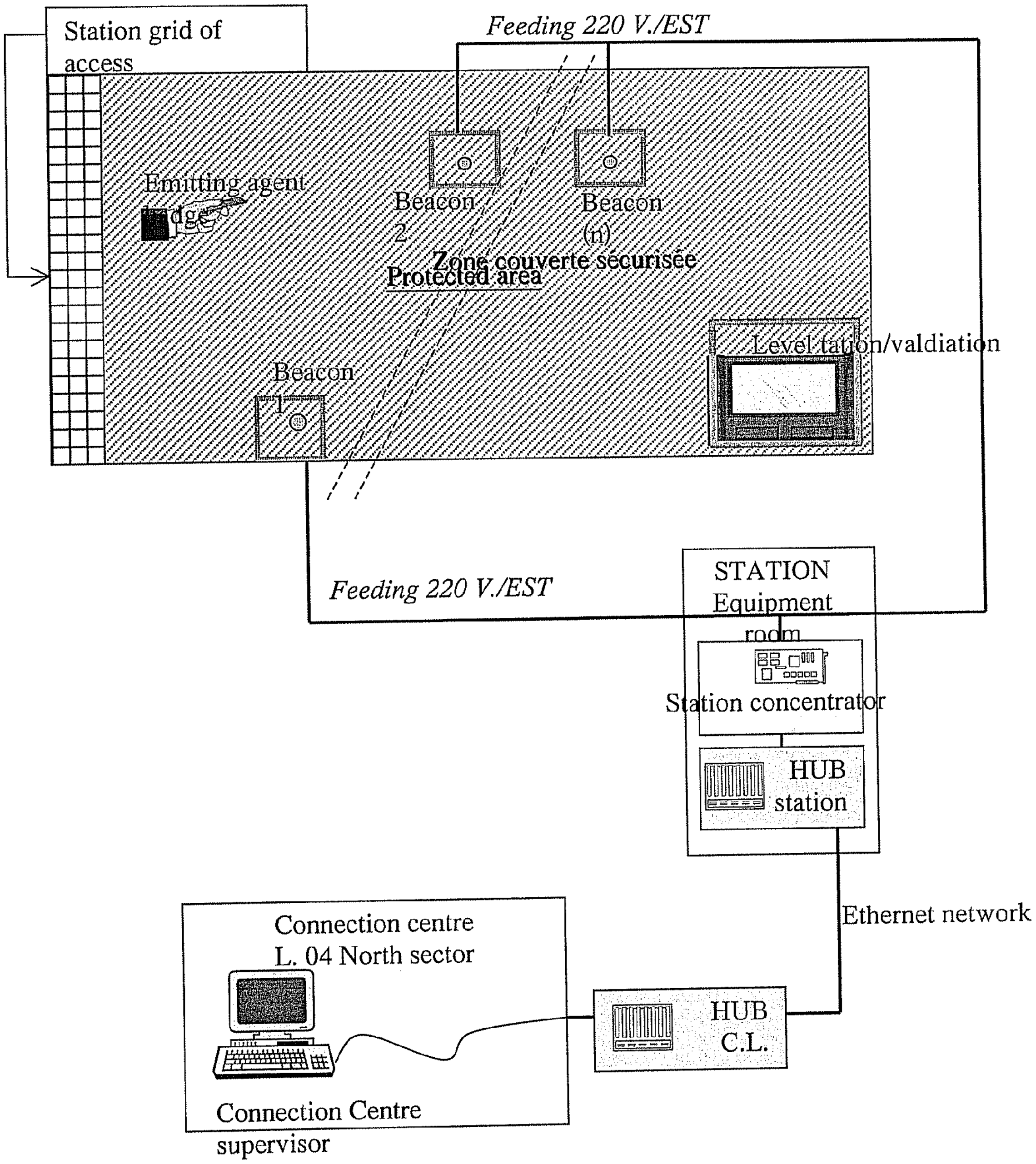
The exploitation agent is supplied with an RATP department card support badge, supplied with an "EMERGENCY CALL" button. This badge is radio broadcasting in real time by a double click (two successive strokes within less than three seconds) from the agent on this button, an alarm shall be transmitted to the Connection Centre.

The system shall ensure the traceability of all information exchange of the various components of the system.

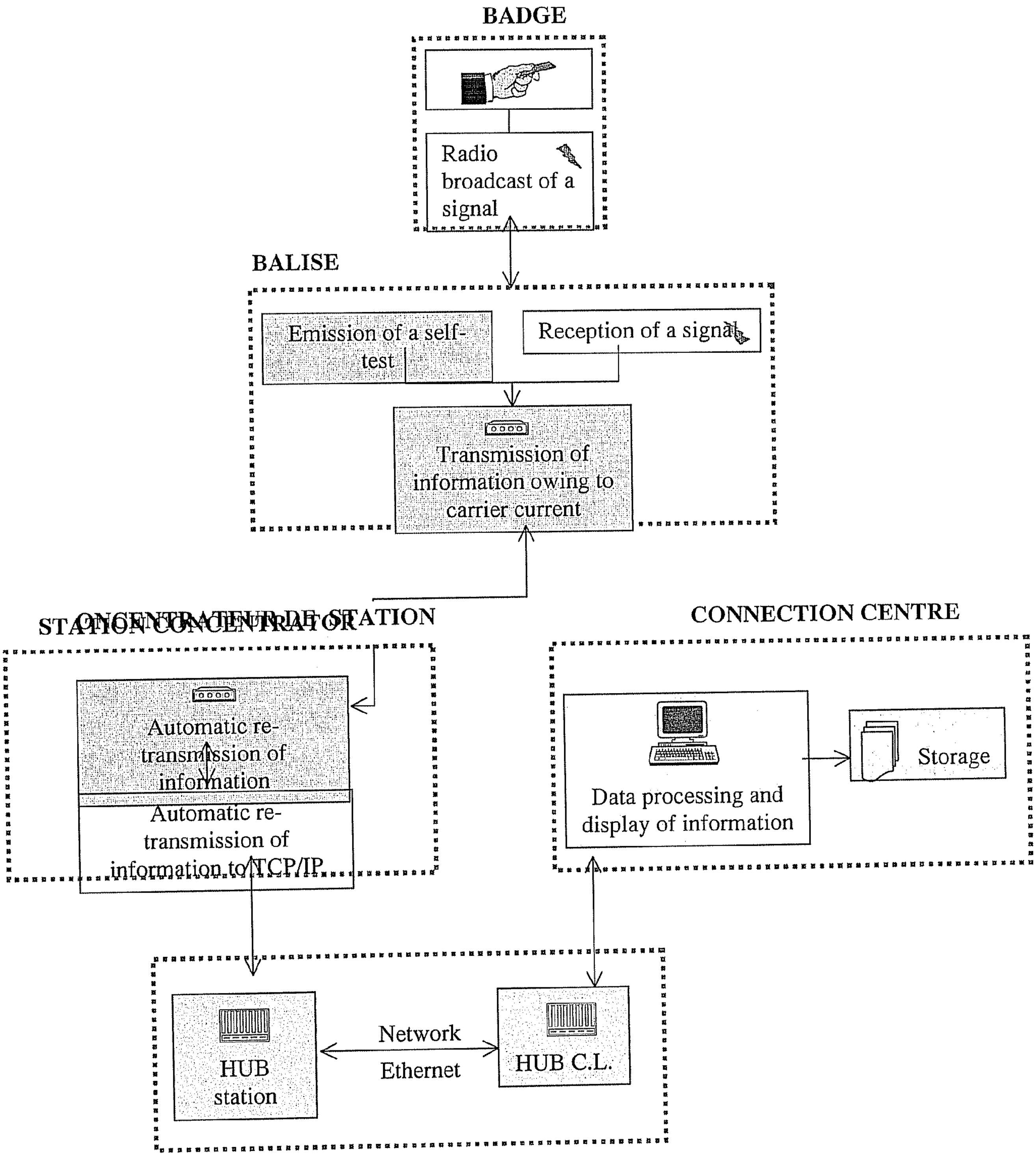
A self-test system allows checking the efficiency of the whole system at anytime and notifies the Connection Centre about any isolated fault.

The System Architecture

Schematic diagram



Functional architecture



Architecture of the equipment

The system is composed of the following components:

- badges
- receiving beacons
- station concentrators
- a Connection Centre supervisor

The agent badge

It is constituted of a department card support box / shell of a socket, of a BAP (PORTABLE EMERGENCY CALL DEVICE) card, of a chip card reading system, of an "EMERGENCY CALL" button and of an encrypted radio-electric emitting system.

It is small-sized, thus allowing to easily be thrust into one's pockets. It ensures the event-driven storage / the storage of events for 10 days.

It is endowed with a system allowing the exploitation agent to check its long-term efficiency by pressing continuously (more than two seconds) on the "EMERGENCY CALL" button.

The beacons

They are equipped with a system allowing to receive the information sent by the agent badge and with a system allowing to transmit these data through carrier current through the RATP LV network (Low Voltage network).

They are endowed with a self-test system allowing to simulate a whole sequence of alarm transmissions, a different sequence from that of an actual alarm.

They are electric-fed through RATP LV network.

Their numbers and introduction are defined by the constructor so as to ensure the whole covering of the areas to be protected.

They ensure the event-driven storage for 10 days.

If the "EMERGENCY CALL" is set off, the beacon(s) receiving the call emit(s) a signal indicating that the supervisor has taken this "EMERGENCY CALL" into account.

The station concentrator

This equipment allows receiving the information sent by the beacons through the RATP LV network.

It ensures the remote-transmission / re-transmission of these data through the RATP Ethernet network.

It is usually installed within the equipment room(s) of the station which are provided with low electric current and according to its configuration (if it matches or not).
It ensures the event-driven storage for 10 days.

The Connection Centre Supervisor

The supervisor is constituted of a central processing unit, of industrial PC type, of a flat screen, a keyboard and a mouse.

The central processing unit ensures the reception of "EMERGENCY CALLS", "SELF-TEST" alarms, and the analysis and data processing.

It displays the "EMERGENCY CALLS" alarms and the "SELF-TEST" values in real time. It stores the event-driven data of all the information exchanges of the various elements of the system during two months.

The system indicates the exact station, beacon within the covered area of "EMERGENCY CALL" and "SELF-TEST" values.

It accounts for the periodic remote inquiry of beacons.

A badge account system is associated to it (acknowledgement, loss, theft).

A user friendly IHM allows to view the information easily.

4.6.3 Project Description: BAP – Portable Emergency Call Device for MES agents on line 4 (north sector)

This project named BAP (Portable Emergency Call Device) has been undertaken by the SIT Department in collaboration with the SEC Department, in addition to the tests at Gare de Lyon line 1 ,carried-out in the framework of PRISMATICA project .

The aim is to enhance the safety of the station agents, especially during the opening and closing of stations. 8 stations are concerned:

- Château Rouge
- Porte de Clignancourt*
- Simplon
- Marcadet Poissonniers*
- Barbès Rochechouart*
- Gare du Nord*
- Gare de l'Est*
- Château d'Eau

* Telemonitoring already available or planned for 2003

Principle

A pass needing non-contact/grip (specific) is used together with the unit card. During the tests the RATP agents (after a training program) shall pull the push button (double call) in order to validate a simulated emergency call (868,32 MHz frequency). Efficiency test of the badge: a long support (2 to 5 seconds) with reply from a buzzer located near the beacon.

The emission of a distress signal is received owing to a network of low-power beacons located within the station.

The low-power beacon that is being requested is now emitting the received information on the carrier current (number of the badge and number of the beacon); they shall then be recovered at the checking position (monitoring) located in the connection centre.

The checking position, built around a PC under NT 4, owing to an IHM (Man-Machine interface), allows viewing distress signals on the area corresponding with the number of the beacon and is able to identify the owner of the non grip badge.

Then the operator of the connection centre is able to contact the PC 2000 in order to send a stand-by crew.

The test

Beginning of the test

- Testing in engineering shop Technopuce from January to March 2002
- Technical approval of the chain badge – beacon – concentrator – supervisor at the laboratory LEM at Boissy. Planned in April 2002
- Setting of the Chateau Rouge Station 23/05/02 and of the supervisor subsequently.
- Technical approval of the final badges June 2002.
- Setting of 7 other Stations on line 4 North sector, planned June 2002.
- Delays occur due to the project on the enhancement of safety of 100% of the areas of the 8 stations concerned.

Additional setting planned for the UITP Congress (Committee for new information and communication technologies) and for PRISMATICA, of the Gare de Lyon station line 1 concerning the beacons and in the connection centre for the IHM part, during March 2003.

4.6.4 Key Findings and Conclusions

The research and technical development undertaken by RATP in this field have been carried-out in 3 steps:

- step 1: before PRISMATICA, in 1998, 1999, preliminary tests of the "concept"
- step 2: through PRISMATICA in 2000,2001,2002 research works and tests carried-out within WP4 ,WP5 , WP6,
- step 3: after PRISMATCA in 2003 setting-up the system on 8 stations of line 4 + Gare de Lyon line 1 of PARIS metro ,

A fourth step is to be considered as far as the reliability and efficiency of the system used in site operating conditions is proved through the former step 3 .

As far as the 2nd step is concerned , the tests performed on the "experimental system " installed at GARE de LYON / line 1 in the framework of the workpackages WP5 and WP6 of the PRISMATICA project have allowed to proceed with various and continuous improvements, for instance :

- the distance of reception of a message sent from the pass-card and received by the nearest beacon was raised from some metres to 50 metres and then to 100 metres in direct connection without any obstacle, but the various changing of direction met in the Metro corridors were deeply affecting the distance of reception of a message. That is why through the 3rd step , a new process has been experimented and proved successful. The message sent from the emitting badge of the user is carried (no more through the "air " by a radio wave) but through the existing electrical cable wiring network of the metro station to the nearest beacon and then to the "equipment concentrator" of the station.

- the pattern of the badge has been reshaped to consider in particular its possible use by blind people,

- the efficiency and lasting quality of the battery has been increased

- the coding of the various messages to be received and recorded by the computer used as "connection centre supervisor " has been several times updated , completed , and such improvements are still in progress to take into consideration the remarks brought by the operating staff using now the system

- the liaison to the MIPSA and all the codification language to be prepared in this connection has required several phases of improvements to settle the "bugs" and other technical difficulties met in connecting two systems prepared by two different contractors (KCL / KU and RATP) and without neglecting the problems met by the other subsystems to be also connected to the MIPSA ;

- and as usual in such experimental works various failures of some components were to be settled and relevant solutions to be found .

At the end of WP5 works and tests , the "pass-card /emergency calling system " has been proved working properly.

At the end of WP6 tests , the a.m. system has been proved working properly within the whole MIPSA process.

Such satisfactory results have led RATP to undertake the 3rd step which is consisting in a large "spreading " of the system in actual site operating conditions.
The effectiveness of the PRISMATCA project has been quite demonstrated by this practical use of one of its technical outputs.

4.7 Wireless transmission (Paris)

The wireless transmission system is intended for video, audio and control data transmission in a multipoint to central point scheme. The real-time video compression-decompression based on wavelet transform and the asynchronous CDMA with successive interference cancellation (SABIC architecture) are advanced technologies developed at LETI and implemented in a 3-million gates FPGA.

This system combines the advantage of DSSS in multipath propagation with the multiple access capacity of A-CDMA (Asynchronous - Code Division Multiple Access) systems and the efficiency and resistance to transmission errors of wavelet transform.

The main components of this system are:

- Five transmitters able to transmit audio and live video with a slightly perceptible visual degradation, with embedded receivers for remote control (ON/IDLE/OFF, wake-up date/time, Tx power control).
- Remote RF head (Radio Frequency) allowing for up to 150m (RG59 type) cable connection, significantly increasing the radio coverage of the station.
- An advanced DSSS/A-CDMA receiver able to receive up to 5 simultaneous audio-video flows using the same RF bandwidth and orthogonal spreading sequences.

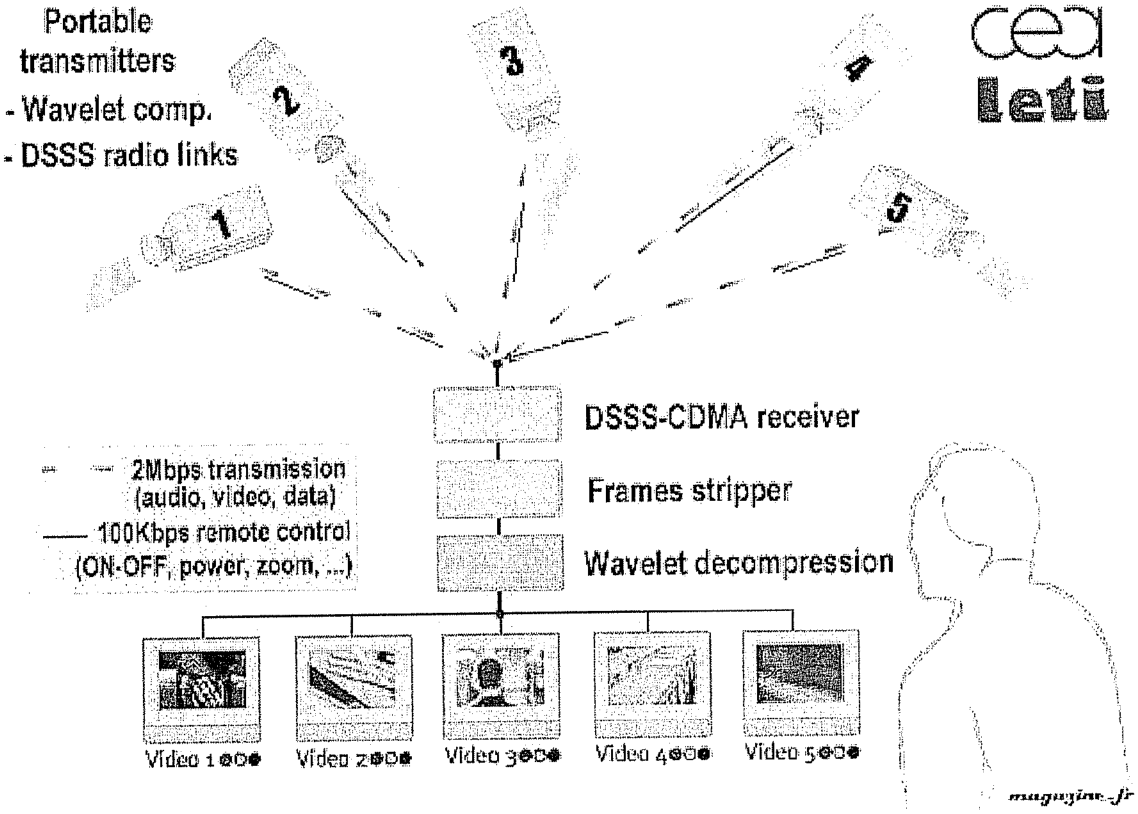


Figure 60: Wireless transmission system principle

4.7.1 Description of the demonstration site

The demonstration has to be performed in the Gare de Lyon station on line 1 (RATP). For the wireless transmissions this site is very interesting, it gathers the main difficulties in one site:

- Extensive metallic structures present in the building
- Low ceilings in the platform part of the station
- Different levels for platforms, access corridors and halls, passenger bridges
- Many changes of directions and sections (corridors, halls)

- Narrow doorway passing through
- Crowded station

Figure 61 Metallic structures of Gare de Lyon station

4.7.2 Scope of the trials

The trials aim to assess the reliability of the wireless transmission and the image quality of the transmitted video after compression and decompression :

- robustness against significant fading (due to metallic environment)
- suitability of remote head principle against wave absorption by the crowd and trains
- suitability of remote head principle against important variations of the infrastructure
- image quality versus compression rate
- trade image rate with image resolution

For the demonstration, one remote RF head is connected at a monitoring camera (CS 5) located in the main access hall. At this location the receiver is ideally located to cover the surrounding halls and corridors but totally misplaced for platforms coverage (lower level platforms, walls with metallic structure, narrow doorways). For a complete coverage of the station , another remote head has to be connected at the end of the platforms, close to points 9 or 10 (Fig. 61).

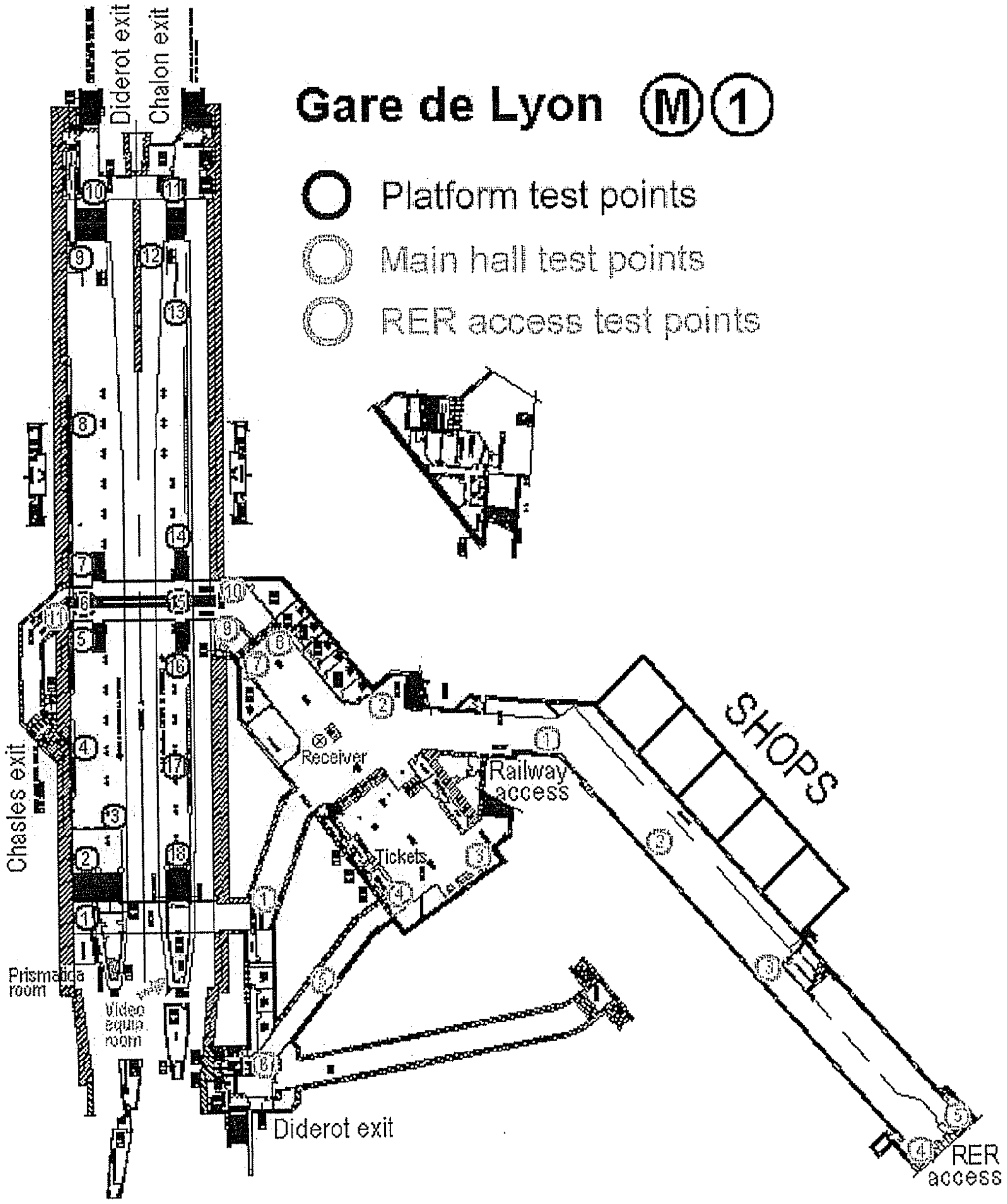


Figure 62 Paris demonstration site (RATP)

In the current state of our development we have not been able to carry out the demonstration up to now, we still aim to partly test the wireless transmission by the end of March 2003.

Although we did not finish the whole job during the project time, we spent a lot of efforts on Prismatica project and we plan to carry on this development until completion, hopefully before the end of this year. We largely under estimated the time for the definition of the whole system and we faced huge difficulties with the VHDL simulation of our wavelet compression IP. Nevertheless we overcame these difficulties and we have now the main parts of our system, the CDMA board, the wavelet compression and soon the new RF parts implementing the remote RF head, we just need time to gather all these boards and to make them working together.

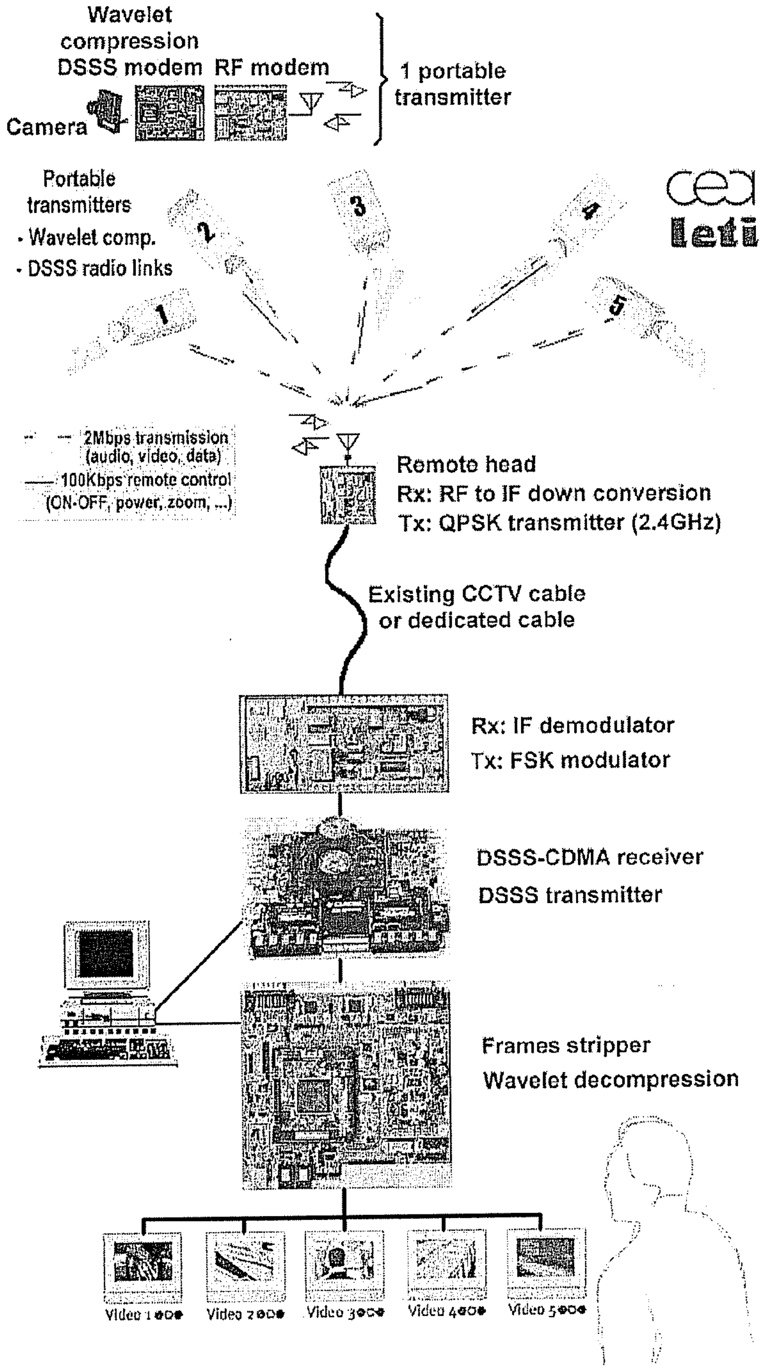


Figure 63 Wireless transmission system boards

The above picture (fig. 63) shows all the boards for the wireless transmission, all digital boards have been developed and tested at laboratory. For the RF parts, we first developed QPSK boards implementing one-way simplex transmission for the transmission from the portable transmitters to the CDMA receiver and an FM radio link in the 433MHz ISM band for the remote control channel. Unfortunately this ISM band is partly used by RATP for the contact-less pass-card system, joint tests with RATP in Gare de Lyon showed that with the remaining bandwidth and the low level of power that we could used, this solution was unworkable.

Afterwards, we had to find another solution, in order to save development time we first looked for existing system in licence free radio bands, this process was unsuccessful, no available devices fulfil our requirements. We finally decided to implement a 2-way simplex transmission in the 2.4MHs ISM band, but all these steps consumed time and this is the reason why the RF parts are not ready now, these boards are currently under manufacturing.

Before we can test the whole system, we have to debug and tune the RF boards, then to implement the 2-way simplex protocol for the power control of the portable transmitters (mandatory for CDMA systems) and finally to gather all the boards.

Obviously this is unfeasible before the end of the Prismatica project, so we are coupling the video compression boards to the 1-way simplex boards in order to test in Gare de Lyon station the transmission of wavelet compressed video, before the end of March 2003.

4.7.3 Results of laboratory tests

The following description presents the results that we obtained at laboratory on the developed parts.

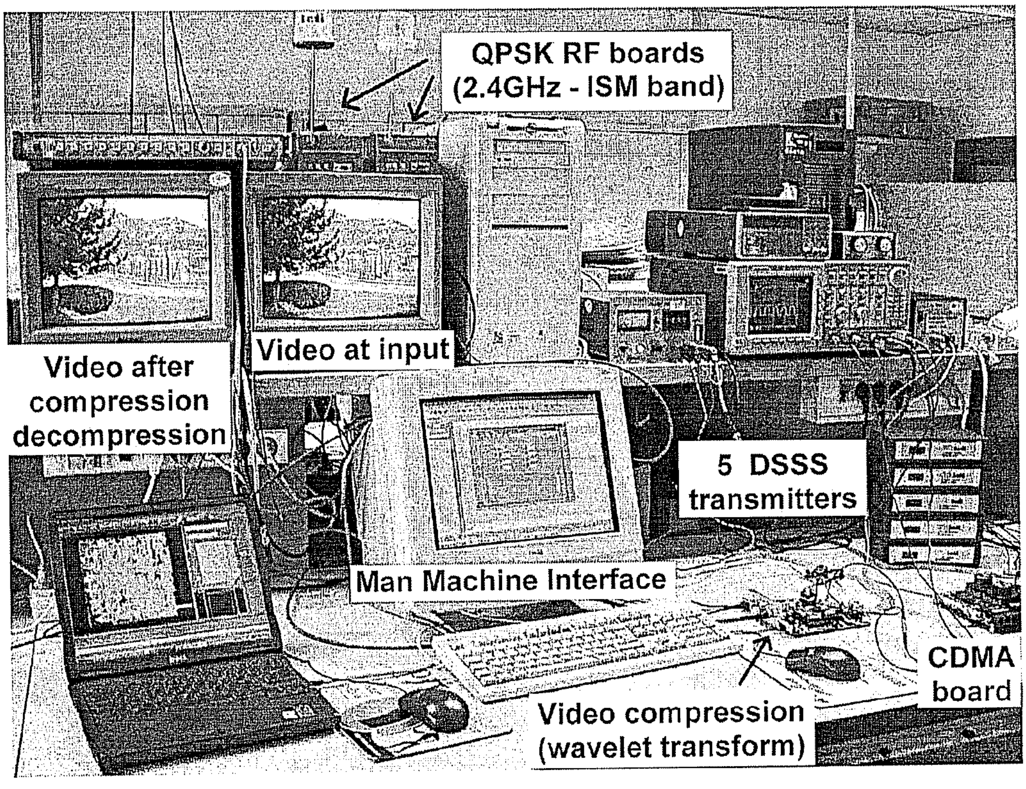


Figure 64 Laboratory tests

Figure 64 shows the tests carried out at laboratory, mainly on the digital parts:

- 5 Direct Sequence Spread Spectrum transmitters
- an asynchronous Code Division Multiple Access receiver implementing Successive Interference Cancellation
- video compression-decompression based on sub-band decomposition processed by a wavelet transform
- Man Machine Interfaces developed in Visual C++ for each of the digital boards

CDMA tests:

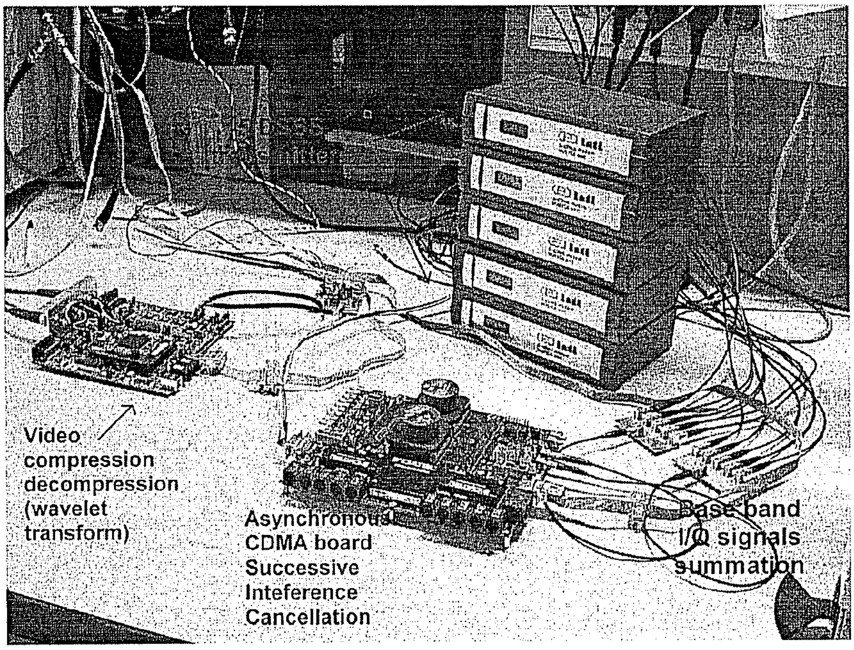


Figure 65 **CDMA tests**

The block-diagram of lab tests (fig. 65) shows the base-band tests carried out to validate the SIC structure of the CDMA receiver.

The BERT tests with a 3dB power ranking between each code, results in :
- no error for up to 4 simultaneous asynchronous users.
- 10^{-8} for the 2 first users and 10^{-7} for the others with 5 simultaneous asynchronous users

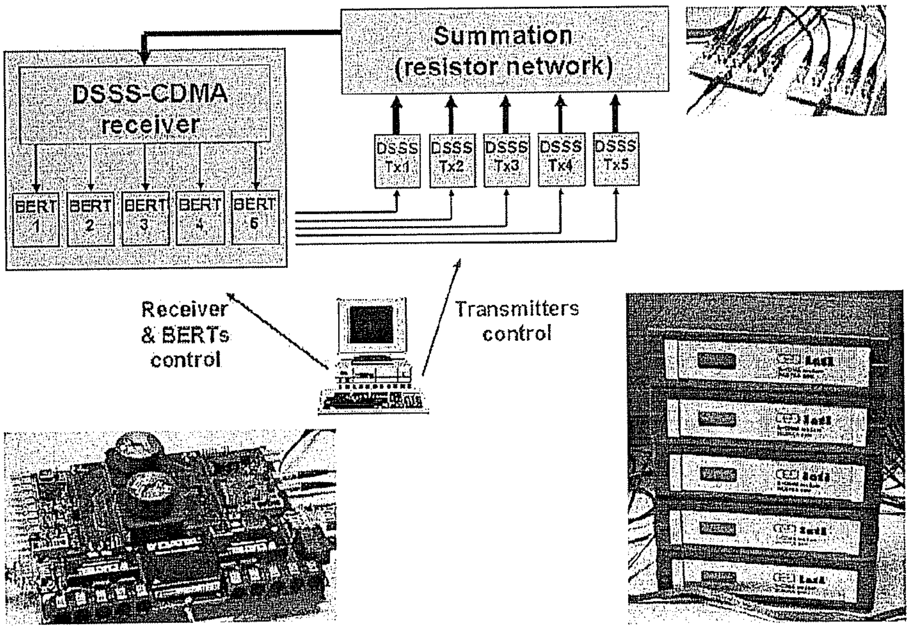


Figure 66 Block diagram of CDMA tests

The 5 transmitters and the CDMA board are controlled through a man-machine interface running on a PC (under Windows 9x, NT4, 2000 O.S.). These 2 MMI, developed at laboratory using Visual C++ tool, enable full control over the CDMA system.

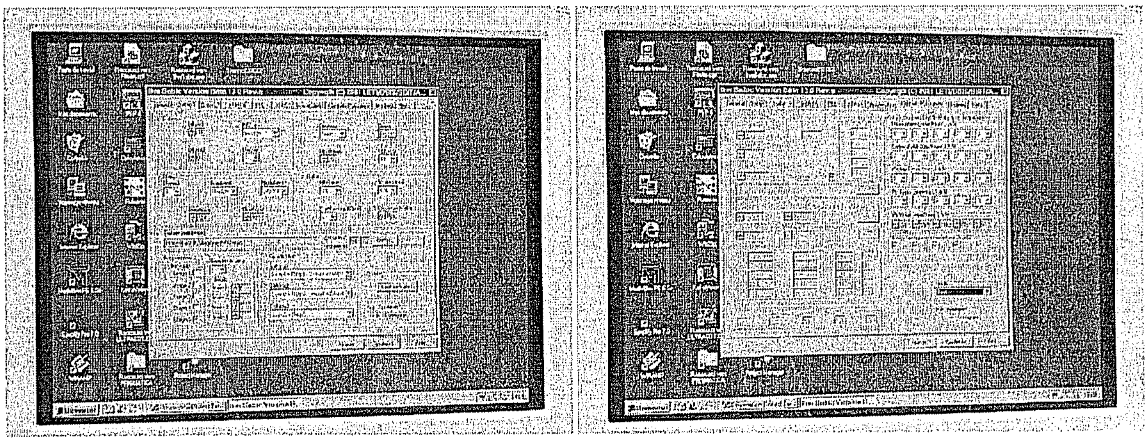


Figure 67 Man Machine Interface for CDMA board

Video compression tests:

The video compression system can process the video at 25 images/s. A compression rate of 0.25 bit per pixel and 25 images/s require a transmission bit rate of 2.5 Mbps. Image quality can be increased by reducing the frame rate at constant bit rate or by reducing the compression ratio and increasing the bit rate.

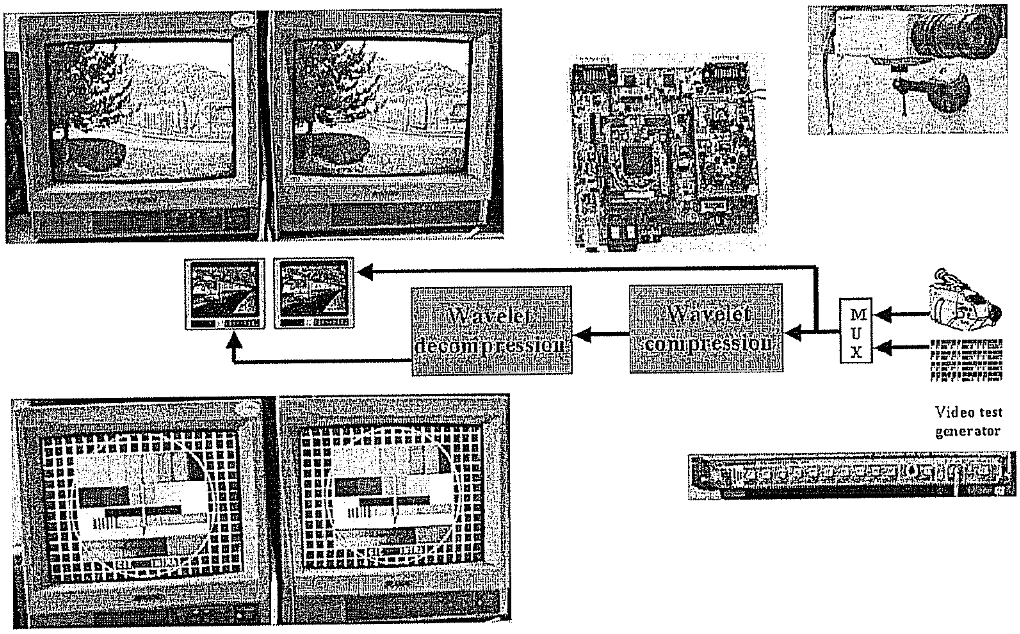


Figure 68 Block diagram of video compression tests

Three types of images were used for the tests, 2 cameras with indoor and outdoor scenes and a video test pattern for (more) objective visual evaluation. The following figures, obtained with a luminance to chrominance ratio of 20 and 0.5 bit per pixel, give an idea of the visual quality with static scenes, the sensation of quality increases with moving scenes.

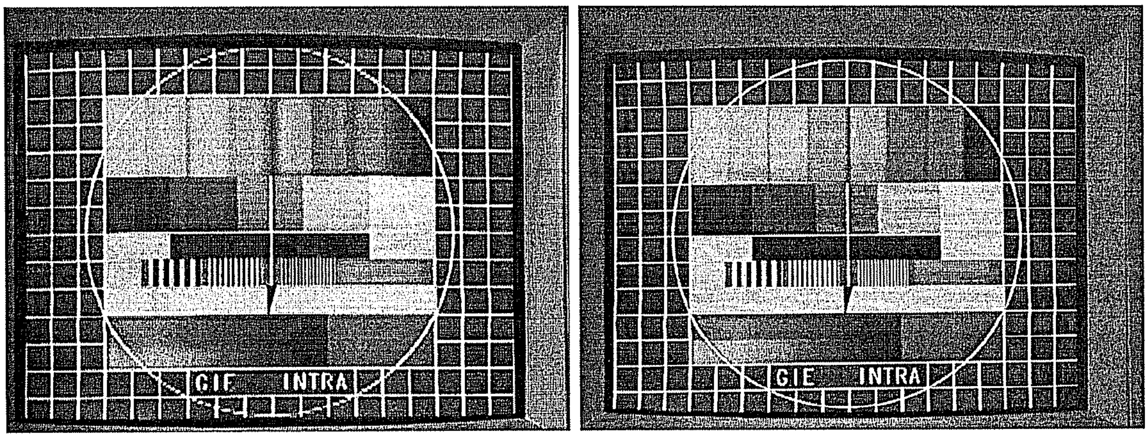


Figure 69 Comparison of compressed (left) and original (right) test video

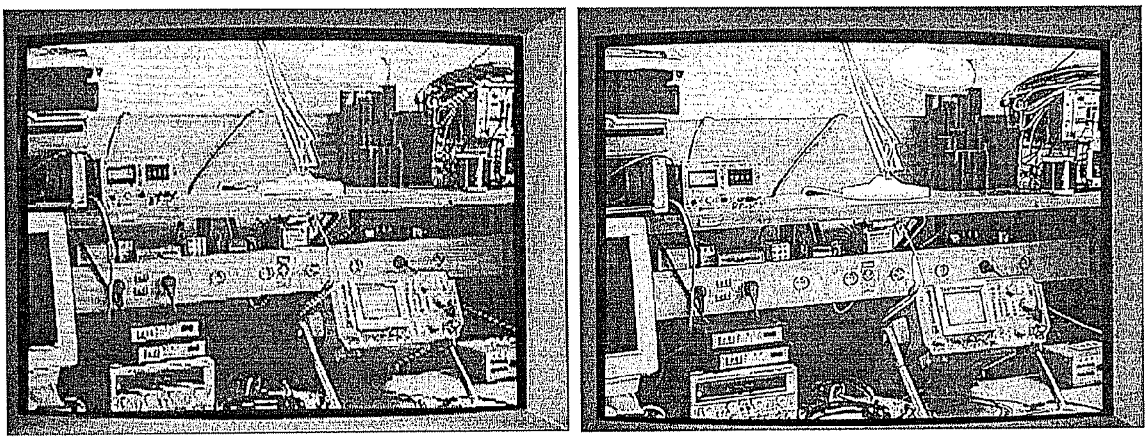


Figure 70 Comparison of compressed (left) and original (right) indoor video

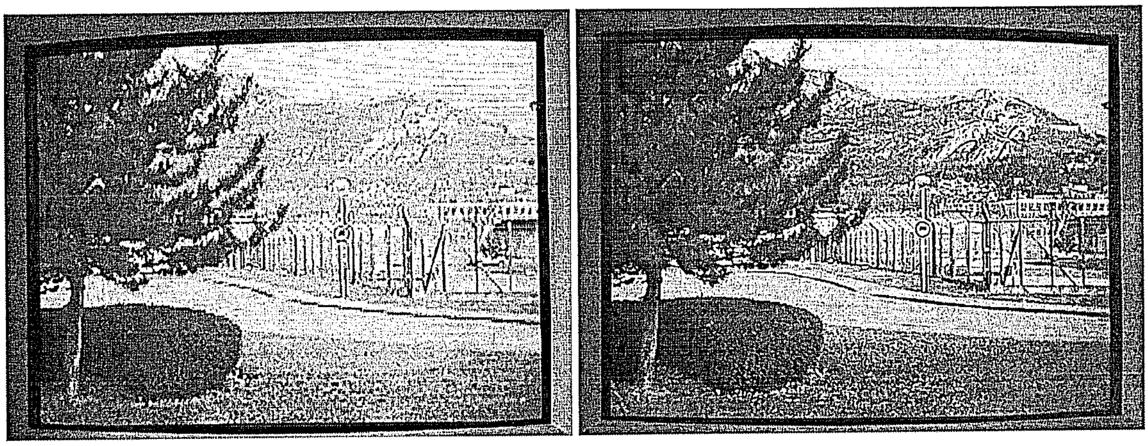
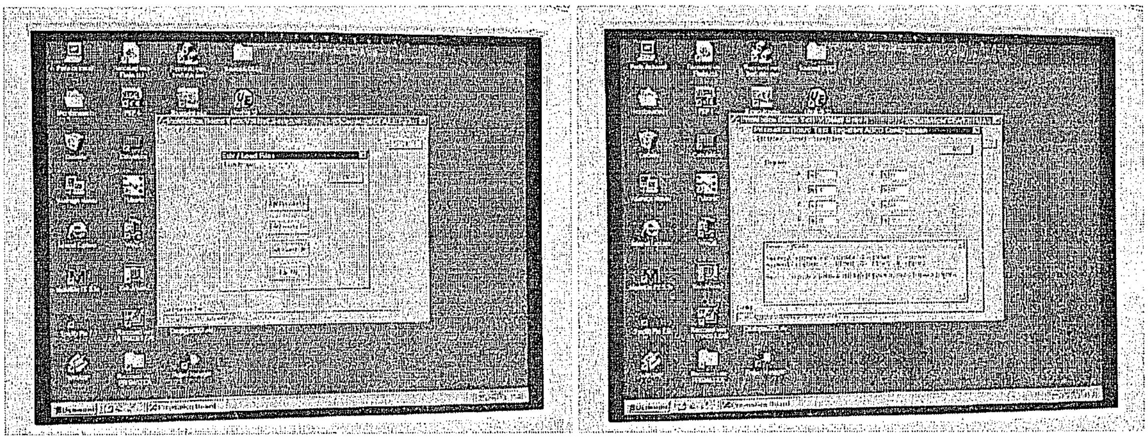


Figure 71 Comparison of compressed (left) and original (right) outdoor video

As for CDMA boards, an MMI has been developed for the compression-decompression board, that enable to control all the resources (PAL to ITU-R 656 decoder, ITU-R 656 to PAL encoder, table of quantization, image resolution, allowed bit rate, etc.).



4.7.4 Conclusion

The results of the evaluation tests in Gare de Lyon for the radio transmission, showed that the principle of remote RF head allows for large coverage of an underground station with minimal installation of low cost devices. The remote RF head is a very efficient means to deploy DSSS radio systems in complex infrastructure such as underground environment.

The base band CDMA tests at laboratory, showed that the successive interference cancellation structure of our architecture is successful with up to four simultaneous asynchronous transmitters having a received power hierarchy of 3 dB between each transmitter and a sequence length of 64. In the same conditions, with five transmitters a limit is reached, at the receiver level the sum of the instantaneous power of the four weakest signal is recurrently stronger than the strongest signal (frequency variations of oscillators), leading to errors. In the latter case, the two strongest signals produce a bit error rate of 10^{-8} and 10^{-7} for the others, in spite of this weakness, this type of errors is equally distributed in time and can be easily corrected with forward error code correction such as Reed-Solomon or Turbo codes.

The video compression using wavelet transform for sub-band coding provides acceptable visual quality at 25 images/s for situation recognition with a compression rate as low as 0.25 bit per pixel, a transmission bit rate of 2.5Mbps is required. Image quality can be increased by reducing the frame rate at constant bit rate or by reducing the compression ratio and increasing the bit rate.
If these good results are confirmed when using the radio transmissions, this CDMA system will be a suitable way to increase the spectral efficiency of the direct sequence spread spectrum technique while preserving its robustness against fading phenomena unavoidable in dense urban or indoor environments. If underground stations are pre-equipped with remote RF head, the deployment of a cluster of camera is a matter of hours (compared to weeks for wired cameras), offering the possibility to quickly react to urgent situations (delinquency, terrorism) or for temporary video monitoring (dangerous works, special events).