AIRPORT NOISE / ANNOYANCE ANALYSIS

Marc Boyer , Laurent Chaudron
ONERA Toulouse

Keywords: *Noise, Annoyance, Artificial Intelligence, Formal Analysis*

Abstract

The aim of this paper is to design a generic model of the correlation between the noises generated by an airport's traffic and the annoyance felt by the residents. This Artificial Intelligence project focuses on the study of the relations between systems and unvoluntary users. Beyond a mere "noise level" $\rightarrow$ "annoyance" function, we aim at defining more precisely the causal relations between noise characteristics and the actual annoyance. Hence, we work both on annoyance cognitive models and on noise data.
In this paper, our contribution consists in: the description of the experimental campaigns and the the definition of the theoretical tools.

1 Introduction

Noise influence on annoyance is a widely studied problem. Many numerical approaches have been carried on and usually statistics are used to represent general perception of phenomena [15] (e.g. "In context c, a particular noise event $(n > \sigma)dB$ exasperates 60% of population p"). Unfortunately, such kind of information does not express psychological annoyance, nor describes the correlations between noise and discomfort. In [7], the approach consists in designing a model based on physiological behavior of the auditive organs. In transport field, noise annoyance problems are identified [9], but they often depend of the context [12] (due to the ground noise, traffic on roads for example). Psycho-acoustic researches showed that categorisation (ability to recognize a sound) is opposite to continuous noise perception with just a few significant events. This approach, using cognitive science knowledge, seems to be a promissing one as a human being is able to discern - and distinguish between - various noise features. In aeronautics, the control problem evolves faster than plane's characteristics [13], however, companies modify take off/landing procedures in order to decrease noise effects. Finally the existing solutions consist in directly reducing the noise [8] [14]. If it is clear that noise reduction (active or passive) is the simpliest way to protect our sound environment, the idea is to analyse more precisely the causal links between the various parameters of noises and the characteristics of the resulting annoyance felt by persons.
The aim of this paper is to present a global approach based on a genreic frame devoted to knowledge representation and exploration.

1.1 The conjecture and the theoretical frame

The problem adressed by the noise/annoyance correlation question is characterized by two main points: - from the experimental point of view, different classes of data have to be collected (noises, annoyance expressions), - from the theoretical point of view, a generic analysis of these heterogeneous data has to be performed. The challenge of this conjecture is summarized by the following requirements:

(1) to provide means to **represent** within the same frame, sets of heterogeneous information (numerical data /symbolic knowledge, objective measurements / subjective information...)

(2) to allow knowledge **exploration** to be performed on them (data mining, symbolic analyses, rough classification, rules induction...),

(3)to design an **experimental** setup so as to collect the noise/annoyance information.

Considering that the knowledge representation model is a pivotal point in the way data will be captured and processed, in the sequel, we describe the models dedicated to knowledge before the presentation of the experimental data collection.

1.2 Reading guidelines

The paper describes both theoretical aspects (related to artificial intelligence) and applied questions (related to acoustic environment of airports). Thus different levels of reading are required. The first section (# 2) is devoted to the theoretical frame for kowledge representation and processing, i.e: the Cube model and the Generalized Formal Analysis. Then the first experiments - based upon expressed annoyance - are presented (section # 3) and the results of their formal analyses are given. The second generation of experiments - based upon the evaluation of the cognitive performance - is then detailed (section # 4).

2 The theoretical frame

The CLP (Contrained Logic Programming) is a well-known environment in the Artificial Intelligence domain and it provides a suitable answer to the first previous requirement (1). That is why in this study, Prolog is the standard language.
The theoretical basis of CLP is predicate logic; the specific subspace of predicate logic concerning conjunctions of properties (which is the pattern we need in our application) is called the "Cube" model and it is described hereafter. Then, requirement (2) is satisfied thanks to the "Generalized Formal Analysis" model.
In this section the formal definitions will be examplified through a very simple set of noise events.

2.1 Knowledge representation

Definition A **cube** is a conjunction of first-order logic literals. The set of cubes ($\mathcal{C}^r$ can be equiped with a struture of a lattice thanks to an extension $\cup_c$ and $\cap_c$ of the classical set operators.
Example: the cube c_1 = *{Level(inf80db), Period(Am), Annoyance(Medium), Activity({Rest,TV})}* captures the sound level and the main annoyance characteritics of a given subject submited to a noise event denoted Id_5. If c_2 = *{Level(inf80db), Period(Am), Activity(Manual)}* is the cube of event Id_{16}, then the common features of both events is captured by the cube:$c_1 \cap_c c_2 =$ *{Level(inf80db), Period(Am), Activity(V)}*, while the aggregation of both cubes is:$c_1 \cup_c c_2 =$ *{Level(inf80db), Period(Am), Annoyance(Medium), Activity({Rest,TV,Manual})}*
Thus, considering simultaneously different events, we can analyse the correlations between their cubes. Such a set of event is a context. As an example, let us consider the very simple context:

	Activity	Annoyance	Period	Level
Id1	rest	high	am	inf80
Id3	intell, rest	low, medium	am	sup80
Id5	tv, rest	medium	am	inf80
Id16	manual	low	am	inf80
Id20	rest, outside	low	pm	inf80

Definitions Such a table can be formally defined: a **context** is a pair (O,ξ) where O is finite set of objects, and ξ is a mapping from O onto $\mathcal{C}^r$. Each object o in O has one and only one image $p = \xi(o)$ in $\mathcal{C}^r$ which represents the set of properties of o. The dual operators $\boxed{\,'\,}$ and $\boxed{\,\circ\,}$ between O and $\xi(O)$ are defined by: $A' =_{def} \cap_{\mathbf{c}\, o_i \in A}\, \xi(o_i)$ $\quad B^\circ =_{def} \{o_i \in O | B \leq_c \xi(o_i)\}$.

A' is the set of attributes common to all the objects in A, and B° is the set of the objects possessing their attributes in B.

2.2 Knowledge exploration

As we have to determine the links between subgroups of event and the properties they share, we can define the generalised concepts as pairs of correlated objects (events) and their typical properties:

Definitions A **generalized concept** is a pair (A,B) $A \subset O$, $B \in \mathcal{C}^r$ such that: $A' = B$ and $B^\circ = A$.

The set of all generalised concepts defined by the context (O,ξ) is denoted as $\boxed{\mathcal{L}^1}$ and it verifies:

Theorem defining: $\sqcup$ (supremum) and $\sqcap$ (infimum) on $\mathcal{L}^1$ as follows:

$(A_1,B_1) \sqcup (A_2,B_2) =_{def} ((A_1 \cup A_2)'^\circ, B_1 \cap_c B_2)$

$(A_1,B_1) \sqcap (A_2,B_2) =_{def} (A_1 \cap A_2, (B_1 \cup_c B_2)^{\circ\prime})$

We have: $(\mathcal{L}^1 \sqcup, \sqcap)$ is a lattice.

Back to our example, such a diagram represents the symbolic dispersion (a kind of symbolic gaussian curve) of the knowledge as it is structured in the lattice $\mathcal{L}^1$:

Each node is a generalized concept, i.e. a stable couple $(events, features)$ and two concepts have a supremum and an infimum. A given concept ⓝ inherits all the properties which are linked above it in the diagram and ⓝ is constituted of all the events which are linked below it. For example: concept ⑥ is: *({id16, id3}, {Annoyance(low), Period(am), Level(V2), Activity(V3)})*. ⑥ is the "class" of all events that looks like id16 and id3, characterized by the fact that they occurred in the morning and they induce a weak annoyance while activity and sound level were undefined (thus they are represented by variables).

Thus, the top-down subtree represents the emergent contextual classification of the events thanks to the labelling properties. The more events there are, the less characteristics they share and conversely. The relation between

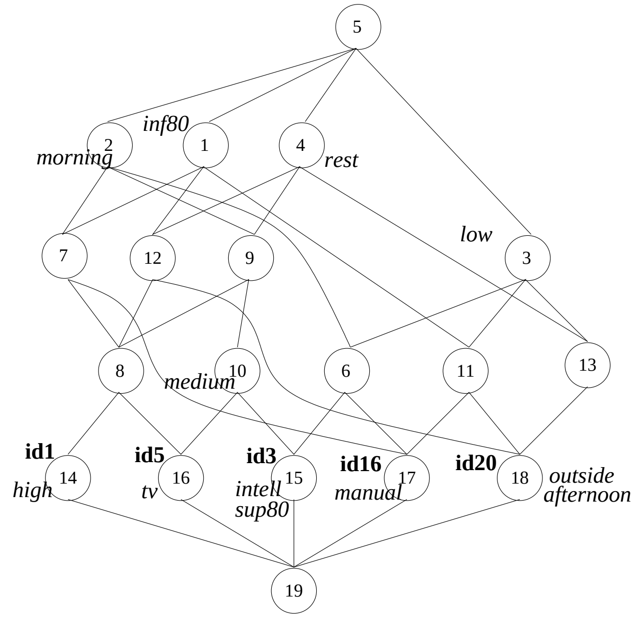

Fig. 1 Data extraction protocol

comparable concepts works like communicating vessels.

Such a flexible self-emergent classification suits our problem of amorphous knowledge mining. Indeed, thanks to the implementation of FGA, the context and the concept lattice can be considered as a global Prolog knowledge base $C \cup L$ on which knowledge exploration experiments are performed. In particular, the knowledge base $C \cup L$ is used so as to look for contextual dependencies (i.e. rules) between either objects or attributes. The induction of the context-based rules relies on a fundamental lemma: $(\forall A \in P)$, $\models (A \rightarrow (A'' - A))$. Thanks to this result, a context rule generator based on a simple saturation algorithm was implemented. It allows to induce all the contextual rules generated by the considered events. For example, the following rule can be formally derived from our context:

(Level(inf80) $\wedge$ Activity(rest) $\wedge$ Period(am)) $\rightarrow$ *Annoy(x)* $x \in$ *{medium,low}*

Which means that "If an event occurs in the morning and during rest, even if the sound level is less than 80 dB, the person feels an annoyance (at least at a medium level)".

These different capabilities of knowledge mining and rules induction are still under study.

3 Experimental data collection

3.1 Introduction

Given an airport and riparian persons, if we want to understand the correlations between the noise generated by the aircrafts and the annoyance which is induced among the population, we need actual data to be collected.
As we try to design a global causal model, our objective is not to find a new physiological ratio. We have also to define a psychological annoyance cognitive model [5], keeping the cause multiplicity and the actualy felt annoyance heterogeneous aspects. Moreover, at each step of our project, we try to reveal the actual links between noise parameters and annoyance characteristics. Thus the information and the correlation model have to be simplified in a first step and then they are hardly enriched.

3.2 Context of the study

The noise / annoyance correlations study is within a prospective framework of an ONERA federative project named “Airport of the Futur” (“Aéroport du Futur”). A project presentation is available on our web site : http://www.cert.fr/en/dprs/activites/adf/. Our task consists in studying annoyance criterias and in linking them to noise characteristics [3], [4].

3.3 Experimental protocol

The aim of our experiments is to try to design and validate the methodology. On the other hand, we collected correlated sets of data: noisy events and simultaneous annoyance characteristics. The experiment took place on the may 29^{th} 1999, from 6 a.m. to 9 p.m. around Toulouse Blagnac Airport. A zone was choosen in a significant area near the the tracks'axis of the airport. A central point was equiped with a noise recorder while approximatyvely 15 selected volontary persons, living in a radius of 5 Km around the recording point, were asked to fill a questionnaire. Each time an aircraft was audible, predefined items and free fields allowed the volonteers to express various features of annoyance. The questionnaires were collected one day after and translated in a prolog database. The acoustic device were

- Tape Recorder IV NAGRA SJ
- Preamplifier BK 2619
- microphone BK4165

The objective is to record aeronefs' movments within natural human environment. The recording was continuous in order to not loose temporal reference. The data tapes were postprocessed so as to extract the significant value; many of them are not yet relevant (technical motor characteristics...) and in this first campaign we just took into account four noise levels in dB.
It seems to be the first time these two kinds of data were recorded really simultaneously. Indeed, we made a direct link between each noisy event and pinpoint annoyance expressions. Generally, so-called noise-annoyance evaluation are mere links between average noise values (measured at time t) and a vague discomfort expressions (time t')[1].
Thus, for each event (an aircraft flight) time is the fundamental join parameter between the two sets of data.

The acoustic peace of equipment are :

- Recording tape NAGRA IVSJ
- Preamplifier BK 2619
- microphone BK4165

The objective is to record aeronefs' movments within natural human environment. We recorded continuously in order to not loose temporal reference.

[1]Moreover we discovered that the smallest time deviation between mean noise measurements and annoyance polls, was: $|t' - t| = 6\ months$!

3.4 Data Acquisition

This part focuses on relevent noise characteristics extraction from analogical recording. These characteristics are to connected to the residents' annoyance expresses who participate in this operation.

3.4.1 Noise parameters extraction

Successive stages are necessary to extract nois characteritics :

- analogical recordings reading;
- signal processing with a Dual Chanel Signal Analyzer 2032 type, Brüel&Kjaer;
- acquisition on a computer with Star Acoustique Software;
- data recording with Excel Software

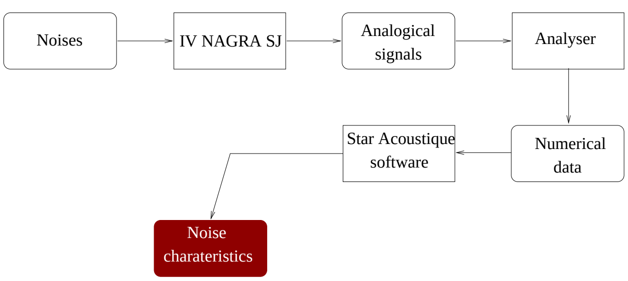

Fig. 2 Data extraction protocol

3.4.2 Annoyance characteristics extraction

To express for the best the resident annoyance feeling, we create a questionnaire in which each person can describe noisy events conditions. Hence we have to know :

- the person's activity;
- his safety environment;
- a simple qualifiquying of annoyance;
- other sources of distressing noises (different to aircafts's noise);
- any other comment (in a free case).

3.5 Data processing and rules production

The aim objective is to build a data base implemented in Prolog; in fact in CLP (Constrained Logic Programming) which allows to express properties and numerical contraints. The knowledge is captured and structured as follows:
• the set of noisy event characteristics:
◦ time (which we can aggregate by periods: morning, afternoon, evening, night),
◦ noise characteristics (noise level in dBA for example, frequency, duration, number of previous noisy events);
• the set of the human features:
◦ the person,
◦ his activities,
◦ his noisy environment (described by noisy events which are not aircraft ones),
◦ his safety environment (did she or he see the plane?),
◦ his annoyance expression (weak, medium, strong, very strong).

3.5.1 Prolog base construction

Data processing processus is made of successive stages beginningwith recording of two databases (the first one for the noise events, and the second one for the annoyance expressions). These bases constitute the context which Formal Analysis processes. A Prolog program converts the bases into context. Hence, from the context, A.F. find noise events sub-sets and produce inference rules.

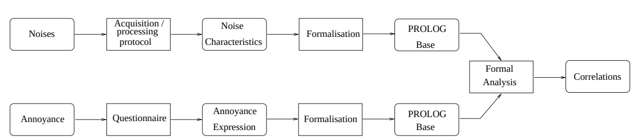

Fig. 3 From information to correlations

3.5.2 Cubical Formal Analysis

The properties of each base (noise and annoyance) are captured by predicates. In this context, two kinds of data are considered:

- objective data
  - the set of persons;
  - the period of the day when the noise occured;
  - acoustic levels of the events;
  - persons' activity.
- Subjective data
  - annoyance expressions of persons who answered

3.6 Example

The rate of well-recorded flight, with regard to ones potentially recordable, is weak (about 10 %). This weak ratio can be explained by tha bad meteorological conditions. The actual database is constituted by 12 noise events and 16 annoyance expressions.
●Noise events base:

```
ev(id1, 0652,59,44,57,50)
ev(id2, 0702,42,36,40,42)
ev(id3,0712,68,50,65,55)
ev(id4,0804,69,50,66,55)
ev(id5,1050,68,48,66,55)
ev(id6,1156,63,4760,51)
ev(id7,1309,76,48,75,57)
ev(id8,1350,73,45,72,56)
ev(id9,1413,53,43,49,47)
ev(id10,1514,58,46,51,47)
ev(id11,1600,60,46,56,50)
ev(id12,1620,52,38,51,46)
```

The predicate ev parameters are :

- the event's identifier;
- the time of the event;
- the global noise level (in dBA) in the 0-3200 Hz spectrum
- the average noise level (in dBA) in the 0-3200 Hz spectrum
- the global noise level (in dBA) in the 0-1000 Hz spectrum
- the average noise level (in dBA) in the 0-1000 Hz spectrum

We can notice that a lot of acoustics ratios were proposed for acoustic measurments. A synthetic document was written [2] to show them, in order to choose well appropriate.
Remark : In the 0-1000 Hz spectrum, we can observe the two significant wavelets of aircrafts noise.

The "human" database describes persons' activities and felt annoyance.The unidentification of the persons is proceeded thanks to denotations beginning by X.

```
base(Xx,id3, <act(rest),
  win(clos), seen(no),
  ann(medium)>)
base(Xy,id1, <act(rest),
  win(clos), seen(no),
  fly(loff), ann(high)>)
base(Xy,id2, <act(rest),
  win(clos), seen(no),
  fly(loff), ann(medium)>)
base(Xy,id3, <act(rest),
  win(clos), seen(no),
  fly(loff), ann(medium)>)
base(Xy,id4, <act(tv),
  win(clos), seen(no),
  fly(loff), ann(low)>)
base(Xy,id7, <act(air),
  act(rest), seen(no),
  fly(loff), ann(low)>)
base(Xy,id10, <act(air),
  act(manual), seen(yes),
  fly(loff), ann(medium)>)
base(Xz,id4, <act(rest),
  win(open), seen(no),
  fly(loff), ann(high)>)
base(Xz,id5, <act(manual),
  seen(no), fly(loff),
  ann(low)>)
base(Xz,id6, <act(manual),
  seen(yes), fly(loff),
  ann(low)>)
base(Xz,id9, <act(manual),
  win(open), seen(no),
  fly(loff), ann(high)>)
base(Xt,id8, <act(manual),
  seen(yes), ann(medium)>)
base(Xu,id3, <act(rest),
  win(close), seen(no),
  fly(loff), ann(low)>)
base(Xu,id11, <act(tv),
  win(open), seen(no),
```

```
   fly(loff), ann(medium)>)
base(Xv,id3, <act(intell),
   win(open), seen(no),
   fly(loff), ann(low)>)
base(Xv,id10, <act(intell),
   act(manual), win(clos),
   seen(no), fly(loff),
ann(low)>)
```

Remark : the disparity between opinions of residents put trough noise. An event can involve from 1 to 6 annoyance reactions.

Prolog database construction allows us to have the following context :

	Period	NivG	NivM	NivIG	NivIM
id1	am	low	med	low	med
id2	am	low	low	low	low
id3	am	med	med	med	med
id4	am	med	med	med	med
id5	am	med	med	med	med
id6	am	med	med	med	med
id7	pm	high	med	high	med
id8	pm	high	med	high	med
id9	pm	low	med	low	med
id10	pm	low	med	low	med
id11	pm	high	high	med	med
id12	pm	high	low	low	low

	Activity	Ann
id1	rest, win(clos)	high
id2	rest, win(clos)	med
id3	intell, rest, win(open)	med
id4	tv, rest	high
id5	manual	
id6	manual	
id7	plein-air, rest	
id8	manual	med
id9	manual, win(open)	high
id10	plein-air, win(clos) intell, manual	med
id11	tv, , win(open)	med
id12	manual	

The concept lattice contains 123 concepts (thus it's diagramm is not developped here) and constitutes a analysis. Thanks to the knowledge induction mechanism of Formal Analysis, some rules are induced:

There is a very large spectrum of different concepts (the concept lattice contains 123 items) on which we can process a microscopic analysis of the different noise events, their conditions, . Nevertheless, it appears that no significant nor regular macroscopic outline can be formaly derived from this set (nor from the pre-experimental data we collected before the main campaign). derive macroscopic main outlines[2]. This first experimental campaign and its analysis confirmed the results of large scale studies (see next section) according to which in noise/annoyance analysis, no sgnificant feature can be proved. This led us to design a second experiments campaign presented hereafter.
Nevertheless, thanks to the knowledge induction mechanism of Formal Analysis, many contextual rules can be derived, e.g:

$$\textit{Ann(high)} \rightarrow \textit{NivIM(med)}$$
$$\textit{Ann(high)} \rightarrow \textit{NivM(med)}$$
$$\textit{NivIG(high)} \leftrightarrow \textit{Period(pm)}$$
$$\textit{Activ(win(open))} \rightarrow \textit{Ann(x)}$$

This kind of causal relations confirm intuition and the rule generation mechanism stands as a fundamental knowledge mining tool whic has been validated by this experiment.

One of the conclusions of this first experiment relies on the fact that subjective annoyance and its consequences must be differently, objectively and more precisely described if an informative analysis of the effects of noise upon subjects has to be achieved. The idea is to capture annoyance characteristics as measurable features of the cognitive performance of the subject. Thanks to a collaboration with Inserm, we design a second generation of experiments in which discomfort of the subject is considered (and measured) in terms of reasoning ability.

[2]in other words: our data analysis showed that "the signal remains hidden within the ground noise"

4 Cognitive based Experiments

Different studies about annoyance in different airports' vincinities have been carried on; for example, Pr. Coblenz's team from LAA (Applied Anthropology Laboratory, Paris) has been studying the dynamics of the medical acts (i.e: medicaments consumptions, consultations) around Charles-de-Gaulle airport since 1965 [6]. This work allows to conclude that the felt annoyance is sunjective and adaptative: no medical effect can be significantly measured after at least one year[3]. Our results confirms this hypothesis as far as no significant relation can be derived from any analysis based upon the subjective expression of annoyance. Consequently, the expression of annoyance will be described through the decreasing of measurable as a cognitive abilities [1].

This second experimental campaign aims at evaluating the reasonning errors due to noise. In this protocol, after classical neuropsychological tests, the subject has to react to different situations in a dynamic environment [11]. Each test sequence is about 2 hours long. On the one hand, results are processed with statistics models by an Inserm team while on the other hand we use our qualitative approach based on Formal Analysis. The experiments are still going on (from May to September 2000). A first set of results is simplified and presented in this last part of this paper.

The **contexte**:
It's an 5 human subjects observation. There are three age intervals (I1, I2, I3), they can be male (ma) ou female (fe). These persons passed Hanoï Tower test (Ha), Trail Making Test (tmt), Stroop test (Str) during which we measured time. They already passe Wharps test (Wa). The results of the examination can be fail (Fa) or success (Su). Two environments are possible to pass these tests : a quiet one (qu) or a noisy one (no). The data in captured in the following table :

[3] Pr. Coblenz' work allowed to refute many totally biased studies for example trying to state that noise around some US airports had biological consequences upon new born children.

ζ	age	left-handler	sex
Sj1	I1	•	ma
Sj2	I1		ma
Sj3	I2	•	fe
Sj4	I3		fe
Sj5	I3		fe

Personal characteristics of the subjects context.

ζ	Ha	Wa	Tmt	Str	No	SQu
Sj1	70,Su	Su	65,Fa	290,Su	•	
Sj2	100,Su	Fa	64,Fa	350,Fa	•	
Sj3	60,Su	Su	67,Su	300,Su		•
Sj4	80,Su	Fa	70,Su	300,Su	•	
Sj5	65,Su	Su	62,Su	290,Su		•

Subjects ability context.

The context generates 22 **concepts**. The labelled **lattice** is :

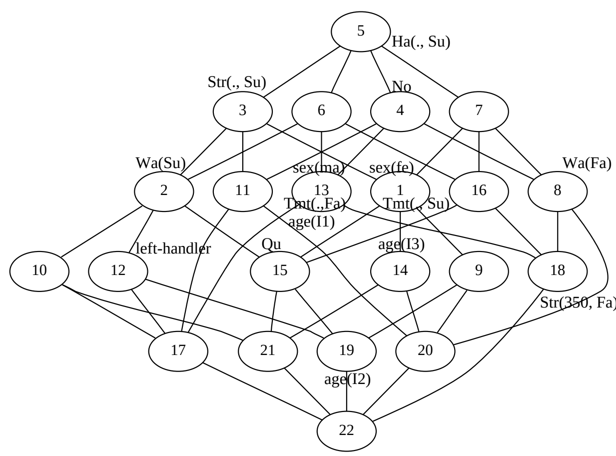

Fig. 4 Lattice

As explained section #2, this lattice allows to formally derive a set of contextual rules. Here, the following relations are proved:

- Rules which express links between ability and noise level:
  Qu $\rightarrow$ *Str(., Su)*
  Qu $\rightarrow$ *Tmt(., Su)*
  Qu $\rightarrow$ *Wa(Su)*
  Str(., Fa) $\rightarrow$ *No*
  Tmt(., Fa) $\rightarrow$ *No*

Wa(Fa) $\rightarrow$ *No*

- Rules which express links between abilities:
  Wa(Su) $\rightarrow$ *Str(.,Su)*
  Tmt(., Su) $\rightarrow$ *Str(., Su)*
- Rules which express links between personal characteristics and ability:
  left-handler $\rightarrow$ *Wa(Su)*
  sex(ma) $\rightarrow$ *Tmt(., Fa)*
  sex(fe) $\rightarrow$ *Tmt(., Su)*
  sex(fe) $\rightarrow$ *Str(., Su)*

Extension: constrained rules production The constrained cubical Formal Analysis, a specific case of Generalised Formal Analysis which is currently under study, allows yet to perform symbolic information and numerical constraints on variable. The following rule can be deduced :

$$Wa(Fa) \rightarrow \{Str(x, .), x \leq 300\}$$

The combination of numerical constraints and logical representation of knowledge is the current research study.

5 Conclusion

If the biological relations between noise and physiological relations are covered by a large amount of studies - thanks to which the various criteria dB, dBA,.. were defined -, the simultaneous analysis of noise and psychological annoyance is little or none formally studied yet. Our approach aims at designing a generic causal model of the correlations between noise and annoyance. Hence, Formal Analysis as symbolic knowledge exploration tool, allows to process the experimental results whithout extra hypothesis. Indeed, if the ability of the persons can be measured as numerical score (duration, rate...), it appears more informative to take into account the symbolic representations of these praxies thanks to the constrained cubes model [10].

Studies are going on about rules production, in order to propose a classification of them. Hence, we will be able to upgrade rules based on a large part of objects and to downgrade rules processed with a objects minority.

From the applied noise/annoyance question, the first experimental campaign confirmed in a symbolic way, the classical results. The second campaign allows to foresee a first set of results of the measurable annoyance in terms of cognitive performance and its comparisons with medical diseases (parkinson) and also mental workload effects.

References

[1] Bayssié L, Boyer M, Chaudron L, and Josette Pastor J. Corrélations entre le bruit et la gêne exprimée en termes de dégradation de performances cognitives. *Proc ERGO-IA*, Biarritz, France, Oct. 2000.

[2] Boyer M. Projet MoCou : Modélisation des couplages systèmes personnes : Eléments de base. Technical Report 1/2615.00, ONERA-CERT/DPRS, Juillet 1999.

[3] Boyer M and Chaudron L. Mocou : Systems/persons correlation modeling. application to noise/annoyance analysis. *Proc HCP'99, European conference on Human Centered Processes*, pp 149–154, Brest, 22-24 Septembre 1999.

[4] Boyer M and Chaudron L. Mocou : Un nouvel outil de modélisation de la gêne sonore. *Revue "Acoustique et techniques"*, , No 18, pp 43–47, Juillet 1999.

[5] Boyer M and Chaudron L. Projet MoCou : Modélisation du couplage personnes/machines. *Proc Actes du III^e Colloque Jeunes Chercheurs en Sciences Cognitives*, Soulac, 26-28 Avril 1999.

[6] Coblenz A and Martel A. Influence du bruit des avions sur la santé des riverains d'aéroports. *Bulletin du CIDB*, , No 69, pp 11–15, 1990.

[7] FAA. Aviation noise effects. Technical report, Federal Avaiation Administration Service, March 1985.

[8] Gaudriot L and Martiant J. Une nouvelle perspective de réduction de la gêne autour des aérodromes : le lampadaire anti-bruit. *Acoustique et Techniques*, , No 16, pp 61–63, Décembre 1998.

[9] Leroux M. Les écrans acoustiques : Perception et représentation des riverains. *Acoustique et Techniques*, , No 16, pp 29–32, Décembre 1998.

[10] Maille N. *Un modèle logico-algébrique pour la fusion symbolique et l'analyse formelle*. PhD thesis, Supaéro, 22 Novembre 1999.

[11] Pastor J, Agniel A, and Celsis P. Artificial reasonners for the cognitive assessment of patients with parkinson's disease. *Proc ECAI'98*, pp 119–123, 1998.

[12] Remy H. Les bruit aérodynamique des avions Airbus : état de l'art et programmes de recherche. *Acoustique et Techniques*, , No 10, pp 12–20, Juin 1997.

[13] Rigaudias J.-B. Les besoins des compagnies aériennes en matière d'acoustique. *Acoustique et Techniques*, , No 10, pp 5–8, Juin 1997.

[14] Valentin G. Ancas, un produit qui fait du bruit pour le réduire. *Acoustique et Techniques*, , No 10, pp 51–52, Juin 1997.

[15] Vallet M. Annoyance after changes in airport noise environment. *Proc Procedings of "INTER-NOISE 96"*, pp 2329–2334. INRETS, 1996.