EUROCONTROL

ANIMS CARE-INO: State of the art on sound and animations in Human Machine Interfaces

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Contents

1 Introduction

As a part of the Eurocontrol CARE INO research programme, the ANIMS project proposes to further explore the benefits and conditions for ATM software of use of two related design-intensive interface technologies: animation and sound. Research and experience in the last decade have shown how what some years ago, may have appeared as details, namely interaction styles and visual design, could today determine the success or failure of an ATC system. In the same way, recent research shows that the quality of feedback and alarms, however subtle they are, has a notable influence on situation awareness, mutual awareness and safety.

At the same time, user interface technology constantly evolves and provides potential solutions to some of the problems mentioned above. IntuiLab and Intactile Design propose to explore and demonstrate the potential of those technologies: the use of visual animation and sound in HMIs to provide efficient notifications and feedback to users.

Animation and sound are two interaction modalities that share many characteristics: they are intrinsically dynamic modalities (as opposed to graphics, which are mainly static), they are time intensive in terms of computer CPU, they introduce potentially complex notions of synchronisation into software architectures, and they solicit specific perceptual and cognitive capabilities of users.

This document summarises state of the art of animations and sound in Human Machine Interfaces. It reviews both the state of the art from a theoretical point of view (based on scientific literature review) and from a practical point of view (based on current HMI practices in from various domains mostly outside the ATC field).
After this introduction, the document focuses on animations (chapter 2). We try to define what animations are, how they can be modelled, which techniques can be used. We then list the main possible uses before considering the Human Factors, advantages and the possible drawbacks of animations.
Then we focus on sound (chapter 3) from a more theoretical point of view as current experience and research in sound are more limited in the field of HMI. We first define the sound both as a physical phenomenon, and as a perceptual phenomenon. We then identify the possible use of sound in HMI following three different possible applications: feedback, alarms and information.
In chapter 4 we identify the current use of both sound and animations in ATC HMI, both in operational systems and in the field of research, before concluding (chapter 5) and giving and extensive bibliography on sound and animations in chapter 6.

1.1 Acronyms used in this document

ACC	Area Control Centre
ASTER	ASsistant for TERminal sectors
ATC	Air traffic control
AMAN	Arrival MANager
ATM	Air traffic management
AVI	Audio Video Interleave
CARE	Co-operative Actions of R&D in EUROCONTROL

CENA	Centre d'Etudes de la Navigation Aérienne
DMAN	Departure MANager
ETMA	Extended Terminal Manoeuvring Area
Flash	tool and format used to produce animations and publish them on the World Wide Web. Flash animations are rendered using a plug-in of the browser.
GIF	Graphic Interchange Format, a picture file format which can contain animations
GUI	Graphical User Interface
HMI	Human Machine Interface
PD3	Phare Demonstration 3
Perl	Practical extracting and report tool, a programming language used to make animations with zinc and perl-anim
SMIL	Synchronized Multimedia Integration Language
STCA	Short Term Conflict Alert
SVG	Scalable Vector Graphics
W3C	World Wide Web Consortium
WIMP	Windows, Icon, Menu and Pointing
XML	Extensible Mark-up Language

1.2 Definitions

As animations and sound are useful for signalling alerts and alarms, it is important that we define these terms as they will be used in the document.

An **alert** is a signal emitted by the system to draw the attention of the user since an event of some importance occurred. **The user is free to act or** not.

An **alarm** is a signal emitted by the system to draw the attention of the user since an important event occurred and **the user should or must act** to correct the problem.

2 Animation

2.1 Definitions

An animation is a continuous change of a graphical element or a graphical property over time. This includes the succession of pictures used in cartoons as well as the position of an object or the transition used between two slides in PowerPoint.
It is not clear whether alternatively displaying two different pictures can be considered as animation or if more than two are needed to be considered as an animation. In fact a graphic effect can be called an animation as soon as the user sees or imagines the transition between two pictures whether it really exists or not.

We should particularly insist on the fact that animations are not used in HMIs only to make it appealing. Animations can carry information. Information conveyed can be of secondary importance in which case, the goal is to improve awareness or animations can provide information not given by any other means. Animations can be used for signalling state changes (by the user or by the system) or for signalling long lasting states (e.g. a non-urgent alert, system waiting for file loading...). So the information conveyed by animations can either span a short or long period of time.

To create an animation numerous parameters can be used. More exactly, an animation is made of successive drawing of different rendered pictures. Those pictures can be either hand drawn (that is the technique used in cartoons) or computer rendered using different parameters such as colour, text, transparency, shape etc...
For examples the following parameters can be animated:

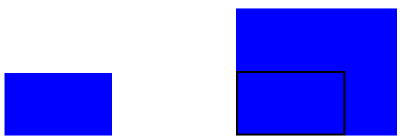

Figure 1 : Size parameter

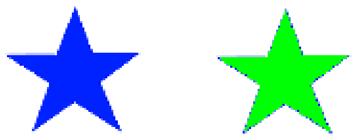

Figure 2 : Colour parameter

Figure 3 : Blur parameter

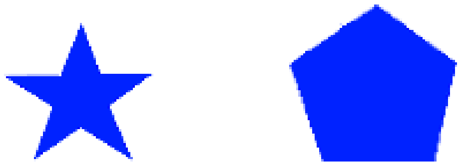

Figure 4 : Shape parameter

From an external point of view we can distinguish three types of animations: storytelling animations, user driven animations and user or system triggered animations.

Storytelling animations

Those animations are the ones used in cartoons. The goal is to tell us a story. A typical example in HMI is the clip agent meant to help in MS Office. [Geiger, Paelke] study such “intelligent animated agents” further. To make such an animation, it is only necessary to display one picture followed by another etc ... This is exactly what is done in video games during scenario presentations or transitions. It can be used as a tutorial for learning how an HMI works [Foley] [Sukaviriya].
Such animations have been used to teach algorithms. Some studies [Lawrence] (and in a limited way [Byrne]) say that it does not improve learning ability though it improves students' feeling about learning. Others authors say that it really improves it [Kehoe].
Those animations can easily be made with computers. However, they are not interesting in our case because we are focusing on HMI for experts and users who do not want to be disturbed or distracted. Therefore we will not explore them further in this document.

User driven animations

Those animations are the ones depending totally on user interaction. During the course of such a user-driven animation, the absence of user input implies a static graphical state; any user input implies a graphical change. The aim is to give users immediate feedback (e.g. when they move their mouse) as if they are directly interacting with application data. One of the simplest user driven animations is the drag and drop of a window or an icon or the scrolling within a long document. Scrolling occurs when a user moves the scroll bar with the mouse, each user movement producing events is immediately processed by the interface, which makes the corresponding text scroll up or down. The amount of displacement and its speed is directly related to user movement of the scroll bar. This kind of animation will be tackled briefly in this document as it is commonly used.

User or system triggered animations

Those animations are somewhat standalone animations. Their duration may be either short when triggered by user interaction, or long if triggered by the system (such as an alarm or an alert). The aim of these animations is to provide more information within an interface. They can be used to maintain awareness of information provided. These are the ones we will examine more in- depth in this document.

As we will focus mostly on one type of animations (user or system triggered animations), we need to provide as relevant a model as possible to describe those animations before being able to study animations themselves.

2.2 Model

To analyse each animation in more depth throughout this document we use a model divided into three parts: rendering, trajectory and control. The rendering part is how, using parameters, each part the animation will be displayed on a screen. The rendering function converts a description such as a SVG source file or a list of parameters into an object on a screen. Doing this multiple times gives the animation feeling. The trajectory part describes the evolution of those parameters during time. The control part describes how a program or a user can interact to give orders to animation:

- **Rendering** is defined in the same way it is in OpenGL or any graphical toolkit. It is a way (generally a function) to display on a screen something described in memory using a chosen data structure. It can be driven by change as in most toolkits, or it can be driven by an external clock which refreshes the screen regularly. Rendering is both the responsibility of a designer and a programmer.
  This part is the visible part of the animation which makes it a part of a graphical interface.

- **Trajectory**[1] is the description of parameters which change over time. It can be as simple as defining a mathematical function over time with a parameter, but it needs to be more accurate when it comes to synchronization and complex behaviour. We divide it into a pacing part and a path part. The pacing part describes the rhythm of animations. For instance, two objects that follow the same trajectory at different speeds can be obtained by using two different pacings and sharing the same path. Pacing is not necessarily constant, nor linear. Slow-in and slow-out are examples of such non linear pacings. The path part describes how this change affects a parameter, which can be either numerical like the position of an object, or a choice within a set like a colour. This part is the one giving the feeling of the animations; it gives life to the HMI and makes alive (animates!) a static object. It is the trajectory which makes the impression on the User.

- **Control** is a description of an animation's sequencing: how an animation can be interrupted, modified or synchronised with other animations (for example: how an animation should start after another one). It also tells what physical phenomenon triggers the steps of the animation: a clock, movements of the mouse, etc. An animation made of a given pacing and a given path can be controlled by clicks on the mouse, by ticks of a clock, or by another animation. Control is the same as flow control used in programming. Loops, conditional executions, jumps and function calls are the basis of animation and flow control.. It makes possible for a program or a user to interact with animation.
  This part of the model is the view of the animation by the software designer.

This model is well suited for describing animations because it can describe all animations other models can describe. Moreover some of the other following models (e.g. key frame model) cannot describe every kind of animation or can be hard to implement in some cases (constraint based model). These other animation models are the key frame model, the actor's model or the constraint based animation model.

- **Key frame** animation model is based on the description of some rendered parts by the designer. After what, the computer creates intermediate frames and displays them to give

[1] Trajectory must be understood in a more general sense than a 2D or 3D trajectory

the feeling of a smooth animation. This is a computerized version of what is done to create cartoons.
Any animated GIF displayed on the web is exactly a basic key frame animation; it contains a fixed number of frames and a display rate. Note that the computer does not need to compute intermediate frames with animated GIF.

- **Actor** based animation model is based on the description of elements of the picture named actors. Each actor has its own life which is described separately. An actor is then autonomous and has its own process to render the animation. This is the metaphor of a movie with independent characters.

- **Constraint** based animation model specifies constraints, formulas and any specification on objects properties. The computer is then used to solve them and display the resulting animations.
  For example, the upper left corner of a rectangle could be constrained to be attached to the centre of a small ovalA, while the lower right corner is attached to the centre of small ovalB. Thus moving one of the ovals will stretch the rectangle.
  This kind of description seems useful and natural, but solving an animation based on constraints is not always possible, and it can produce different animations with different solvers. The advantage is that it is easy to render physical systems as naturally as possible.
  Amulet is a constraint based toolkit for making animations [Myers].

Those different models, based on technical knowledge on animations, are to be used to evaluate feasibility and pertinence of animations. We are now able to dig further into animations techniques themselves.

2.3 Animation techniques

As different techniques are used to produce animations, we split them in several categories: "direct user action", "appearance/disappearance", "distortion, movement, colour", "picture succession", "bitmap transform" and "smoothing, morphing". Those techniques can be used in common with different trajectories (i.e. paths and paces).

A special case of path should be noted: it is the movement-exaggerating path. An object moving from a point to another does not necessary go straight to the destination point. It can go a little bit farther and come back. This gives a feeling of respecting the laws of physics for an object and represents the growing difficulty of targetting a particular point when being far away from it. This technique is called **exaggeration**.

A special case of pacing should be noticed. It is the **slow-in/slow-out**. It accelerates from an initial null speed to full speed and then slows down to null speed at the end of the path. This can give the user a feeling of natural movement especially when the path is a displacement. It is also useful for other parameters such as size or shape parameters.

Those two special cases can be combined with any of the following techniques:

Direct user action

As already said, this kind of animation is special as it only relies on user input. No user input means no animation. They are made using a path which is not directly created using rhythm

and parameter elements. The control part is directly bound to the drawing part. Moreover they cannot be described using a key frame animation. The aim is to give users the illusion that they are directly interacting with application data.
For example, this is what is done when a user scrolls a document with the help of a scrollbar. A more complex user-driven animation is the Dock of Apple Mac OSX desk.
The HIPS (Highly Interactive Problem Solver) [Kessler, Knapen] developed and tested during Phare Demonstration 3 is an example of such user-driven animation applied to ATC HMI. The user could explore a 4D space (where there were some potential conflicts between aircrafts) in a 2D display by dragging points of a trajectory in another 2D space.
The following illustrations give some simpler examples of user-driven animations during a drag & drop interaction.

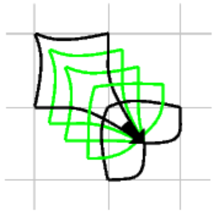

Figure 5 : drag and drop with distortion a magnetic grid

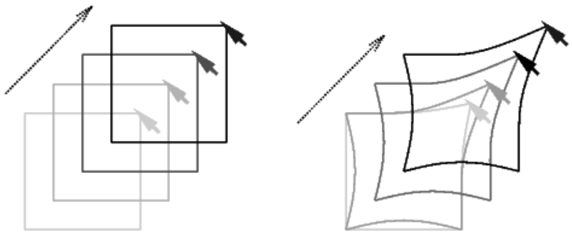

Figure 6 : Drag and drop without distortion and with a material distortion

Animated appearance/disappearance

Any object used in the interface has been created either during the creation of the interface or during its use. During use, objects often appear "magically", as if they have no relation with anything else on the HMI. The user may have difficulty to know where they come from or if they have a relation with other objects. In some cases users do not even see objects appearing. With animated appearance, users may perceive the object appearing and may be able to make a connection between an object and its origins.
The appearance of an object can be done in various ways, for example it can be faded-in using transparency or it can be translated. It is possible to achieve this effect without too much processing power simply by progressively clipping the given object to make it become visible.
Animation can also be used to make object disappearing smoothly.

Distortion, movement, colour

Movement is an animation that can be simply described using path and drawing. It is used in many animations as well as colour change or deformation. Deformation can easily be described when using vector based rendering. Distortion of bitmap pictures is much harder. [Lasseter] also recommend the use of deformations to keep continuity between pictures . This enables a direct perception of the movement of an object when its refresh speed does not permit drawing two consecutive positions having common object points. The following picture illustrates a ball bouncing on the floor. It clearly shows that the ball is distorted. The quicker the ball is supposed to move, the more the ball is distorted.

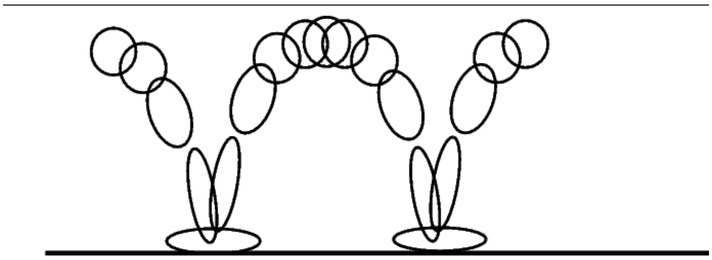

Figure 7 : Distortion

Picture succession

A cartoon is made of successive pictures displayed at a given rate. A succession of properly drawn pictures makes the perception of continuous change. This is what is commonly used in animated GIF on web pages mainly for advertising animations.

Figure 8 : Picture succession

Bitmap transform

Bitmap pictures can be transformed using filters for example distortion, blur (see for example Figure 3), video inversion etc... A lot of these filters can be found in image editing tools such as Photoshop. A blur filter can be used to progressively move a foreground window to a background window. However, such filters often require high processing power and currently can be used only in research prototype HMI.

Smoothing, morphing

It is possible to create pictures based on two extreme pictures, this can be done either with bitmap or vector based pictures. The animation then comes from the succession of all different intermediate pictures created. This can be used with the same object between two different forms and positions to smooth the change. It can also be used to create a succession on pictures so called a morphing to transform something into something else.

Figure 10 : Morphing

2.4 Animation typical uses

We just listed different animation techniques. We now identify their typical uses in HMIs.

Alarms/alerts (e.g. blink, wave, vibration)

An alarm/alert is a signal indicating a problem or information of some importance.
The first use of animation has been to alert the user that something went wrong. The blink is a degenerated case of animation which both proves the usefulness of animation and gives an example of what is not easily readable with animations. A better example would be vibrations of either a component or whole display which can indicate an error with user input such as in a login [Hudson]. [Athenes] studied how different types of vibrations can draw the user attention in a context of air traffic control. She also identified some way of hierarchizing alarms/alerts coding through vibration.

Interface prosody (e.g. opening and closing modal windows)

In its original meaning prosody is what makes a vocal utterance easily understandable. It is made of stress and intonations in voice which help the listener to detect some subtle meaning of the utterance (question versus affirmation, fear, stress, irony…). This type of information can be hard to convey without prosody, and listeners just perceive this information in a very unconscious way. The prosody of an HMI is similar: it should allow the user to perceive information in an unconscious way.
Animation can be used to provide perceptual information like the origin of an object or its destination. For example a menu can appear directly from where it has been activated. A moved item can go smoothly (which does not mean slowly) to its new location. This provides the user with information not absolutely necessary for using the interface but helpful in understanding what the object he/she is acting upon is related to.
Another example is kinetic typography where a text is animated according to its meaning, which enables the reader to perceive some feeling through the animation [Forlizzi]. See also http://www-2.cs.cmu.edu/~johnny/kt/ for some examples. However, it seems difficult to use kinetic typography for expert users due to its disruptive nature.

Feedback for a change originating from the user (e.g. value change, colour change)

When a user interacts with an HMI, he/she can make actions which are perfectly valid for the system but are not as intended by the user. Feedback is the way in which the user may detect his/her errors.
Animation can be used to enhance input feedback every time the user inputs data or changes the system state. The animation may help the user, verifying that he/she inputs the proper data in the proper field, specially if there is some distance between the interaction point and the resulting feedback (e.g. between the selected value in a menu and the place where this value will be displayed after input). As an example, it is possible to colour and/or animate the changed value.
A very obvious example is in Excel when the user removes or adds a column. All columns on the right of the added/removed column are moved to or from the right. This is really very useful when the user edits some complex datasheet where there is no clear structure in the document. The user will simply perceive the result of his/her action thanks to the animation.

Error checking (e.g. password error, out of typing area)

When a user provides data to the interface, the data can be invalid (for example when using a keyboard). This is an error the interface has to signal.
Animation can be used to tell the user he/she failed to give a correct entry to the interface. A common way to tell the user he/she failed to give the right password is to make the screen or a window vibrate. The user quickly understands that he/she has made a mistake. During the ANIMS workshop, it was clear to most participants that **vibration was associated with error**.

Unintentional user driven animation for notifying error or alert

When a user provides invalid data, he/she needs to realize the mistake even if he/she is focusing his/her attention on another part of the display without looking at the input data.
A particular case of a user driven animation can be to use a line to link the user's mouse pointer to the place where invalid data has been input or where important information must be read by the user. When he/she moves the mouse, he/she will quickly perceive the line movement.

Notification (e.g. appearance of an object, change of a value)

A notification is given when an event of low/medium importance comes to the interface. It is similar to alerts except for the degree of urgency or importance.
Animation can be used to notify a user that something just happened (e.g. a new email). The appearance of a new object in the HMI needs to be notified to the user. This may be done by using a movement from its source point. Notifications aim at conveying information similar to alerts but they require much less attention because they are of a lower importance.
Animation may help the user perceive the notification.

Action taking place (e.g. waiting state, processing)

Animation can be used to show a state of the system. For example, when a file is loading an animated hourglass is used in WIMP interfaces.

External user information (e.g. telepointer)

An external user is somebody working on another part of the system and who interacts with the user's system and HMI.
From a user point of view, seeing another user moving an object is an animation in the full sense, not a directly user driven animation. Some intentional movement from the distant user (circling around an item) can convey rich information to the local user.

Information overload (e.g. text change, news, other information coding)

A display is limited by the quantity of information it can display.
Animation can be used to provide more information than displayable in the working screen. A typical example is the news thread used for CNN information, the text is scrolled continuously to display more text than can be contained within the screen. A study has been made on how information is best displayed [Stasko, McCrickard]

HMI discovery (e.g. metaphor, possibilities indications)

An HMI is not always perfectly known by the user. Feedback on objects behaviour may help the user to better understand the HMI.
Animation can be used to give to the user a natural perception of what can be done with objects within the interface. This is mostly done for games or for educational software. To indicate that an object is usable, an animation makes it scintillating (with a variable glow) or reacting to the cursor's proximity. Another example is a sensitive zone within a flight data block of a radar display, it reacts when the user's cursor goes over it.

Hiding states changes

In every previous case, the goal of animations was to convey information. Here is a different case: it is possible to hide state changes using animations. A really slow animation would be imperceptible by the user. A possible use of such a slow animation could be to "apply an HMI change" using subtle variation during a long period, allowing it to change without a user noticing it. A more practical example would be an interface reacting to ambient light. It is possible to put light sensors near the screen to change the interface's luminosity according to ambient light. Such a change can be done within a long period keeping the user concentrated on his/her task without noticing it.
A similar use of slow animation already exists in some radar display. Flight labels should not overlap. Thus an algorithm, called anti-overlapped algorithm is often used to avoid such overlap. This algorithm should avoid any brutal move of the label, by computing stable positioning of flight label over time. However, each flight label moves around its corresponding current flight position. In complement to this algorithm, some slow animations could be used to minimise awareness of flight label movement.

2.5 Animations and Human Factors

Change blindness is one of the reasons why changes in the interface should be animated for the user to be able to perceive the change. Change blindness has been studied in the experimental psychology. It is due to brief visual disruptions caused by eye movement (during micro-saccades), flicker in the image or the HMI, or blink of the eye [O'Regan].. See for example http://www.usd.edu/psyc301/ChangeBlindness.htm for a java based demo of the phenomenon.

Human peripheral vision is more sensitive to movement/change than central vision, but has lower acuity. Thus movement in peripheral vision can be used to direct central vision attention to another locus. As animations defined previously (2.1) are precisely movement or changes of appearances, animations are well detected in the peripheral vision of the user.
This is the main reason why animations are very useful in HMI for alarms, alerts or notifications as well as for enhancing user mutual awareness.

We now list some benefits of animations, from the Human Factors point of view and after that we identify some possible drawbacks of animations.

2.5.1 Human Factor expected benefits in using animations

Better mutual working

As controllers are usually working in team of two (or three) controller(s), one of their tasks is to always be aware of what the colleague is doing. To enable controllers to align their activities on each other, they need to be aware of what their neighbours do. Animation, by functioning within peripheral vision is an efficient way to enhance mutual awareness. A user can notice something moving on a colleague's screen thanks to the user's peripheral vision. This enabled somebody to know what his/her co-worker does without actively looking at his/her display.

When watching somebody else's action on an HMI, animations are useful to perceive and then understand what he/she does. Without animations, the watcher controller may need much more cognitive effort. This is very similar to a remark of participants of the ANIMS workshop: for children to play and collaborate together on video games (in fact strategy games), the games must be animated. In this case, even if only one child is using the mouse and thus controlling the game, the other children can help him/her because they do understand what he/she is doing.

We call this mutual awareness between close users sharing the same environment **mutual working**.

Better remote awareness

Controllers are working with distant users (controllers, pilots, airline operators,..) of the ATC "global system". Mutual awareness with these distant users is important. Animations can enhance this awareness, mainly by easing the perception of either changes initiated by distant users, or messages / data send by these distant users.

We call the mutual awareness between distant users **remote awareness**.

Better situation awareness

Situation awareness is the knowledge of the state of the system and of any change of that state. With growing automation, the system state becomes more and more complex. Many of the changes can be notified with smooth animations. Again, using animations could reduce cognitive processing to understand some system state's changes by shifting to the perceptual processing. McCrickard's thesis conclusions point out that "the use of animations can assist in maintaining awareness without causing undue distraction in particular situations".

Of course animations should not distract the user. Thus they must be well-designed to make some changes[2] explicit, without distracting the user. This means that the animations should neither be too quick nor should they 'span' too much (in terms of time or space).

Enhanced confidence/trust in the system

Animations may help to improve confidence in HMI. When a controller is using an HMI with animations, he/she may better understand what is done with the HMI. For example the apparition of a popup menu without animation may momentarily disrupt the user, while using animation to make it smooth, keep the user focused on his/her task by shifting the user's

[2] Of course all changes do not have to be animated: for example, it is certainly a bad idea to animate the Actual Flight Level field in a flight label every time it changes

interpretation to the perceptual system [Thomas]. An animation following a data input may help the user to perceive the exact result of his/her input. This will allow the user to verify very quickly that the correct data has been input (i.e. he/she did not mistakenly input a wrong value in the menu). It may also help the user verify that the data has also been input in the right place (the correct field, or for the correct flight). If the system helps the user in detecting incorrect input, the system may appear as more honest, more reliable as the user may be able to correct his/her errors immediately.

Cognitive load reduction

When using carefully chosen animations, an interface can indicate to the user the source of information and its importance without further analysis on the user's part. Much information is only made available to help the user. Animations may help conveying this information using perception instead of central cognition thus reducing cognitive load.

User efficiency

Similarly by focusing on perceptual processing it may be possible to reduce the amount of time needed to use an interface, thus helping the user be more efficient. See for example [Zhang] who considers the case of visual search within a web environment.

Ease of use

Animations may make interfaces more usable for young, old, or disabled people [Worden et al.]. Even if this is not the primary goal for an HMI designed for experts, it is worth recognising the possibility. In fact, even very experienced or trained, users may have their motor or perceptual capabilities reduced in the case of high stress or high cognitive load. This has been observed in a CENA experiment [Mertz97] based on the dual-task paradigm. One of the developers of the HMI used for the experiment, encountered serious difficulties during the experiment setup phase, even if he was highly knowledgeable about the HMI. The reason was that even this experienced user was cognitively overloaded by the additional task.

Better user acceptability and satisfaction

When carefully designed, animations (as well as graphic design in HMI) may ease user acceptability of a new system. If the HMI exhibits some positive values, it will be more valuable for the user and we might expect that their job satisfaction[3] may be higher.
Controllers are more and more familiar with PC based applications with very advanced graphics and complex HMI (especially games). So using ATC HMIs whose current design is so different (not to say of lower quality), can be quite frustrating. Consequently, graphic design and possibly animations could be important in terms of job satisfaction[4].

[3] This kind of feeling was noted during some preliminary experiment of VigieStrips at the CENA
[4] Job satisfaction and job design in the ATC field has received little study and may deserve more attention.

2.5.2 Possible drawbacks of animations

Animations may be disruptive

Due to their nature, animations can be too 'attention demanding' and thus very disruptive, even in peripheral vision. This may be useful for alarms, but of course should not be the case for animations used in notifications or feedback.

Using animation requires careful design

As there is currently little experience in using animation[5], designing an HMI with animations is currently a skilled job which may require fine tuning. One of the aims of the ANIMS (first year follow up) is to give some recommendations on how and when to use animations.
For example, if animations are to be used for alarms, alerts and notifications, a clear hierarchy must be designed and animations should strongly reflect the position of the associated event in this hierarchy. The most important events (urgent, important alarms) should be associated with the most significant animations. And such animations should be designed by taking into account the full HMI so that they will be consistent.

Cost of implementation of animations, need for new software tools and architecture

As current tools used for developing ATC HMIs do not provide any support for animations, the HMI developer must implement them directly. This will be costly and the result may be disappointing if developers are left unsupported by the tools.
Thus adding animations with limited development cost will require new toolkits or new software architecture.

Underlying HMI and animations must have good performances.

Animations may need the underlying HMI to be responsive and without performances problems. Adding animations to an HMI (or a toolkit) and/or hardware which does not offer correct performances is of course meaningless. Also animations should be of relatively good quality. They should be rendered with some respect of the timing and without 'hiccoughs'.

2.6 Software products

Whereas animation has been addressed by several research toolkits in the user interface community, very few commercial products are aimed at managing animation. Moreover, the available products were initially aimed at animating artwork rather than at allowing programmers to add animation to their applications.

Flash™, Director™

Flash™ and Director™ are similar. They both use libraries of animations and represent animation along a timeline.

[5] The situation is similar to the one 15 years ago when colours where introduced in ATC HMI. Developers were seldom able to select correct colours. Human Factors experts or graphic designer had to work on this to propose some guidelines, or even to propose their own design.

An animation is described as either a succession of timeline based key frames with objects' position or as a standalone animation which is independent of the timeline or as a user driven animation.
User driven animations are drag and drop style animation. They are independent of the timeline, for example they can be used within only one frame. This kind of animation does not fit in the key frame model.
Standalone animations are objects put within one or more frames; their goal is to provide a timeline independent animation which then can be used within only one frame. This kind of animation does not fit in the key frame model.
Flash and Director both use both key the frame model and the actor model.

SMIL/SVG [Schmidt] W3C

SVG and SMIL are standards proposed by the W3C.
SVG is a vector based picture description which is to be based on XML. An SVG picture can be scaled as needed owing to its vector nature; it can be displayed on any machine and, because of its XML basis, can be read inline by an expert.
SMIL is an XML based format aiming at describing time based changes on a document. The first goal was to be able to produce slide presentations. SMIL 1.0 then evolved to become a more generic language. One element allows description of animations within another XML language. The SVG standardisation group has decided to incorporate this part into the SVG standard to allow it to create animated SVG.

3 Sound

Contrary to the domain of animation in which a body of research and experience have been developed, notably through the increasingly complex performances developed for video games and other applications, the domain of sound remains today a comparatively unexplored field.

Since the first theoreticians of 'concrete' music, who attempted to define and to describe a typology of resonant objects, up to the present day researchers of electro-acoustical music, no real modelling of the sound medium has been achieved as the amount of information necessary is large and its combinations complex.

Consequently the elements of definition that we have united to attempt a meaningful approach to this domain appear to be in a more theoretical setting rather than a technical one.

What is more, the very complexity of acoustic objects does not allow us to deliver here an exhaustive definition of their different features. This is why the definition that follows is intentionally oriented according to the perspectives of the potential application in HMI. Thus the definition focuses on characteristics that are particularly interesting from the point of view of the practices and modelling of a particular treatment of the acoustic object in HMI.

3.1 Definition

In its usual meaning, the sound is defined as “all acoustic vibration considered from the viewpoint of the auditory sensations thus created. “[6].

3.1.1 Sound, as a physical phenomenon

In its objective definition, sound is a physical phenomenon of mechanical origin that consists of a variation of vibratory movements (high and low pressure) that circulate by progressively modifying the state of the elements in a chosen medium, the result of which is an acoustic wave.

For the human auditor, it is essentially characterized by its pitch (linked to its frequency), its intensity (linked to the magnitude of the resonant vibrations) and its tone, which depends on the relative intensities of the different harmonic sounds that compose it.

The source of the acoustic wave can be direct (a sound emanating from a natural medium) or reproduced (restitution of a recorded, natural or artificial sound), simple (a man’s voice) or compound (the pen, the paper, the gesture of a hand, etc. in the writing of a letter). It has a marked influence on **causal listening** and **semantic listening**, as well as the perception of the **image-weight**[7].

When the acoustic wave propagates itself, it may undergo different influences or distortions due to the nature of the physical bodies constituting the medium through which it is

[6] Extracted definition of the Larousse
[7] Defined in paragraph 3.1.2.2

transmitted, in relation to its speed (340 m/s): reflection, refraction, diffraction, interference, etc.
If one considers the phenomenon of reverberation, it is clearly the result of the interaction of sound with its medium of diffusion: the perceived acoustic wave carries the sound effects created by the temporal interval between the sound waves in direct propagation and the sound waves reflected by an obstacle. The positioning of the source of the acoustic wave produced and the subject 'listening' can also influence the perception of the vibratory phenomenon affecting the sound wave.
Otherwise, if the sound waves don't meet an obstacle or any environmental differences (such as a hot draft in a cold room, for example), then reverberation can be excluded.

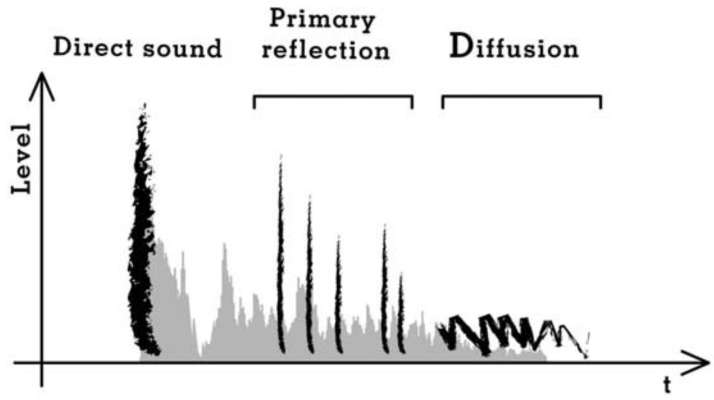

Figure 9 : The evolution curve of sound

In this diagram, we can observe the first reflection of a sound wave (its first echoes), and the resulting densification that follows: the diffusion or propagation. The ensemble of this phenomenon decreases more or less regularly until the total loss of the resonant energy.

It should be noted that all acoustic waves are impaired by its medium of propagation, which in itself determines the nature of this deterioration.

Nevertheless acoustic waves possess invariables that are interesting to consider, particularly from the perspective of analysis and modelling of the acoustic object. This is called the ADSR (Attack, Decay, Sustain, Release) envelope.

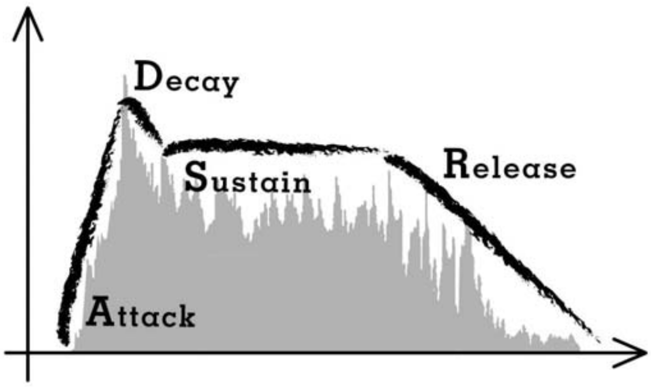

Figure 10 : Sound Envelope

The ADSR envelope of a sound is invariably constituted with a temporal evolution divisible into several segments: the 'attack' or ascension of the sound, an eventual and rapid 'decay', the body of the sound or steady prolongation called 'sustain' and the last segment corresponding to the extinction or the diminishment of the sound, named 'release'.

3.1.2 Sound, as resonant perception

To define the qualities and particularities of the acoustic wave is not sufficient to understand sound in all its physical complexity. It remains necessary to take a closer look at the most subjective parameter of our elementary definition, the 'auditory sensation'; the perceptual processes through which the vibrations take-on form and meaning.

3.1.2.1 Different levels in the focusing of attention

In its subjective definition, sound is therefore the sensation provoked by a vibratory phenomenon, its reception by the ear (which captures acoustic waves between 20 Hz and 20 000 Hz) and its conversion by the brain.

Figure 11 : The listening scale

The first level of listening can be summed up by **'audition'**, meaning the reception of sound waves; the second, by **'hearing'**, in other words manifesting an intention to listen; the third, by **'listening'**, meaning to lend an ear to something or to someone (to treat the sound as an indication); the fourth and last level is **'understanding'**, where the cognitive perception reaches its outcome: this is concerned with recognising a meaning (the sound is treated much like a sign).

The degree of focusing of the attention varies according to the level of listening attained by the subject; this evolves gradually from the subjective toward the objective, from the sensory to the analytic.

The level of listening of the subject can alter instantaneously, notably according to the 'image-weight'[8] of the sounds perceived and distinguished and the nature of his/her personal and cultural sound library.

3.1.2.2 The image-weight of the sound

Indeed, the human perception of a sound is built upon a double process that simultaneously considers the internal representation and the scale of the resonant event:

[8] Expression invented by Michel Chion. Cf. Ibid, *Le son*, Paris, Nathan, coll. "Fac", 2002.

1. The image represented by the event, in other words, the assessment of the ‘power’ of the source in relation to our own scale (stable, independent of the volume of the sound transmitted and of the distance of the perceptive subject in relation to the source)
2. The impression of scale is determined by indications of proximity (the details of high pitch, of articulation, of attack are more in the order of a light image-weight) in relation to the volubility of the source, the agility of a sound during its displacement, etc. [Chion]

Thus, the resonant object which is immediately identified and whose image-weight is light (for example, a distant car being started), does not mobilize the subject’s attention to a maximal cognitive level (in order to 'understand' it). This is because the resonant data processing does not have the same importance (the source of the sound is identified, not immediately dangerous, recognized as unimportant lacking emotional content, etc.).

3.1.2.3 The sound library

Added to this double process of analysis, the qualities of the perceptive subject's sound library are going to determine and to orient the classification and the evaluation of sound data unessential to the activity of the subject and consequently to modify the focusing of attention.

Indeed, everybody throughout their life, makes use of an infinity of acoustic objects that are analysed, ordered and classified according to a complex frame of reference, in relation to his/her experience and the cultural context in which they evolve and to which they are sensitive (for example, the sound library of a Japanese citizen is radically different from that of an African Bushman)

3.1.2.4 The position of listening

When the subject attempts to discover a sense (level of 'understanding'), he/she listens in different ways according to what he/she is trying to discover composed within the sound being listened to. Note that these different approaches can be exercised simultaneously.

Causal listening is the most widespread and most influential, in which the attention is focused on the research and the identification of the cause of a sound. This allows for a classification of sounds (Cf. the different levels of focusing of the attention). [Chion]

Semantic listening is the most complex; it aims at the perception of the sense of the message or code. It relies upon the character “voco-centriste” (*centred on the human voice*) of the attention, which, when given a combination of sounds, naturally gives preference to human speech. It should be noted that even if the sounds are "overlapped", sounds are always discerned by the human ear successively, therefore hierarchized (this is why it is impossible 'to understand' two people who speak at the same time; on the other hand, it is possible to 'listen to' an uproar created by numerous conversations that intersect). [Chion]

Reduced listening is analytic listening that regards the sound as an object of observation, regardless of its cause and its sense. It implies the reification, therefore the fixing of sounds on a support that attains the statute of resonant objects. [Schaeffer]

3.1.2.5 The different factors of vigilance

In the same way, different factors influence the sensation of time, and thus the attention of the subject at the time of listening, as well as the memory and the structuring in time of what he has heard, notably:

- The predictability or the unpredictability of the phenomena, permitting to anticipate or not and therefore the degree of projection of oneself in the future.

- The presence or the absence of temporal reference marks, chants, jingles, motifs, characteristics and repetitions, well affirmed temporal articulations, 'points of verticality' punctuating the time, scanning the listening and giving a certain comprehension of the global shape.

- The acuteness of the resonant events (greater or lesser content in fast and sharp phenomena imposing on the attention an attitude of immediate vigilance).

- The concordance or the non concordance of the rhythms of the sound sequence with other ultra-musical rhythms (natural phenomena, physical and corporal rhythms…). [Chion]

All acoustic design work should therefore be preoccupied with the different physical characteristics of the acoustic wave, the nature of its source and the medium in which it propagates itself, at the same time as the multiple factors that mobilize and condition the listening of the object by the subject.

3.2 The use of sound in HMI

The sound interface has naturally been exploited in the domain of video games and the multimedia, more that in HMI, apart from devices using the sound channel such as telephony or radiotelephony.

At the level of the interfaces, sound has been disregarded a long time because it was implicitly considered too intrusive, unpleasant and tiring in its repetitive character, sometimes superfluous and uninformative. Paradoxically, it is mainly thanks to its observed shortcomings that it has largely been used.

Indeed, we can distinguish three major uses of sound in HMI: sound as feedback (notably thanks to its association with the gesture), sound as an alert or alarm (thanks to its character intrusive), and sound as information (thanks notably to its iterative character), with a particular accent on the vocal aspect.

On the other hand, we have spread our observations beyond the sector of the HMI to the domain of film language, where more than 70 years of experience and analysis of the relation between sound and picture opens interesting angles of view.

3.2.1 Sound as feedback

Definition:
The discreet return of given information concerning an action made by oneself, a machine or another user.

Attention process:

These slight resonant tones remain in the perceptual domain without triggering the concious process. These tones are filter-out by the pre-attentive process. They facilitate use without placing large demands on the attention resource. They are part of the background sound[9].

Description:
Generally, feedback sounds are 'light-weight'. They are closer to an impulse, be they tonic (easily located by their high pitch) or complex (closer to a small complex noise than that of a simple note), than that of the iterative sounds (repeated impulses).

Two categories of feedback are identifiable: synchronous materializing resonant indications and asynchronous returns of information.

3.2.1.1 Synchronous materializing resonant indications (visible source)

Sound linked to gesture, to confirm an action:

- To put a glass on the table at the cinema. Here one speaks of materializing resonant indication. The sound used must fall rigorously just with the viewed gesture, otherwise the effect is hopeless. The noise can be very variable, the ear not being too demanding. However the sound-effects engineers avoid direct recording, which is considered to be approximate and hardly ‘legible’. They prefer to create and add more identifiable resonant objects in their sonic form (attack, length, ending). In the same manner, the effect of realism is not always realistic, as the example of the noise of screeching tires demonstrates when associated with the hero’s taxi, (albeit flying), in the film 'The 5th Element'. These materializing resonant indications are part of the ‘background sounds’; they are discerned and are perceived unconsciously.
- The set of little 'noises of the mouth' from the Mac Os9 during all manipulations of files, drag and drop, copy, etc. Pleasing, these little distinct and sharp sounds make up a coherent family. This innovative sound interface presents a resonant illustration of a set of events in the same spirit as the initial contribution of graphics. However through excessive use it has distanced itself from its primary functionality as a tool. The too frequent sounds load the resonant background, in a situation where calm is normally appreciated. In a group work setting, they very quickly become tiring, and even embarrassing to the user, surrounded by the other people who occupy the same workplace.

Sound linked to a simple gesture with certain connotations, meaning that it carries with it an added value bringing a certain sense:

- A glass placed conspicuously on the table at the cinema. The sound can underline a secondary gesture in order to make a primordial gesture, carrying with it a particular sense linked to its context. For example, the noise of the glass can punctuate or emphasise the 'end point' of a sentence pronounced by a character, or if an embarrassing silence prevails, the isolated noise of the glass is going to underline the ambiance, etc. A dramatic or sentimental connotation is therefore associated with the gesture.
- The sound of the rubbish bin (associated with an animation, Mac Os9) at the time of the destruction of a file. It is a noise that procures the same satisfaction as when one

[9] In fact it is often their ‘absence’ which is ‘detected’. For example, the lack of noise of an old floppy drive was usually detected as a malfunction of the floppy drive.

crosses out a line on a list of things to do. It underlines and confirms an important prompt decision.
- The sound of the keyboard shortcut for recording (without animation, Mac Os9) that confirms the realization of an action that one doesn't see.

3.2.1.2 Asynchronous returns of information (non visible source)

Sound that indicate a parallel action off-screen:

- the sound of the e-mail consignment, and of its reception (PC & Mac) while occupied with another task, this sound provides confirmation as to the status and good progress of a parallel task
- The well known dialing sound modem when a computer establishes a dial-up connection

These peripheral informative sounds unsupported by an image or text, function within the symbolic mode. That means that they must first be part of our personal sonic library in order to be understood.

3.2.2 Sound as alert

Definition:
The process of alerting the user; ranging from a simple, unthreatening notification, to a critical alarm.

Attention process:
Alarms/alert are composed of two phases: the actual activation and the informative content. The first phase consists of attracting rapidly all or part of the user's attention, the second to inform him/her. An alarm/alert is not inevitably sonic, however, historically; sound occupies the first phase thanks to its primary quality: it is intrusive. It can also assume the eventual informative phase.

Description:
In most of the cases, the sounds of an alarm have a sufficiently consequent resonant weight to pull the user out of his/her 'bubble of concentration' (using the rapport image-weight). They are often chosen either above, or below the middle frequencies employed by human speech in order to be easily identified. They traditionally present a progressive or sudden rise of frequency and/or resonant volume. Almost always iterative (repeated impulses, stridulating), sounds are often noticeable by their rhythm and their duration. The use of physiological rhythms, such as the beating of a heart or breathing, constitutes a factor of increased vigilance in the listener.

3.2.2.1 Resonant activation, known information in our cultural library

In these situations, information is contained in our cultural library.
- The traditional bell ringing at the end of lessons
- The fire alarm (direct action by the image-weight)
- The ringing of a telephone. A fast evolution took place with the generation of the beeps, followed by vibrations and melodies (personalisation of chimes, phenomenon kitsch) and, more recently, real sound signals have appeared.

Thanks to digital recording, the latest generation of telephone sounds is currently undergoing a quite interesting and creative period. It tends to take us back towards the variety and sound quality of the direct sounds of clockwork watches, clocks, gongs and other bells.

This diversity primarily permits a personalization of telephones. We no longer mistake the ringing telephone of someone next to us as the sound of our own phone, and the ringing is less disturbing because it is not always identified as such (ex: the whistling of a bird[10]). Ringing tones have escaped the ‘unpleasant to the ear’ register, replacing it with sounds which are less intrusive, more nearly pleasing, and do not inducing weariness, exasperation or shame.

3.2.2.2 Resonant release, implicit information

- The sound signal of 'the electronic car', when one reverses back against a wall… No vocal explanation just a 'beep' that intensifies rapidly with the approach of the obstacle. The driver stops his vehicle (because the sound is sufficiently strong to be troubling, cf. image-weight) then he turns his head instinctively to see where the noise is coming from (clearly being issued from the rear boot) and discover the obstacle. In this case, the sound production seems sufficiently coherent to require neither additional information nor training.

Remark: absence of sound
It is interesting to notice that the messages for certain important failures, such as system errors, on the most voluble interface (Mac Os9), remain silent… This silence and immobility remains very weak explicit signs of a failing machine.

3.2.2.3 The specific approach of speech as an interface

Alarms also use speech, in this case the activation and the message form one except if the message is preceded by a jingle. It is then a pre-recorded vocal message or reconstructed by synthetic speech.

The auditory attention of the human being is “voco-centric”. In a resonant ensemble, the voice attracts and centres our attention. This phenomenon doesn't mean that the other sounds are less important, but that they act on a less conscious level[11].

It is interesting to notice that the auditory culture of the Japanese, for example, accepts a large diffusion of talking objects, whereas the European culture is a lot more resistant.

Resonant activation, vocal information:

- The French train service messages. The well known jingle that precedes and introduces the operator's intervention acts like a temporal mark that creates the feeling of a familiar rhythm in the vocal interventions throughout the time passed in the station.

[10] However, in some contexts, e.g. an office, such a ringing tone may disturb more because it is too different from a phone ringing
[11] Cf. the description of semantic listening (section 1-1. b)

Vocal alerts:

- Printer pilot that orders directly: “Add more paper”. This type of message is acceptable because it is rarely issued. It never passes unnoticed, but even its efficiency can be irksome, when compared to the relative unimportance of the subject.

Some stiffness, a repetitive aspect, a lack of adaptability in terms of volume, of sound quality, and of interactivity currently characterizes most voice interfaces.

3.2.3 Sound as information conveyer

Definition:
The acoustic message becomes semantic. It is then the carrier of a coded meaning, as in speech or the sounds of the telegraph. One can consider a complex feedback (or a set of feedbacks) as being carriers of information.

Attention process:
The information detaches itself from the alert in the sense that it doesn't imperatively require the user's full attention, it solicits without imposing itself.

Description:
It is an ensemble of acoustic objects of middle-weight (the same level as speech, maximum).

3.2.3.1 Resonant information

- The sound of a child's small bicycle in the corridors of the empty hotel in the film 'Shining' by Kubrick, changes according to the nature of the floor: carpet, wooden planks or tiling. It is an identical repetitive action that has different acoustic resonances depending on the context in which it takes place. The resonant reaction of the 'milieu' to an identical stimulus is declined on three fashions.
- The percussive sound of the telegraph announcing the arrival of a message
- The scratching of the impression of the strip used by the controllers is collectively informative of the traffic volume to come and of the type of plane.

3.2.3.2 Vocal information

The GPS indicates a course to the driver: 'after the roundabout, turn to the right'. Is quiet for a while after the driver makes a mistake or goes another way, then readjusts its proposition. These pieces of vocal information are supported by a pictographic visualization of the junctions, but alone they are quite capable of directing the driver's activity, allowing him to focus his/her visual concentration exclusively on the road.

3.3 Sound and Human Factors

When the sound doesn't function as an ‘added value’ to the action or the picture that it accompanies, it very quickly becomes tiring because it is useless. To work as an indication of an invisible action, or as support for a logic suggested by a visual feedback, the resonant material should allow the user to move more quickly from one object of focalisation to another - providing an instantaneous resonant confirmation (*better comprehension of a mistake, improved usage, therefore improvement of efficiency*).

To treat sound as the indication of an action taking place somewhere off-screen can also allow the user to detect the imminence of an importance event (*surveillance of the procedures, predictability, anticipation of a phenomenon*) or to attract his/her attention to an event occurring and that would normally lie outside of his/her visual field (*peripheral notification*).

What is more, the recognition and the interpretation of a sound are bound intimately to the reading of the context in which they occur. The context sometimes carries more information that the sound itself, that is going to function as the signal of an event whose informative character will emerge by its confrontation within its context (*situation awareness*).

Finally, it is important to consider the treatment of sound not only as a possible added value to the visual presentation (even though a multimodal approach to the signal seems especially pertinent) but also as an independent transmission mode. Indeed, glimpsing the possibility of a semantic treatment of sound permits us to imagine, for example, the use of sounds in the same 'family' for an identical stimulus (information on the state of the workstation). It would also be possible to modulate the resonant feedback of a user's action according to variable parameters linked to the evolution of the contextual situation (*situation awareness, understanding of the situation, mutual awareness, safety benefits*)

Finally, as the acoustic object in the HMI is not limited to the screens space, (as compared with the visual object), it allows consideration of the benefits of manipulating its various dimensions and some of its particular properties (spatialisation, use of sub-sonic vibrations, use of rhythms and temporal sequences, etc.). It also allows consideration of different “levels of speech” (*mutual awareness, ease of use*).

We are going to develop these points in the following chapter within the context of HMI for ATC.

4 Animations and sound in ATC

We now focus on the applicability of animation in ATC and then on the way sound may be used in ATC.

4.1 Animations in ATC

We first list some applications of animations in current operational systems followed by some HMIs developed in ATC studies and research, which use animation.

4.1.1 Current use of animation and sound in ATC Human Machine Interfaces

Blinking, which is a very simplified form of animation is very often used in ATC HMI. It is the usual way STCA alerts are displayed on the radar display. A new line is added on flight labels involved in an alert with a text such as "STCA". These lines flash at a rate of approximately 1 Hz. Usually, the time during which the line is displayed is greater than the time during which the line is un-displayed. The blinking effect can also be achieved by changing both foreground and background colours at the same rate.

Blinking is also used on the Touch Input Devices (TID) used for managing the phone system. Usually, the most frequently used call numbers are associated with a button on the TID. If one of these numbers is calling, the corresponding button on the TID flashes (with a ring tone) to help the user access the call by depressing this flashing button.

The radar view by itself is also animated at a very low pace. Flights are moved to their new positions every few seconds. However, as has been observed during the ANIMS workshop, controllers are able to perceive flight movements (i.e. flights future positions) very quickly as they have been trained for this. Simply with the previous positions of flights and sometimes with the speed vector, they quickly get a picture of the future positions, at least in the horizontal plan. In a sense, even if the radar display has no real animation, controllers do perceive the movement.

In some airport tower HMI, where there is very little room on the labels to display information, the system switches every 1 or 2 seconds between two different pieces of information. Again this is rather a blink, but can be considered as a simple animation.

Belgocontrol is currently replacing an old flight list display (called ADB) with a new one called ADD, to be implemented by the end of 2004. This new flight list HMI now uses some simple, DigiStrip inspired, animations when the user moves an electronic flight strip from one column to another.

4.1.2 ATC studies or researches involving animations in HMI

EEC uses animations in some radar view when the user modifies the range / zoom of the radar view. This helps the user as well as the other controller (when working in team) to understand the effect of the changes in radar display settings.

CENA developed a number of HMIs where animations are involved. DigiStrips and now VigieStrips make intensive use of animations. Most of these are more fully described in the forthcoming document "Identification of operational scenarios for sound and animations use in ATC" to be produced in Work Package 3 of the ANIMS project. Some simple animations were added to the AMAN HMI of the PD3 experiment at the CENA. The ASTER prototype (dedicated to ETMA control) also used animations, mainly for data input. A prototype radar image named Glance also makes heavy use of animations: for example flight moves are really animated; flight labels are animated when the anti-overlap manager needs to move them. Even speed vectors are animated when flights are turning.

IntuiLab used animations in an AMAN/DMAN HMI prototype developed in collaboration with Sofreavia. It was demonstrated for the Maastricht exhibition in February 2004.

4.2 Sound in ATC, issues and perspectives of an ecological treatment

The treatment of sound in the ATC environment is a particularly delicate topic, considering the fact that large amounts of information already pass by the medium of sound.

The messages exchanged between the different operators and the quantity of the information signals and different alarms/alerts that govern the decisions to be taken according to the contexts (control rooms, control towers, etc.), have until now invalidated all propositions.

It is why it seems essential to us not to limit the perspectives of sound treatment only to a work station dedicated interface (or even to one of its systems) but to consider the sound aspects in their “ecological” dimension.

The ecological dimension

Two remarks seem important for us to formulate.

The first remark concerns the fact that sounds have the capacity to overlap, to mingle, but they can only be identified successively by the human ear. The second remark is that sound, unlike images, cannot be circumscribed spatially. The acoustic wave by nature occupies the whole space in which it propagates itself. This is why the sound interface cannot conceived without taking into account its ecological dimension.

We mean by “ecological dimension” the relations of interdependence that bind different objects to each other as well as to their environment.

Let's consider a set of objects composed schematically of an environment (the space of propagation of acoustic waves), of emitters, of human or mechanical receptors, and a principle activity linking the different objects.

To capture the sound as a signal and therefore to perceive the sense of a message, the recipient must automatically classify the ensemble of the perceived information. Thanks to training in subjective listening[12], the receiver is accustomed to sorting out human speech in a disorganized resonant environment and giving it priority. The more the environment is disorganized, the more the resonant pressure increases and the more the receiver must mobilize his attention to be able to 'hear' (before even trying 'to understand') the information that is destined for him. When the receiver becomes in turn the emitter, he is going to adapt to

[12] The small child doesn't sort out the totality of sounds to extract a useful signal from it. He hears therefore in a more "objective" way than adults who have learned to shut-off the reverberation that comes with all vocal or resonant transmissions and to isolate the verbal message.

this sound load, either by using an unoccupied part of the spectrum (high pitch register, for example) or by amplifying the volume of his communication. He is therefore going to contribute to, or even to amplify, this disorganization until the level of activity diminishes..

In the light of this relational interdependence, it seems impossible for us to consider a treatment of the sound interface separately from the "ecosystem" to which it belongs.

Topography of a resonant analysis and perspective

From the sound analysis of the control room of Aix-en-Provence ACC (Undertaken for the CENA in June 2001), we established a topography of the different sounds identified.

Sounds and effects of the environment
- The surface of the room (1250 m2)
- The ventilation system (operating in a continuous manner)
- The layout in parabolas of the work stations (reverberations)
- The surfaces noises (manipulation of objects on the desks)

The punctual material events (iterative)
- The ringing of the controllers telephones
- The ringing of the telephones of the control room supervisors (for long periods)
- The clanking of foot pedals for activating the radio
- The print rate of the edge-notched strip printers (indicative of the intensity of the air-traffic)

The human activity
- The conversations
    - Words exchanged from one work station to another
    - The communications in hushed voice between the radar controllers and the planning controllers
    - The communications between the radar controllers and the aircraft, amplified on loudspeakers.

- The inherent and punctual load events at rush hours
    - The noises of the accumulation of the strip tablets in their racks (arranged in heaps)
    - The orders given in a high voice from one station to the other, voices raised to overcome the ambient noise, etc.

This topography allows us to think about two essential aspects of the sound treatment:
- The constraints bound to an invariant specific acoustic environment
- The perspectives offered by the treatment of the acoustic objects linked to the tools and the human activity

In their large majority, the recorded sounds constitute the consequence of the Air Traffic Control activity (feedbacks or resonant pollutions) but do not constitute an added value to this very activity.

We are convinced that by an ecological treatment of sound, and notably through the organization of a resonant reality 'waste land', it is not only possible to optimize the occupation of resonant space, but to transform it in order to convert the acoustic objects which give only witness (results of actions), into real supports of task activity (impulses of action). It is precisely what the air traffic controllers have managed by changing sound from the status of a nuisance ("irritating" cadence of the strip printers) to the status of signals (code giving account of the intensity of the traffic).

From the perspective of an ecological treatment of the sound, it is the binary man-machine relation that we put into question.
Indeed, to include the interface in a coherent ecosystem invites us to consider three levels of discussion:

- A first level of discussion, that is located in the man-machine interaction
- A second level of discussion, that is on the manner of collaborative work
- A third level is the manner of collective information

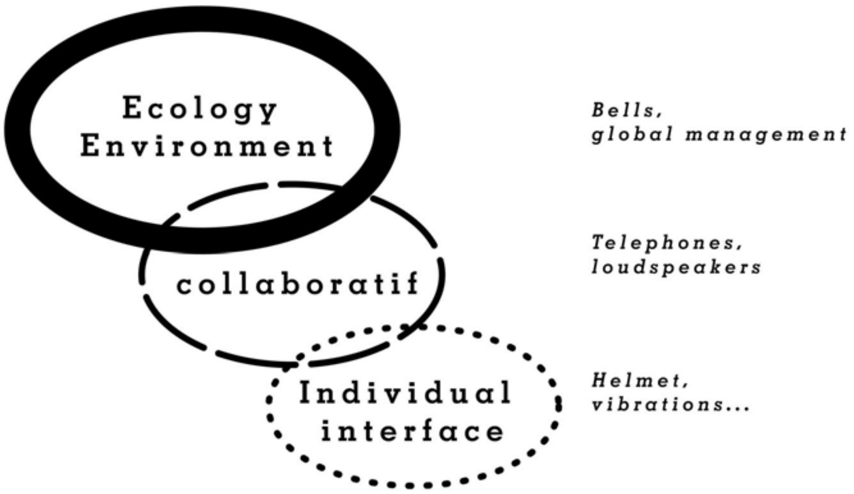

Figure 12 : sound ecology

As a conclusion:
Until now and through a concern over the preservation of the sound channel, the world of ATC has neglected to address its primary source of information. Considering the existing acoustic space according to an ecological approach permits consideration of different modes of treatment that would transform this resonant waste land into an organized ecosystem, where sound would make sense.

5 Conclusion

This document on the state of the art of sound and animations is based upon a bibliographic research of scientific literature, on workshops organized at EEC and internally.

Initially, we began by a revue of animation in HMIs. We gave some definitions of animations and proposed several re-modellings of animations based on the bibliographic research. Then we identified different techniques of animation, before considering the cases of practice in HMIs. Next we presented the possible contributions but also the inconveniences of animation in terms of Human Factors. Finally we made a rapid revue of the software products permitting to achieve or to remodel the animations.

In the second part of the document we treated the case of sound, which remains a far more exploratory medium.

The difficulty that one can have to analyse the set of the constituent parameters of the acoustic phenomenon reflects the extreme wealth of resonant information at the same time as its inherent complexity.

We have recognised the extent to which sound benefits from a paradoxical status that has driven it to be used or rejected on the basis of the same characteristics. This demonstrates proves how much an appropriate treatment of sound must take into account the medium, the context, the practices and the objectives of its use.
Since sound is intrinsically part of our environment, it is interesting to consider the treatment of the sound interface from an ecological perspective that permits a real differentiation of the discussions, toward the emergence of levels of meaning adapted to the different operational objectives of a mastered communication.

In the third part we identified cases of the practice of animations and sound in ATC HMIs, either in operational systems, or in prototypes applied to ATC.

The combined use of sound and animation is still far more exploratory and more open: whether it is animation or sound and although each of these domains possesses distinct characteristics, we have been able to observe that they could both serve (be put to the service of) identical practices, in a synchronous or asynchronous way.

The dynamic, interactive capacities and collaborations of these two modes of data processing lead to believe in the added value which may be born from their combination. The multiplicity of the possible combinations of sound and animations also opens numerous perspectives for studying the particular potentialities of their interaction and the quality of the benefits that can be expected in terms of performance, reliability and usability. This field is especially open because sound itself remains a major topic of research in man-machine interaction.

6 Bibliography

6.1 Animations

[Athenes] S. Athènes, S. Chatty, A. Bustico. Human Factors in ATC Alarms and Notifications Design: an Experimental Evaluation. *3rd USA/Europe Air Traffic Management R&D Seminar, 2000, Napoli*
http://atm-seminar-2000.eurocontrol.fr/acceptedpapers/pdf/paper26.pdf

[Bharat, Sukaviriya] : Animating user interfaces using animation servers , *Symposium on User Interface Software and Technology archive. Proceedings of the 6th annual ACM symposium on User interface software and technology table of contents* Atlanta, Georgia, United States Pages: 69 – 79 Year of Publication: 1993 ISBN:0-89791-628-X

[Byrne et al.] : Do algorithm animations aid learning *GIT-GVU* August 1996

[Chatty 1992] : La construction d'interfaces Homme-machines animées
Thesis

[Foley] : Coupling a UI framework with automatic generation of context-sensitive animated help *Symposium on User Interface Software and Technology. Proceedings of the 3rd annual ACM SIGGRAPH symposium on User interface software and technology.* Snowbird, Utah, United States Pages: 152 - 166 Year of Publication: 1990 ISBN:0-89791-410-4

[Forlizzi, Lee, Hudson 2003] : The kinedit system : affective messages using dynamic text *Conference on Human Factors in Computing Systems. Proceedings of the conference on Human factors in computing systems* Ft. Lauderdale, Florida, USA SESSION: Techniques for n-screen shapes, text and handwriting Pages: 377 - 384 Year of Publication: 2003 ISBN:1-58113-630-7

[Geiger, Paelke] : Enhancing 3D user interfaces with 3D animation encapsulated in user agents *ECAI '98 workshop "Combining AI and Graphics for the Interface of the Future" Brighton*, UK, Aug. 1998.

[Hansen et al.] : From algorithm animations to animation-embedded hypermedia visualisations *Technical report CSE98-05 Visual Information, Intelligence & Interaction Research Group* Department of Cumputer Science & Engineering Auburn University July 31, 1998

[Hudson at al. 2003] : Predicting human interruptibility with sensors : A wizard of Oz feasibility study *Conference on Human Factors in Computing Systems. Proceedings of the conference on Human factors in computing systems* Ft. Lauderdale, Florida, USA SESSION: Modeling user behaviour Pages: 257 – 264 Year of Publication: 2003 ISBN:1-58113-630-7

[Keohe, Stasko] : Using animations to learn about algorithms : an ethnographic case study *ACM Southeast Regional Conference Proceedings of the 36th annual Southeast regional conference* Pages: 194 – 200 Year of Publication: 1998 ISBN:1-58113-030-9

[Kessler, Knapen] : Interactions: Advanced controller displays, an ATM essential. *3rd USA/Europe Air Traffic Management R&D Seminar, 2000, Napoli.*
http://atm-seminar-2000.eurocontrol.fr/acceptedpapers/pdf/paper36.pdf

[Lasseter] : Principles of animations applied to 3D computer animation *International Conference on Computer Graphics and Interactive Techniques archive Proceedings of the 14th annual conference on Computer graphics and interactive techniques* table of contents Pages: 35 – 44 Year of Publication: 1987 ISBN:0-89791-227-6

[Lawrence et al.] : Empirically evaluating the use of animations to teach algorithms *Technical Symposium on Computer Science Education Proceedings of the twenty-eighth SIGCSE technical symposium on Computer science* education San Jose, California, United States Pages: 243 – 247 Year of Publication: 1997 ISSN:0097-8418

[McCrickard] : Maintaining information awareness in a dynamic environment : assessing animation as a communication mechanism. Thesis 2000

[McCrickard] : Maintaining Information awareness with Irwin *Computer Supported Cooperative Work. Proceedings of the 2002 ACM conference on Computer supported cooperative work* New Orleans, Louisiana, USA Pages: 314 – 323 Year of Publication: 2002 ISBN:1-58113-560-2

[Mertz97] Faut-il tuer la souris ? Une comparaison des charges cognitives induites par 6 procédures de saisie. Christophe Mertz *neuvièmes journées sur l'ingénierie de l'Interaction Homme-Machine, IHM 97, Cépaduès, septembre 97*

[Mertz02] : Users Bandwidth in Air Traffic Management: An Analysis from the HMI point of view C. Mertz, R. Benhacène *HCI-Aero 2002 International Conference on Human-Computer Interaction in Aeronautics Cambridge, USA* CENA/NR02-651
http://www.tls.cena.fr/divisions/PII/Rapports/NR02-651.pdf

[Mertz,Vinot] C. Mertz JL. Vinot.Touch input screen and animations: more efficient and humanized computer interaction for ATC . *In Proceedings 10th International Symposium On Aviation Psychology*. Columbus, Ohio. May 1999.
http://citeseer.ist.psu.edu/mertz99touch.html

[Myers, Hudson, Paush] : Past Present and future for user interface software tools *ACM Transactions on Computer-Human Interaction (TOCHI) Volume 7, Issue 1 (March 2000) Special issue on human-computer interaction in the new millennium, Part 1* Pages: 3 – 28 Year of Publication: 2000 ISSN:1073-0516

[Myers et al.] : Easily adding animations to interfaces using constraints *Symposium on User Interface Software and Technology. Proceedings of the 9th annual ACM symposium on User interface software and technology Seattle, Washington, United States* Pages: 119 – 128 Year of Publication: 1996 ISBN:0-89791-798-7

[Myers et al.] : The amulet environment : new models for effective user interface software development *IEEE Transactions on Software Engineering* Volume 23 , Issue 6 (June 1997) Pages: 347 – 365 Year of Publication: 1997 ISSN:0098-5589

[O'Reagan] Change blindness as a result of mudsplashes. J. Kevin O'Regan, Ronald A. Rensink, James J. Clark. *Nature*. March 4, 1999. see also : http://nivea.psycho.univ-paris5.fr/Mudsplash/Nature_text/mudtext.html

[Rist et al.] : Adding animated presentation agent to the interface *International Conference on Intelligent User Interfaces. Proceedings of the 2nd international conference on Intelligent user interfaces* Orlando, Florida, United States Pages: 79 – 86 Year of Publication: 1997 ISBN:0-89791-839-8

[Schmidt] : Multimedia meets computer graphics in SMIL2.0 : a time model for the web *International World Wide Web Conference. Proceedings of the eleventh international conference on World Wide Web* Honolulu, Hawaii, USA SESSION: Multimedia Pages: 45 – 53 Year of Publication: 2002 ISBN:1-58113-449-5

[Stasko, McCrikard et al.] : Exploring animation as a presentation technique for dynamic information sources *International Journal of Human-Computer Studies* Volume 58, Issue 5 (May 2003) *Notification user interfaces* Pages: 515 - 545 Year of Publication: 2003 ISSN:1071-5819

[Sukaviriya et al.] : Automatic generation of textual, audio, and animated help in UIDE: The user interface design environment *AVI . Proceedings of the workshop on Advanced visual interfaces* Bari, Italy Pages: 44 - 52 Year of Publication: 1994 ISBN:0-89791-733-2

[Thomas] : Animation direct manipulation in human computer interfaces
Thesis 1997

[Thomas et al.] : Experiments with animating direct manipulation in a drawing editor
1998 *In ACSC'98" The 21st Australasian Computer Science Conference (Perth, Australia, Feb.)*, 157-168.

[Vodislav] : A visual programming model for user interface animation *VL Proceedings of the 1997 IEEE Symposium on Visual Languages (VL '97)* Page: 344 Year of Publication: 1997 ISBN:0-8186-8144-6

[Worden et al.] : Making computer easier for older adults to use : area cursors and sticky icons *Conference on Human Factors in Computing Systems. Proceedings of the SIGCHI conference on Human factors in computing systems* Atlanta, Georgia, United States Pages: 266 – 271 Year of Publication: 1997 ISBN:0-89791-802-9

[Zhang] : The impact of animation timing and location on visual search performance in the web environment *Proceedings of the Americas Conference on Information Systems (AMCIS'2001), Boston,* MA, 2001, pp. 1361-1366

W3C SVG specification : http://www.w3.org/TR/SVG12/

W3C SMIL specification : http://www.w3.org/TR/smil20/

6.2 Sound

Michel Chion, L’audio-vision, son et image au cinéma, Paris, Nathan, coll. Cinéma, 2004.

Michel Chion, Le son, Paris, Nathan, coll. « Fac », 2002.

Michel Chion, Guide des objets sonores, Paris, INA/Buchet Chastel, coll. « Bibliothèque de recherche musicale », 1994.

Pierre Schaeffer, Traité des objets musicaux, Paris, Seuil, coll. « Pierres vives », 2002.

Emmanuel Holterbach, Analyse sonore et compte rendu de visite de la salle de contrôle du CRNA Sud-Est, CENA juin 2001.

Robert Murray Schafer, Le paysage sonore, Paris, Lattès, 1979.

The World Forum for Acoustic Ecology
http://interact.uoregon.edu/MediaLit/WFAE/home/index.html
The World Forum for Acoustic Ecology (WFAE), founded in 1993, is an international association of affiliated organizations and individuals, who share a common concern with the state of the world's soundscapes. The members represent a multi-disciplinary spectrum of individuals engaged in the study of the social, cultural and ecological aspects of the sonic environment