Proceedings of ICAD2006
4th International Conference on Axiomatic Design
Firenze – June 13-16, 2006
ICAD-2006-17

AXIOMATIC FRAMEWORK APPLIED TO INDUSTRIAL DESIGN PROBLEM FORMULATED BY PARA-COMPLETE LOGICS APPROACH: THE POWER OF DECOUPLING ON OPTIMIZATION-PROBLEM SOLVING

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ABSTRACT

A primary "must" of axiomatic design theory is the first axiom, stating that independence of functional requirements (FRs) should be maintained throughout the design process.
Para-complete logics, such as Fuzzy logic, give us a powerful instrument to express "mathematical/functional" interaction between FRs and DPs (Design Parameters), especially when this interaction cannot be expressed by a precise "mathematical function (i.e. the case in which we want to express several data from VOC (Voice of Customer) investigation, building a FR for a defined design performance), and so can be codified only using "Linguistic variables".
Para-complete logics, among which the Fuzzy logic is, for us, the most powerful, violate the principle of the excluded third party, so that the effects of DPs' changes on the same FR can be considered partially independent each other.
Recent paper investigated changes in Decoupled Design's concept when para-complete logics are applied in FRs-DPs link definition and evaluated, using an example, the impact of decoupling capability of designer using composition rules on FRs, in order to make the design matrix diagonal or lower triangular by decoupling effects of several DPs on different FRs using Fuzzy formulation.
In this paper that kind of approach is extended to optimization method; in this paper we want demonstrate how is possible, using Fuzzy formulation and respecting the first Suh's Axiom, to elaborate a simple optimization routine based on variation and bounding of DPs values in given ranges.
Using that method, Defuzzyfication of DPs for Design optimization will become very simple. A new practical optimisation sequence will be explained.

Keywords: Axiomatic Design, Para-complete Logics, Design Optimization, Fuzzy Set

1 INTRODUCTION

With increasing demand for shorter development time and higher quality, design effectiveness has received growing attention from both academia and industry. In industry, unsatisfactory design results in a great number of process iterations, so improving the effectiveness of design, is crucial in order to shorten product development time and lower costs. The goal of effective engineering design is to *minimize unnecessary process iterations*. To reduce the probability of design failures, systematic approaches have became the trend to efficiently realize designs in recent decades.

Since 1990 the research Group of University of Salerno, headed by Prof. Michele Pappalardo has introduced the Systematic approach to Design in Mechanical Engineering, especially using Para-complete logic approach and Entropy based approach. The Axiomatic Design (AD) method proposed by Suh (1990) represents, for us, a powerful approach that provides a systematic guideline for evaluating the acceptability of designs, so we have imagined to use that approach in Concept Design phase, and support it, in Independence and Information evaluation, using, for example, the Fuzzy logic (a special Para-complete logic by L. A. Zadeh).

That approach would be very useful when designer has to work with large and complex systems, in which several kinds of couplings are still considered acceptable in practice. This is due to the fact that some couplings are weak and have little influence on the design outcome, so that they can be ignored, in particular conditions, in order to proceed with fewer interactions, thus expediting the design process.

Less influencing elements are often very difficult to be individuated and quantification of the error magnitude, when we don't take them into account, is too much difficult. In this paper we will show how the use of Fuzzy function can help us to optimize Design Parameters to obtain a better design.

We've yet demonstrated (Cappetti, Naddeo et alii, ICAD 2004) that the FR value associated to a DP domain value, by membership function, can represent the agreement value (also called agreement index) and so the quantification, in Fuzzy domain, of the overlap between design range and system range.

The application of dependence concept, evaluated, for example, by Fuzzy logic, allows to operate with a rigorous method, if possible, in order *to optimize coupled design* for which is impossible to define an uncoupled or a decoupled version. The method explained allows to improve the design objective simply evaluating good constraints for Design Parameters.

We've also demonstrate (Naddeo, Pappalardo, Cappetti, IPMM 2005) that we can use the **α-level cut** in order to optimize a single parameter because it allows to enlarge or limit DPs limits, *choosing a different approximation level.*

In this paper we use the last work's results to create a simple optimization method for choosing best Design.

We just want to remember that when we make a Fuzzy formulation, we can quantify the Information content of a design solution using the membership values as the quantification of common range between probability distributions, so evaluating the project also by second axiom (Naddeo, ICAD 2004).

That kind of approach (information based) will be used to evaluate the best solution, in optimization process.

2 LOGICS AND AXIOMS IN DESIGN

Several methods were studied for helping design choices in concept design, and several mathematical instruments are useful for that topic. In University of Salerno an approach based on the use of Design Axioms and Para-Complete Logics was experimented for design problems as explained in following paragraphs.

2.1 AXIOMATIC DESIGN

Motivated by the absence of scientific design principles, Suh (1990, 2001) proposed the use of axioms as the scientific foundations of design. Out of the twelve axioms first suggested, Suh introduced the following two basic axioms along with six corollaries that a design needs to satisfy:

Axiom 1: The Independence Axiom

Maintain the independence of the functional requirements

Axiom 2: The Information Axiom

Minimize the information content in a design

In axiomatic design approach, the engineering design process is described in Figure 1, in which the array of functional requirements *(FRs)* is the minimum set of independent requirements that completely characterizes the design objective based on customer attributes (*CAs*). Design is defined as the creation of synthesized solution to satisfy perceived needs through the mapping between the Functional Requirement (*FRs*) in the functional domain and the Design Parameters (*DPs*) in the physical domain and through the mapping between the *DPs* and the process variables (*PVs*) in the process domain.

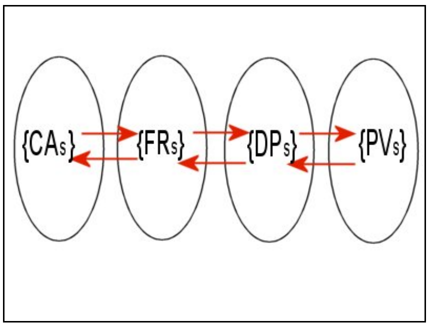


Fig.1 Axiomatic Framework

The physical and process mappings can be expressed mathematically as

$$\{FR\}_{mx1} = [A]_{mxr} \{DP\}_{rx1}$$
$$\{DP\}_{rx1} = [B]_{rxn} \{PV\}_{nx1}$$

where $\{FR\}_{mx1}$ is the vector of independent functional requirements with *m* components, $\{DP\}_{rx1}$ is the vector of design parameters with *r* components, $\{PV\}_{nx1}$ is the vector of process variables with *n* components, ***A*** is the Physical Design Matrix, and ***B*** is the process Design Matrix.

For our purposes, the mapping process can be mathematically abstracted as the following matrix equation: $\{FR\}=[A]\{DP\}$, where ***FR*** is the array of *FRs*, ***DP*** is the array of *DPs*, and ***A*** is the Design Matrix that contains FRs-DPs relationships. Axiom 1 states that the design parameters (*DPs)* and the functional requirements (*FRs)* have to be related such that a specific *DP* can be adjusted to satisfy its corresponding *FR* without affecting the other functional requirements, which will require that ***A*** should be either a diagonal matrix or triangular matrix.

After satisfying the Axiom 1, design simplicity is pursued by minimizing the information contents per Axiom 2, where the information content is defined as a measure of complexity. One popular measure of information content is *entropy* (Shannon 1948). FR entropy is related to the probability of satisfying its specification in the physical mapping (the *DP* in the process mapping).

Entropy and Information content can be mathematically expressed in different ways; the more useful measures are those that evaluate the probability of meeting design specifications, which is the area of intersection between the *design range* '*dr*' , (design specifications) and the *system range* '*sr*' , (process capability). The overlap between design range and system range is called the common range '*cr*'. The probability of success is defined as the area (probability) ratio of the common range to system range, i.e. the common measures are based on the logarithmic function: in probability the information related to an event of probability *p* is $I = log_2 (1/p)$; on that concept we will base our Information content evaluation [Donnarumma, 1997].

When we formulate the Information Content for the Fuzzy Design approach we can declare that its measure is based not only the "process capability", but also on the "agreement index" that express how much a DPs value has the capability to achieve a desired FRs value.

The concept of "agreement index" plays a fundamental role in our method because of its relation with probability concepts.

2.2 FUZZY-ANALYSIS FUNDAMENTALS

Linguistic inexactness (imprecision) is the most common feature of many real life situations. Dutta (1985) classifies imprecision according to its source: measurement, stochastic, ambiguous definitions, incomplete knowledge, etc. In decision making, for example, the usefulness of mathematical algorithms is in having clearly defined objective criteria and constraints for evaluate the Information content.

In the early phases, a design is a collection of scattered conceptual thoughts and rough drawings. The difficulty in design problem formulation often has in establishing precise objectives, constraints as functional requirements which are uncertain, do not fall between what we consider as definite and precise.

All Design matter is not deterministic, but has to be used to make deterministic assertion and to take deterministic decisions.

The first used approach is the use of probability theory to handle randomness.

In customer oriented design, customers have wants and needs that are hard to interpret. They are expressed, linguistically, using terms which have no precise definition. A statement is not always right or wrong; in such cases solution can be found using the logics that violate the principle of the excluded third party, like Fuzzy logic.

The dichotomous property is the basis of classical set theory but we cannot use it because, for complex systems, a property may be viewed as a *continuous measure* of some *possibility distribution.*

The Fuzzy logic, based on L. Zadeh theory [1965-1974], allows to express in mathematical terms several not precisely defined concepts; unlike of binary logic, that logic does not require that a proposition assumes a defined truthful value, true or false, but allows to assign a membership value (between 0 and 1) to its truthfulness. Generally we can declare that an element satisfies a requirement [Klir, 1995] even if this requirement has a not clearly meaning, giving to it a membership value in the range $\{0 - 1\}$.

An example that may be used to facilitate the fuzzy concepts is as follows. Assume that there are 3 design proposals (solution entities); say the crisp set C (C1, C2 and C3).

We would like to select a solution entity at random from C. The probability distribution in this case is:

$p(\{C1\}) = p(\{C2\}) = p(\{C3\}) = 1/3$.

If we were asked to select randomly a successful creative design, we can’t use the probability distribution above because of the fuzziness in the word ‘successful’. The answer is in defining ‘design solution’, say Y, as a variable that takes in values in the set S, according to a probability distribution constructed around the proposition “Y is successful”.

A fuzzy set accepts objects with certain degree, the so called membership function (Zadeh 1965). The fuzzy set A is represented as:

$A = \{(FR, \mu_a(FR)) / FR \in FRs\}$ with $m_f(FR)$, understood to represent a mapping of membership of

$$FR, m_f / FRs \longrightarrow [0,1], FR \longrightarrow m_f(FR) \qquad (1)$$

It is understood that in the crisp case, $\forall FR \in A$, $\mu_a(FR) = 1$ and zero otherwise. Every mapping of this nature with some conceptual realization (in alignment with intuitive semantics of imprecise description of FR) is a fuzzy set. For example, FRs can be the universe of fuzzy functional requirements, such as stylish, cheap, convenient, etc.

In Design process, it’s very important to underline the key role of mapping process between what we want to achieve and how we want to achieve it: using that definition we can declare that Design problem formulation starts from Functional requirements (FRs) and Design parameters (DPs) identification.

The Fuzzy logic approach helps designers to identify the relationship between FRs and DPs, to formulate a judgment on several design hypothesis and compare different concept design solutions each other, putting into account exact, not precise and not quantifiable requirements, thanks to the formulation explained in (1).

The concept of membership function plays a key role in that approach: FRs can be correlated, by membership function, to DPs that characterize the project while FRs for a project’s “element” can be decomposed into simple ones (sub-requirements) directly depending from design parameters; this operation allows to decompose complex property, associated to a requirements, in simple ones, and to combine each other by fuzzy membership function composition laws [Scott-Antonsson, 1998].

In our approach, defined for Mechanical Design, but extendible to all Design problems, we’ve to define the Design Goal through all requirements opportunely weighted or composed by simple rules. Those rules can be combined each other in order to create an Objective Function (OF) that provides all design aspects. The design process finishes with the formulation of several design hypotheses.

Each hypothesis is evaluated and makes a score defined by the final composition rule. The score expresses the membership value to the chosen objective; the best design solution will be naturally chosen among ones which have the best score [Antonsson, 1992 - Naddeo, 1999].

After the complete characterization of the design problem, by identification of FRs and DPs, the second, and most important step of fuzzy formulation, is the Fuzzyfication of the problem, and so the definition of the membership functions (m_f) and of the evaluation rules.

There are a lot of papers in literature dealing with membership function definition [3, 11, 21], their construction and methods of composition; for our application we will use several simple *mf* such as triangular, trapeziform and based on simple mathematical function, for evaluating quantifiable parameters, while, for evaluating several not quantifiable requirements, we will use the “one expert direct method”; for the last one we need to give to readers a brief explanation:

“One expert direct method” allows to directly assigning a membership value for each of examined alternatives, in comparison with other methods that indirectly (by membership function) make this operation [Donnarumma, 1997 - Naddeo, 2001]. The first step for that method is the interview with an expert that gives a judgment for each design solution; after that, his evaluation is expressed in terms of adjectives (that modify the truthfulness value of a proposition) or by collocating the alternative in a predefined list, in which several kind of judgment are provided. Finally, for each alternative, the judgment is transformed in membership value by using a table of predefined correspondence judgment<–>value.

Once the membership functions are defined, they have to be combined by composition rules; some of these are: minimum rule, maximum rule, arithmetical average rule, geometrical average rule. The first of those is applied in evaluating requirements that have to be necessarily satisfied, and assigns, to requirements, minimum of obtained scores among all; the second is applied especially when at least one of the requirements has to be satisfied, and assigns to element the maximum among scores; arithmetical average is applied when requirements interact each other compensating themselves, and assigns to the element a score calculated as weighted average of several requirements scores; geometrical average is applied when every judgment on design's requirement makes worse the final one.

That rules are used to define the Objective Function for evaluating the Designs' hypotheses.

Finally the Design Problem requires a Defuzzyfication, in order to extract the physical values of DPs from Fuzzy formulation.

3 USING MEMBERSHIP FUNCTIONS TO DEFINE THE DESIGN MATRIX

When we have to choose among several different design solution, it's very useful and interesting to measure the accordance of a design solution to the FRs' set using a membership value (typical of Fuzzy approach); that's approach is suggested especially when we consider FRs that suffer the user's or customer's subjectivity ("a car has to be capable to move itself" is a proposition that express an objective FR while "a car-seat has to be comfortable" express a subjective FR).

Both the objective FRs, that can be often mathematically codified, and the subjective one, can be built like a Fuzzy membership function. If we, for example, think about a simple problem in which three FRs and three DPs are involved, we can imagine that a Design Matrix is expressed as follows:

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{Bmatrix} = \begin{bmatrix} 0 & X & X \\ 0 & X & X \\ X & X & X \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{Bmatrix} \qquad (2)$$

In that case Design matrix is evidently coupled.

Now we've to make a more deepened consideration on FRs and on DPs in order to understand the "relevance level" of the impact of a variation of Design Parameters on different FRs and how our coupled Design can be decoupled.

We've demonstrate in a past paper (Naddeo, 2004) that if we can select a particular sub-domain (in DP functional domain) in which we can choose a DP value without affecting the FR value, the coupled design problem becomes a *well-constrained decoupled design*.

It's necessary to establish a coupling measure that allows to evaluate also not numerically quantifiable parameters (i.e. some expressing aesthetic characteristics).

Necessity to evaluate not quantifiable parameters makes indispensable to use a methodology based on a logic system that, using the linguistic or the comparative approach, allows to do that.

The first step, starting with Fuzzy approach, is the detailed analysis of the relationship between FRs and DPs for evaluating the "satisfaction" value of the proposition "the FR_i is satisfied" for each FR, on the DPs domain. The satisfaction value can be expressed by the value of membership, whose meaning was before explained, to the Fuzzy set individuated for the evaluated proposition.

Our coupled design matrix, expressed using membership function, becomes the following:

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{Bmatrix} = \begin{bmatrix} 0 & 1-mf_{12} & 1-mf_{13} \\ 0 & 1-mf_{22} & 1-mf_{23} \\ 1-mf_{31} & 1-mf_{32} & 1-mf_{33} \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{Bmatrix} = \underline{MF} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{Bmatrix} \qquad (3)$$

If a weak-dependence between a FR and a DP exists, it's expressed by a mf_{ij} like a trapezoid one, for which the "satisfaction range" is wider when the dependence between FR and DP is lower. A typical membership function is expressed, for example, by the following fig. 2.

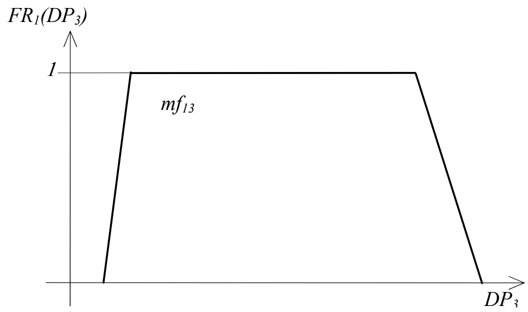


Fig.2 - mf_{13}: Membership function that express the satisfaction of FR_1 on DP_3 domain

It's now evident that since mf_{ij} are defined, we have quantified the dependence between DPs and FRs, but we can encounter three kinds of possibilities:

- when a mf_{ij} has a value identically equal to zero (0) then the FR_i cannot be never satisfied, so we've to redefine the DPs values;
- if a DPs range for which the membership function is equal to one (1) exists, then the correspondent member of the design matrix became zero: that value means that we can choose, in that range, what value we want for DP_i without affecting the $FR_{k\neq i}$ eventually DP_i dependent;
- if mf_{ij} has a value too different from 0 or 1 we come back to the original coupled design matrix.

4 α-CUT AND DECOUPLED DESIGN

The use of membership function, as described in the last section, allows to individuate some constraints on DPs' values in order to reduce the coupling level of the design. That thing is really possible only if several common values' ranges for DPs, in which more than one FR is satisfied, exist; into those ranges we can identify a sub-range in which more than one FR reaches a very good agreement level. It's also real that if those sub-ranges don't exist, the design problem maybe not-solvable.

The method that allows to constraint DPs seems to be not always employable because we cannot say that a good sub-range of the useful range always exists. The Fig. 3 shows three membership functions that drive to maximum satisfaction of three different FRs for 3 different, and not superposable ranges of the same DP: choosing a good value for one FR automatically penalizes the satisfaction level of at least one (but in our case, of both) FR; that condition represents the worst case with the maximum value of coupling level.

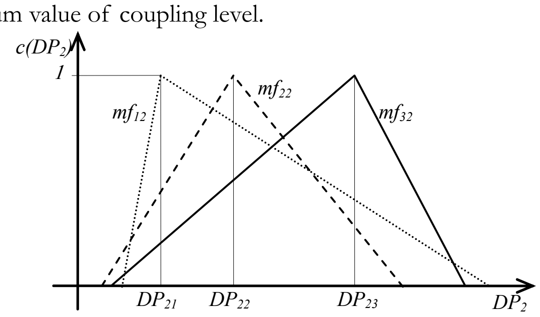


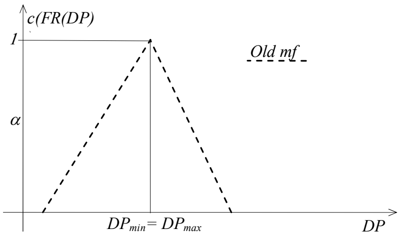
Fig.3 *m.f.* FRs-DPs

From Fig. 3 it's evident that variation of DP_2 value causes a change all the FRs' values of satisfaction, depending from the slope of the triangles chosen as membership function (a typical Fuzzy Function's shape) or generally from the tangent to membership functions' representation curves: we can say that generally a DP's value that optimizes all FRs can exist.

We can now imagine to ask to designer to set a maximum value of "*tolerances on satisfaction*" of Functional requirements, hoping that the enlarging or the reduction of FRs' domain (DPs value) involves a new decoupling condition as described in the previous sections.

Researchers can make an objection to that kind of method because it's yet difficult to write a good membership function that faithfully reproduce a judgment, and, in that function, an approximation always exists; therefore the "not-expert user" often gives to the membership function the same domain range, causing an advantage of some mf_i on others.

Values given to membership function suggest the satisfaction level of several functional requirements; when a designer chooses to accept a value less than 1 (one) he knows to accept a configuration that is not the optimal one, implicitly accepting the concept of "tolerance on satisfaction". If a designer chooses to accept, as having a very good satisfaction, all solution with $c(x) \geq \alpha$, in which α is a pre-fixed value, we can asset that FR is independent from DP in the range in which $c(FR(DP)) \geq \alpha$, so implicitly we're accepting a maximum error equal to $(1-\alpha)$; this operation will be named "“complementary α-cut operation”.



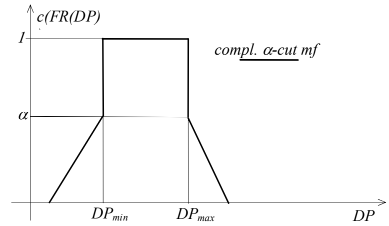


Fig.4 – Complementary α-cut

Fig. 4 shows how we can modify a membership function, that expresses a generic mathematical link between a DP and a FR, and how we can give the same satisfaction value, equal to 1 (one) in the range in which FR is independent from DP.

During the development of a Fuzzy codified Design, we can operate on membership function using a tolerance value, equally distributed and applied on all mf_i in order to decouple the design matrix and to individuate the right sequence of variables optimization.

Obviously we can use the same Optimization method also when we meet more difficult and complicated membership functions' shapes.

5 DESIGN OPTIMIZATION IN COUPLED, DECOUPLED AND UNCOUPLED DESIGNS

Now we can explain how to apply the concepts recalled below in order to develop an optimization procedure.

5.1 UNCOUPLED DESIGN CASE

When we deal with an uncoupled design defined using a Fuzzy approach, we can find this kind of problem:

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 \\ 0 & X & 0 \\ 0 & 0 & X \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{Bmatrix} \quad (4)$$

When this configuration is available, we can express each FR-DP link using a function defined like:

$$X = 1 - mf_{ii} \quad (5)$$

In which mf_{ii} is the membership function that links the FRi to the DPi; in 2004 Naddeo's paper it's demonstrated how we can use the second Suh's Axiom to define a simple rule to individuate the best Design among several based on the same design structure; after we've defined a composition rule for membership function, to define an Objective function, we've to apply a maximum search method in order to understand which are the best value in DPs' domains to reach the best value for Information content (the lower).

In case of Uncoupled design we're sure that variation on a DPi' value doesn't affect membership values of the other $FR_{k \neq i}$.

We've to underline that an uncoupled design, defined by Fuzzy approach, is very uncommon to be found.

5.2 DECOUPLED DESIGN CASE

In decoupled design case, optimization routine can be based on decoupling sequence: we’ve, first of all, to arrange the Design Matrix in order to obtain a matrix like the following:

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 \\ X & X & 0 \\ X & X & X \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{Bmatrix} \tag{6}$$

In this case we can choose among two different ways to make the design optimization; the first one doesn’t introduce any kind of approximation while the second one is based on the introduction of what we’ve called a “tolerance on satisfaction” in par. 4.

First method is based on re-arrangement of the Design Matrix: when we arrange a design matrix in order to obtain a lower (or upper…is the same) triangular matrix, we automatically find a solving sequence to find design solution. If we want to find the optimal design solution when Fuzzy approach is used, we’ve to find, using the second Axiom, the one that has the lowest information content; to do that, we’ve to define the composition rule for obtaining the Objective Function, we’ve to define the “information composition rule”, using results of [14] and then, starting from solving the first row of Design matrix, we’ve to find the value of each DP, with a maximum search routine, that minimizes the information contents; after the first row is solved, we’ve to use the value of found DP_1 in the second row, in order to find the best value for DP_2, and so on.

Second method is based on the introduction of “*tolerance on satisfaction*”, using the complementary α-cut, whose mean is explained in [2].

For example, in Fig. 5 we’ve defined three FRs depending from one DP; we can easily underline the necessity to stay in the range between DP_{min} and DP_{max} in order to have values different from 0 for all three FRs, for a chosen α value. A very high value for α parameter doesn’t change the optimization range, while if we accept a lower value for α parameter, we can move in a new range [DP_{Imin}, DP_{Imax}] in which values for mf_1 and mf_2 are equal to one and mf_3 can be optimized. So accepting a tolerance we can reach the following results: “mf_1 = mf_2 =1 = maximum value” and mf_3 can be optimized using a "max-search" routine, optimizing the information value.

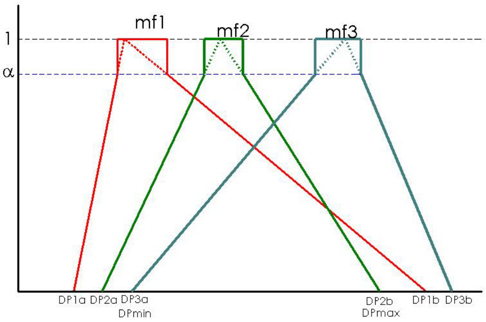


Fig.5 - *membership functions* and complementary α-cut

At this point we will find an uncoupled design in which we’ve introduced a known “tolerance” on satisfaction.

When we use this kind of approach we can optimize this approach using different tolerances for different FRs.

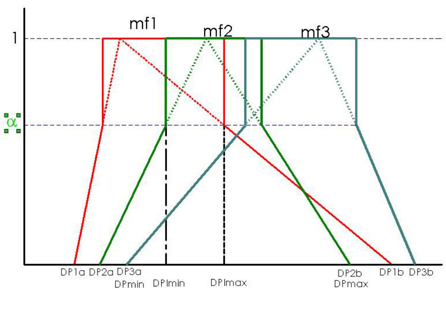
If we’ve a Design matrix like (6) we can choose the raw from which we want to start applying the tolerance, among the second and the third one; a sequence of choice can be the following:

We have to

1) individuate and design the membership functions;
2) define several different acceptable levels of tolerance;
3) apply complementary α-cut for the chosen tolerance levels;
4) find of DPs’ domain in which new mf_{ij} values are equal to one;
5) find the best DP value that optimize all design information content (using the first method approach);
6) find the best solution among ones with different “satisfaction tolerance” level: the best solution will be the one with the higher value of α and so the lowest “accepted tolerance”.

That kind of procedure allows us to define a right sequence of optimization of FRs and so optimize the whole design.

Using this method we can play on satisfaction levels to reach a very good design, introducing a chosen value of tolerance.



5.3 COUPLED DESIGN CASE

A coupled design can be treated like a decoupled one, but only with the second method.

6 CONCLUSIONS

Design Axioms are a very useful method to approach the choice problems in technical field, and mainly in design problems.

A good Axiomatic approach depends on the experience and knowledge of designer: a unique approach to technical problems doesn’t exist!! The best method seems to be the alternation of phases in which designer chooses independently Design Parameters and Functional Requirements, and arranges them using a Design Matrix; that approach often (always!!!) leaves the design coupled.

We've shown how Fuzzy Logic use can be integrated in Axiomatic approach and used to render explicit the FR-DP link using membership functions: FR value associated to a DP domain value, by membership function, wants to represent the agreement value (also called agreement index) and so the quantification, in Fuzzy domain, of the overlap between design range and system range.

We've also demonstrated that the use of a tolerance on satisfaction, expressed as what we've named "complementary α-cut", allows to define an optimization procedure that permits to individuate the most important (most affecting) DP for each FR and to optimize it.

The optimization method is always based on the use of second Suh's Axiom and a Para-complete Logic approach allows designer to define Information content using the concept of "Information in Metric Space" [30] like an extension of theory of information in probability spaces.

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