

GLOBAL STATISTICAL APPROACH TO THE BIRD STRIKE

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This paper has two purposes :

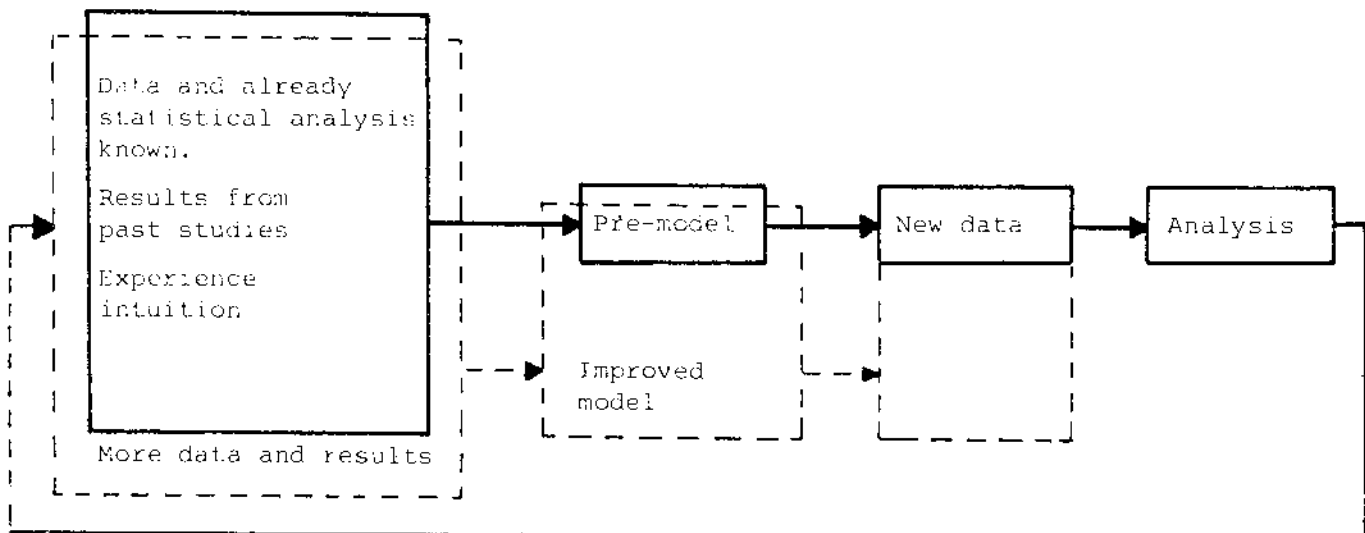
- to deal with a general model of bird strike and to bring up some statistical results from Bird Strike Report forms.

BUILDING THE MODEL

The model given in this part has as an only goal to organize the present knowledge - or unknowledge - of a bird strike.

The previous instrument is a preliminary model, a guide in collecting data. Swallowed and digested by the statistical computing system the data are synthesized to the different levels of interpretation.

The results are then helpful to build a better model. According to the following schema, the model allows to go through the same steps more accurately :



Let us build now a pre-model

The input can be composed of :

- the time
- the localisation (including altitude)
- the meteorology (including visual distance)
- the "biotope"
- ... and so on

The output can be :

- the technical damage
- the drawbacks in planning
- the financial consequences
- the damage to personnel
- ... and so on

without forgetting that not much from the bird is left.

The connection between input and output is now the delicate part of the model. Two types of connections may take place : the short term and the long term connections.

The short term connections are bound to the density of birds and of planes, the directions of flights, and the immediate reactions of the pilot to the bird (bound to the viability) and of the bird to the plane (bound to visibility and to the plane structure).

The long term connections are bound to time and places. Some information is collected by radars a little time before. More information concerning migrations is available a few weeks before. The information concerning local birds has been known for more time. All this data related to the probability of a strike. This probability depends also on the place defined by its geographical co-ordinates for the migrations and by

the biotope for all the migration and local birds.

The pre-model is more precisely developed in mathematical terms in appendix A.

It will be improved by any criticism and by the results of the analysis. Its only use now is to give an answer to the question : which data is needed to verify what ?

GATHERING THE DATA

One has to collect the data needed to quantify the relationships proposed by the model.

One chooses a unit of time (the hour) and a unit of space (a square-mile per hundred feet high).

DATA CONCERNING THE BIRDS

One needs a history of the densities of birds, for each spatial unit and each area .

This enormous mass of data can be reduced to manageable dimensions with the help of sampling and estimations techniques.

DATA CONCERNING THE PLANES

Similarly one needs the history of the activity of planes. One can limit oneself to simplify over space or time, if one selects the same times and spaces as for the birds.

DATA CONCERNING THE EFFECTS

This data is collected in the form of reports. One has to check especially the quality of the data related to the birds.

The remains of the birds are systematically examined by ornithologists. Besides, one could benefit from similar reports when the collisions were avoided by a manoeuvre of the pilot. Besides the extra-information one would get about the presence of birds at that spot at that time, one would find out complementary information about the local behaviour of the birds and about their reaction to the plane configuration.

.../..

ECOLOGICAL DATA

One needs to describe some other aspects of the location : possibilities of resting, of food and of nesting. The daily or seasonal habits of the birds should also be described.

FROM THEORY TO PRACTISE

All these considerations were made from the study of real data. Over a thousand of strikes have been coded, stored on a magnetic tape and analysed with the help of a UNIVAC 1108 computer. The programmes used are written with FORTRAN and as they are of general interest in data management and global statistical analysis they are composed of more than 10 000 instructions. At the time when this paper was written, the results are just arriving. They will be presented at the Meeting. An appendix of more than ten pages results will be given. However, in order to prepare the interpretation of the results, we are going to see the form in which they will be given.

The datas are given by a form written by the pilot. An exemple is given in appendix B, 1121 forms have been feeled up between 1965 and 1973. The forms of last year are gathered and will be soon in the computer.

First, a univariate analysis will be given. As in appendix C, histograms w. ll be given for each parameter. Some arrays will given to ; And, concerning the localization, maps will be outlined by the computer.

But, secondly one should like to know if some variables have joint variations. The results will be given by multi-entry arrays. For example type of plane and location of the strike on the plane.

To analyze such an array, we are going to use the method of "analyse factorielle des correspondances" (1) which is described in appendix D.

It is enough to know that the results will be given on a plan. In the example above, there will be one point for each type of plane and one point for each location. And the types of plane near a point of location are correlated. Such a plan allows to see how the types of plane gather in groups, concerning the question of strike location. (See example in appendix D)

This will be done for any couple of parameters which may have an influence one on the other.

CONCLUSIONS

By comparing among themselves the different results of the univariate analysis, one can bring to light some of the relationships underlined by the model.

By making use of the results of the "analyse factorielle", one can simplify the model by retaining only the significant variables.

Then one puts together the links between variables brought to light by the "analyse factorielle". Some aspects of the phenomenon may remain unexplained that we would like to include into our model. This can necessitate new data.

The model is the present summary of the present knowledge about the problem. That is to say, it is in everlasting evolution, especially when the subject is concerning the living world.

This evolution will be conducted in good condition when exist a narrow collaboration between ornithologists, pilots and operational research specialists.

- A P P E N D I X A -

Time and space are divided in small parts. Each part is homogeneous with respect to all the variables. For example the unit of time be the hour, and the unit of space a square mile by one hundred feet.

The short term :

λ_p be the density of planes of type p (among n_p)

The density is defined as the average number of planes of type p per unit of time divided by the number of units of space contained in the considered area.

λ_b be the density of birds of type b (among n_b)

Same definition as above.

λ_s be the density of strikes of type s (place of the strike on the plane) (among n_s)

Same definition as above.

\mathcal{D}_B and \mathcal{D}_S be the corresponding vectors.

\mathcal{L}_B , $\mathcal{L}_B(\mathcal{D}_B)$ and \mathcal{L}_S , $\mathcal{L}_S(\mathcal{D}_S)$ be the corresponding probability laws.

\mathcal{S} be the set of the statistical laws

\mathcal{R} be the set of n couples or real numbers.

The model is then : $DS = F(DP, DB)$

where F is a vector function of two vectors : $\mathbb{R}^{m_1} \times \mathbb{R}^{n_b} \xrightarrow{F} \mathbb{R}^{n_s}$

or in terms of probability

$$\mathcal{L}_S(DS) = FF(DP, DB)$$

where FF is a mapping

of the two forms vectors into the set of the statistical laws :

$$\mathbb{R}^{m_1} \times \mathbb{R}^{n_b} \xrightarrow{FF} \mathbb{L}$$

If DP and DB are only forecasts, then the model takes the form :

$$\mathcal{L}_S(DS) = \mathcal{F}(\mathcal{L}_P(DP), \mathcal{L}_B(DB))$$

where \mathcal{F} is a mapping of the set of couples of statistical laws into itself :

$$\mathbb{L} \times \mathbb{L} \xrightarrow{\mathcal{F}} \mathbb{L}$$

Not only the densities have an effect on the probability of the strike.

The angle between the flight direction of the bird and the plane, and the immediate reactions of the pilot to the bird and the bird to the plane have also an effect.

Let

θ be the angle between the flight direction of bird and the plane

P be the immediate reaction of the pilot to the bird (which so far is a two state variable : avoidance manoeuvre took place or did not take place).

\mathcal{B} be the probability law of the locus of the strike given a type of bird and a type of plane.

The general form is then :

$$\mathcal{L}_S(DS) = \mathcal{F}(\mathcal{L}_P(DP), \mathcal{L}_B(DB), \Theta, P, \mathcal{B})$$

THE LONG-TERM APPROACH

Some bird density configurations may be projected in advance : either, exactly, some hours (time t_1) before, following some radar observations $\mathcal{O}(t_1)$ for instance, either roughly, weeks in advance (time t_2) (Migratory movements or local movements with same regularity : $\mathcal{O}(t_2)$).

More generally, some information on daily or seasonal movements will be known for all year long : $\mathcal{O}(t_3)$.

The location configuration, defined either by its geographical coordinates G , or by a set of variables pertaining to the environment.

E also is to be taken into account.

$\mathcal{O}(t_1)$ refers to the set of time information known at time t_1 .

G or E define the location.

The model then becomes :

$$DB = F(G \text{ or } E, \dots \mathcal{O}(t_i) \dots)$$

or better

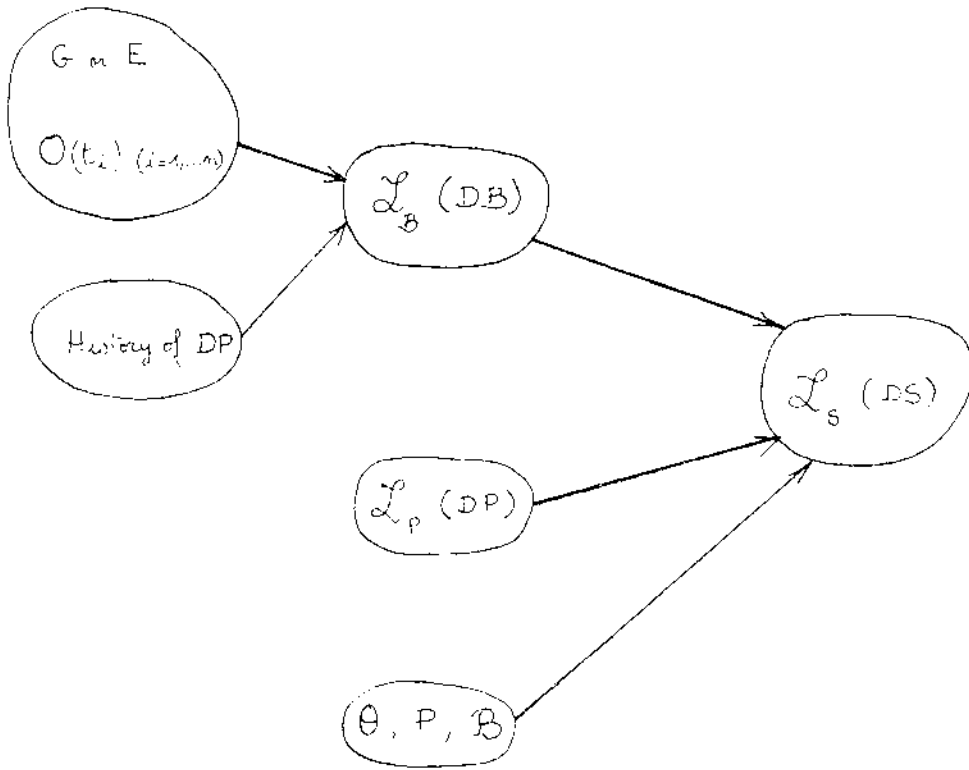
$$\mathcal{L}_B(DB) = \mathcal{F}(G \text{ or } E, \dots \mathcal{O}(t_i) \dots)$$

with \mathcal{L}_B probability law of DB .

It is quite possible that the density of planes has an influence on the presence of birds (influence of DP or DB).

This is called the reaction of birds to the milieu.

Before any verification, the model is presented as follows :



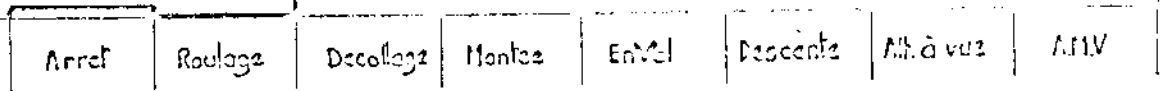
nombre de
missions
1972-73

Frequence (%)

135 67.5

24 12
13 41.5

6 3
4 2
0



PHASE PRINCIPALE DE VOL

SECRETARIAT GENERAL A L'AVIATION CIVILE
Service Technique de la Navigation Aérienne

Le 05 NOVEMBRE 1973 à 1400 heures EXPLOITANT : SAFRAN

TYPE DE L'AERONEF : SAFRAN 340 Immatriculation : FR 100

TYPE D'INSTALLATION MOTRICE : 4 *

LIEU GEOGRAPHIQUE de l'INCIDENT : DEL D'AMSTERDAM

030000

REACT.	<input checked="" type="checkbox"/>
TURBO.	<input type="checkbox"/>
CONVENT	<input checked="" type="checkbox"/>

HC 33 17

ALTITUDE : 0 * mètres * VITESSE : 300 * Kts Km/h

* LIEU	* PHASE DE VOL AU MOMENT DE L'INCIDENT	* CONDITIONS DE VOL	* CONDITIONS ATMOSPHERIQUES
FIR Nord	Roulement au sol	1 FR	Ciel clair
FIR Sud-Est	Décollage	2 VR	Nuageux <u>5/8</u> <input checked="" type="checkbox"/>
FIR Sud-Ouest	Montée	3 MC	Couvert
Côtes	Croisière basse	4 VC	Pluie
Etranger	Croisière haute	5	Neige
	Attente	6	Brouillard
	Descente	7	Jour
	Approche	8	Nuit
	Atterrissage	9	Aube
	Incident	0	Crépuscule

* PARTIE HEURTEE :

INFERA Voiture Pistolet HP Fusil Chasse

GMP Cellule Eject. Charges Equip. Nav. Rad. T. Sin.

OISEAUX Espèces : Grue Noire
Petit Moyen Gros Isolé Volé

* DOMMAGES : Appréhendé

* Blessés Tués Dégâts aux tiers Mat. PLN Changt. moteur Mise HS

* MONTANT DU DEVIS ESTIMATIF en \$

* Observations oiseaux par pilote

* Y-a-t-il eu avertissement de l'ATC

* Y-a-t-il eu manœuvre d'évitement

* Observations impact par pilote

* Impact

* Arrêt moteur : VOLONTAIRE
INVOLONTAIRE

* GMP		* CELLULE	
Réacteur N° 1 G	1	Voiture	1
Réacteur N° 2 G	2	Fuselage	2 <input checked="" type="checkbox"/>
Réacteur N° 3 D	3	Habitacle - Portes verrières - Hublots	3 <input checked="" type="checkbox"/>
Réacteur N° 4 D	4	Gouvernes	4
Réacteur Central	5	Divers	5
Hélice	6		6
Entrée d'air	7		7
Saumon de pale	8		8
	9		9
	0		0

CAS PARTICULIERS :

OBSERVATIONS : Vol de grue noire sur la piste et décollage devant l'aéroport

05 NOV 1973

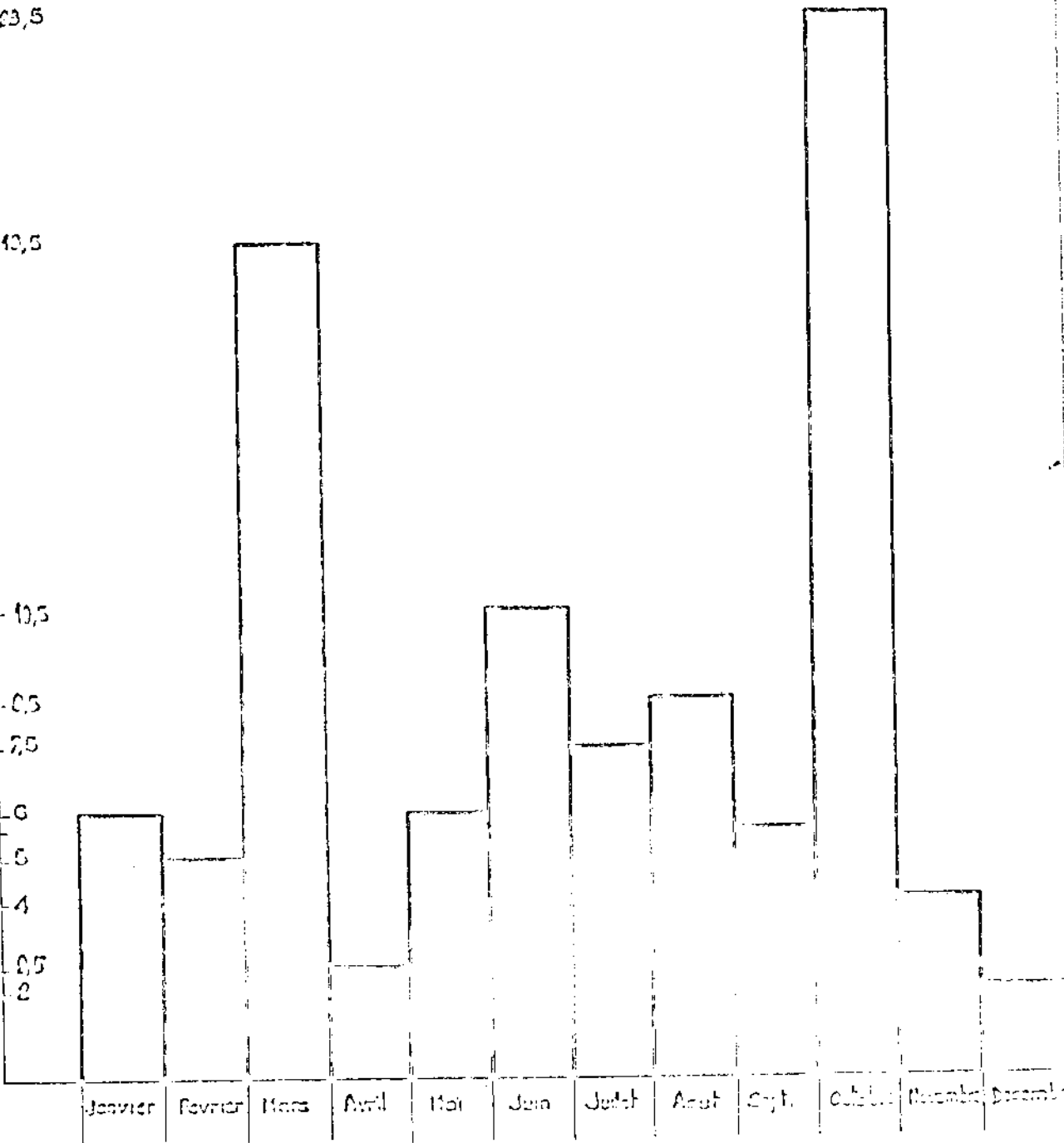
Compte rendu rédigé par :

Fréquence (%)

C - 2

BSCE/10 WP/19
APPENDIX C

23,5
13,5
10,5
7,5
6
5,5
4,2



MOIS

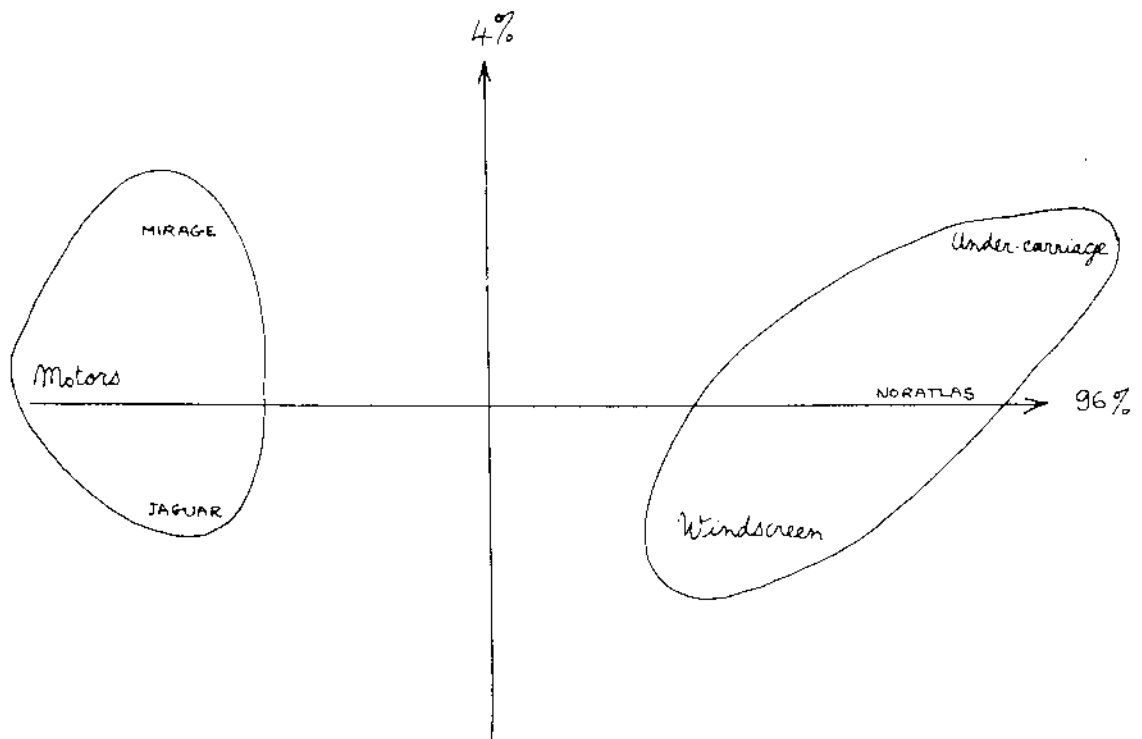
- A P P E N D I X D -

In order to enable to analyze the results presented by the "Analyse Factorielle des Correspondances", here is an example.

The multi-entry array for type of plane and location of strike on the plane may be the following one :

	Windscreen	Motors	Under-carriage
NORATLAS	45	26	67
JAGUAR	24	56	10
MIRAGE	15	60	17

This array may be represented on a plan.



On the plan, the Mirage and the Jaguar are near the motors because in the array most of the strikes for these two planes are on the motors. On the other hand, the Noratlas is near Under-carriage and Windscreen and far from Motors.

This plan where the links between two types of variables (plane, place of strike) are analysed is obtained by the following mean.

Let us consider the three lines :

- Noratlas (45,26,67)
- Jaguar (24,56,10)
- Mirage (15,60,17)

as the coordinates in R^3 of 3 points.

These 3 points determine a plan.

On the other hand, we can do the same with the three columns :

- Windscreen (45,24,15)
- Motors (26,56,60)
- Under-carriage (67,10,17)

are the coordinates in R^3 of 3 points.

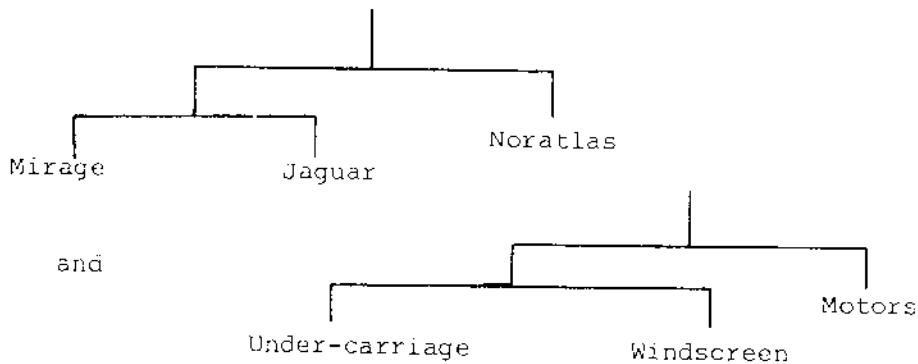
These 3 points determine usually another plan. But the theory gives a mean to obtain the same plan. (This plan is defined by the two first eigen-values of the covariance matrix - see BENZECRI).

On this plan, the theory says that a line, the Mirage for instance, is placed at the center of gravity of the 3 locations of strike, when each one takes the weight given by the array. (15 for windscreen, 60 for Motors, 17 for Under-carriage). The same property exist for the other planes : Mirages and Jaguar are not very far because the relative weights are nearly the same.

The relationships between planes and places of strike appears more clearly.

In this example, the array is small and a quick recognition is possible on the figures. But in big arrays, it is more difficult, at least impossible to see the links in the array. The preceding method can be used. Except that in general, many points are not on a plan. In this case, the theory (and computer) give the plan on which the projection of the points are the more spread. In other words, it is the plan on which the projections are still grouped in the way the corresponding points are in the space. The percentage of information kept is given by the two first eigen-values of the covariance matrix.

When this percentage is low (under 50 %) the groups of projections do not reflect very well the groups of points. A hierarchical taxonomy will give us the groups. In the preceding example we would have



The groups appear clearly.

Most of the results will appear in this form. This example is here, in order to help their reading.