The Iterative Nature of the "Zig" and How to Define the "Hows"

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Abstract. The AD's design equation depicts the relationship between the functional requirements (FR) and the design parameters (DP) by the design matrix (DM), through a unique zigzag decomposition path. At the "zig part" of each level of the zigzag decomposition, the designer needs to find out the DPs that can fulfil the given FRs. This paper proposes that the designer has to perform three main actions in a zig process in order to define the design equation: to define the DPs at a nominal condition and its magnitude; to evaluate the interactions of the DP with the system at actual conditions; and to check back the set of FRs verifying if they fit inside the design range. The purpose of this paper is to illustrate the actions performed on a zig, emphasising the changes that may occur in the arrangement of the design during the synthesis of the DM at any level of the decomposition. At each level of decomposition, the estimation of the DPs that fulfil the FRs allows the designer to define a subset of the DM, making it possible to evaluate afterwards the DM with all the interactions of the system. Moreover, in what concerns to the information content, it is possible to evaluate the probability of success of the system taking into account the interactions of the system and the tolerances of the DPs. This paper presents an example regarding the evaluation of the DM using the equations of the design for a variable air volume (VAV) air conditioning system.

1 Introduction

Nam P. Suh described in his book, "The Principles of Design" [1], the Axiomatic Design (AD) theory, stating that there are rules to do a good design.

AD defines the design in four domains, the Customer, the Functional, the Physical and the Process Domain, as depicted in Figure 1. Moreover, a design is subjected to Constrains (CS) not depicted in the figure. A mapping process allows reaching the image of a domain in the next adjacent domain in a sequence of decisions. Reaching the last domain, the process flows to a lower level, decomposing the elements already defined. Therefore, the hierarchical decomposition of the elements of a domain interconnects with the previous level of the adjacent domains. This is the so-called zigzag process: zig when going from one domain to the adjacent domain at the same level of decomposition; zag when returning back to the previous domain reaching a lower level of decomposition.

The middle relationship is the turning point of the engineering work on design, as it connects the Functional Domain to the Physical Domain.

The Functional Domain contains the functional requirements (FR), that expresses "what we want to achieve?", and the Physical Domain the design parameters (DP), or "how we will achieve it?".

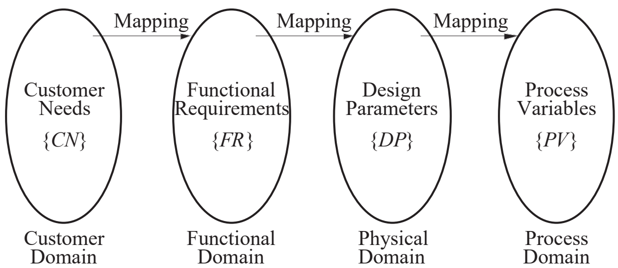

Fig. 1. The design domains.

Equation 1 expresses the result of the mapping between the FR and the DP domains, where $[A]$ is the design matrix (DM), and FRs and DPs are vectors expressed in the design equation by curly brackets.

$$\{FR\} = [A] \cdot \{DP\} \tag{1}$$

According to AD, a good design has to follow two axioms, the "independence axiom" and the "information axiom". The first axiom states that a good design is uncoupled or decoupled, the former having a diagonal design matrix and the latter a triangular DM. The information axiom allows to choose the design with the higher probability of success between a set of possible solutions.

The design equation may cause to a beginner a first feel of easiness of the AD theory, which in turn may jeopardise the result of his design.

The aim of this paper is to help performing the zig process between the Functional Domain and the Physical

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Domain, highlighting a way to help achieving the Equation 1.

The apparent simplicity of AD has a meaning. Karl Popper said that the simplest theories have a great advantage: "Simple propositions should be more appreciated than the less simple ones because they tell us more, because their empirical content is greater; and because they are better testable" [2, p. 155]. Accordingly, it is likely that a large number of authors developed, articulated and interrelated AD to other theories.

Next subsection briefly describes some major contributions on the development of AD, starting by emphasizing the way the tasks that a zig needs.

1.1 Literature review

The zig is a synthesis process that involves "reasoning operations, decision process, and selection methods" [3]. On the other hand, the hierarchical decomposition in each domain is an analytical process. The zig process corresponds to the process that flows from "what" to "how". The hierarchical decomposition includes a reverse process, the zag that flows from "what I achieved" to "why" [4].

D. Tate proposed a "roadmap of activities in decomposition" concerning the process of the zig [5, p. 42] and the process of zag [5, p. 40]. Figure 2 depicts the diagram proposed by D. Tate for the zig process, showing two main tasks: "defining and selecting sub-DP", and "setting DP parameter values".

This diagram shows that failing to achieve the appropriate definitions for the DPs during the decoupling, or failing the optimization process, one has to go back in the design.

The theoretical developments on AD of the last years mainly focus on the following subjects:

• AD principles and the market;
• Mapping between the Customer Needs (CN) and the Functional Requirements (FR);
• Nature of FRs;
• Design equation and the design matrix;
• Nature of information and the computation of the information content of a design.

Regarding the market Masayuki Nakao presented a surprising conclusion. In AD a good design is uncoupled or decoupled, which is a "superb effort of innovation", leading to simple artefacts that work correctly [6]. Anyway, there is a weakness in good designs: they are easy to copy by the competition [6]. He argues that to stay in the market, the design should hide some FRs, while concealing in unopened areas the matching DPs. Furthermore, some effective applications might be coupled in order to avoid antagonistic entities to replicate the solution of a design [7].

To do a design accepted by the market the design team must start by defining the customer needs. Theory of Practices is a theory of the social sciences that allows identifying the components of a practice, namely the materials, meanings and competences. The elements of Theory of Practices have a close relation to the CNs and the FRs, helping to define the mapping between the Customer Domain and the Functional Domain [8].

The Customer Domain includes the needs of all stakeholders that interact with the product under design during its lifecycle. After identifying the needs of the stakeholders, it is possible to define the requirements of the product, respecting the constrains of the design [9].

The success of a product in the market depends mostly on the mapping between the CNs and the FRs. As stated by Suh [1, p. 29] "… the final design cannot be better than the set of FRs that it was created to satisfy". As a matter of fact, in a survey during the period of 2008 to 2009, to 475 everyday products with a ward of good design in Japan, it was found that "20% of all the products" creating "excitement beyond imagination" had special FRs or DPs [10].

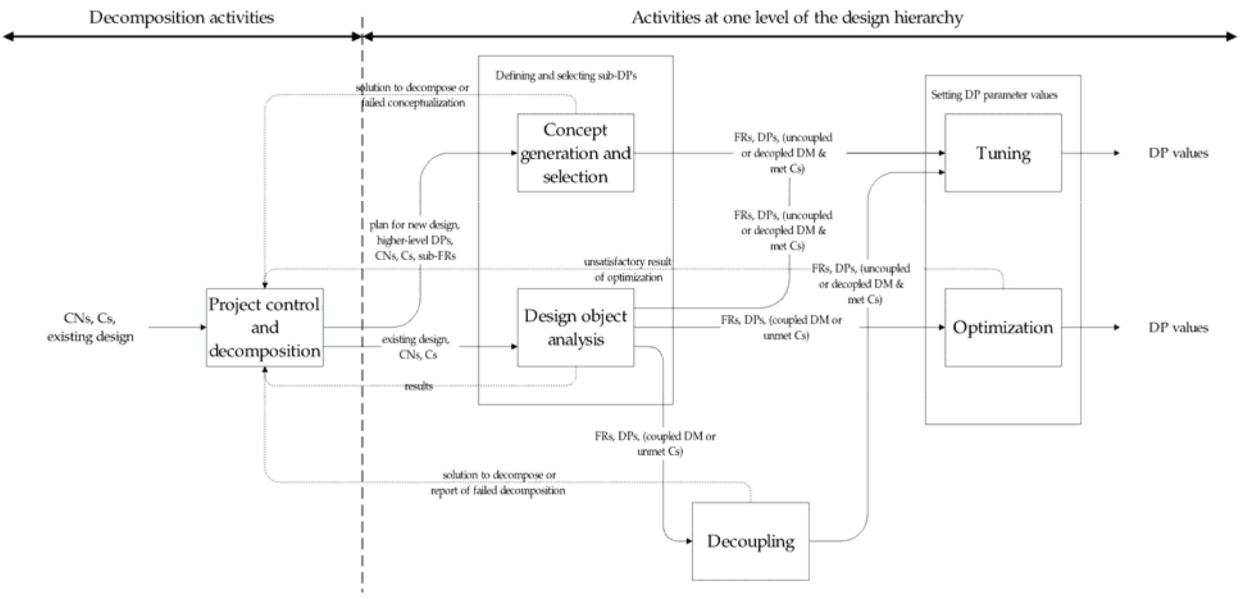

Fig. 2. The zig according to Derick Tate [5].

Therefore, defining the FRs is a major step in design. FRs are commonly verbalized actions. M.K. Thompson gave an important contribution regarding what an FR is [11], by assuming that some design requirements are non-FR. Moreover, she shows that there are a selection criterion and an optimization criterion that are often confused with FRs. Non-FR are many times defined as "to be", as it happens in FRs defined as "to be aesthetic", or to "taste like", therefore expressing characteristics of the entity, not an action. This concept proposed by Thompson is similar to the subjective functions in Value Analysis (VA).

Value Analysis is a design theory raised by Lawrence D. Milles during the World War II that defines primary and secondary functions. Primary functions are objective functions associated to an action, and secondary functions may be subjective [12].

Christopher Brown proposed the need of metrics to guide the definition of FRs, and to select the corresponding DPs, in order to prove that at each stage of decomposition the FRs are "collectively exhaustive and mutually exclusive (CEME)" [13].

In this sense, many actions in engineering are transformations of physical quantities into other physical quantities, like the transformation of electric current into a displacement. Aibin Zhu proposed a definition of FRs by composing "a set of carefully selected physical quantities", and the FR is the transformation of a physical quantity into another one [14].

In a different way, Éfren Benavides [15, 16] associated the FRs to physical variables. The set of physical equations that governs the phenomenon allows defining the design equation. As physical equations usually depend on many variables, typically the set of equations describes a redundant design. Benavides proposes whenever possible to freeze some of the DPs and choose the ones that define a linear design equation.

D. Matt uses the set of physical equations to design a "flexible assembly operation focused on consumer demand". Evaluating the effects on variations on demand and annual evolution of an enterprise, he proposes a re-initialization loop to allow a functional periodicity in the management design of an enterprise [17].

Anyway, defining good FRs is not a warranty of attaining a good design. The fulfilment of FRs can be disrupted by the interdependency between FRs and "variability" [18]. Hilario Oh "develop a mathematical understanding for the two types of failures". The solution of the inverse of Equation 1 helps to achieve the DPs in an iterative process [18]. The formulation shows that the determinant of the design matrix cannot be zero, a generalized statement of Axiom 1 of AD. Moreover, this condition is necessary to attain a zero bias in the functional domain, relating therefore the mathematical formulation to the 2nd Axiom.

A common source of variance of the FRs is the influence of the tolerances of the DPs calculated by the design equation. In mechanical engineering, the variance of FRs may arise from the synthesis of tolerances. Synthesis of tolerances can be seen as a redundant decoupled design, due to the fact that generally there are more parts than interfaces. Such synthesis "should be integrated in the design structure, instead of being done in the final steps of the design" [19]. Tolerances define the range of acceptance of FRs and therefore the information according to the AD theory. For coupled designs with 2 DPs and 2 FRs it is possible to calculate the minimum information for an uniform probability distribution [20].

The decomposition process allows defining any design, starting at the high level requirement and ending in the leaves of the decomposition tree. This procedure applies in the evaluation of any design, for a passenger movement inside a large airport [21] or for the design of a faucet. In the development of AD theory it is necessary to reach the "how to apply the theory", making it possible to spread AD in the engineering field.

2 The proposal

In the AD theory the zig process is a synthesis process that expresses the "what" to "how" and the zag process that goes from "what" to "why" in the next level of decomposition [4]. In the end of the zag, the design process achieves the children FRs that have to be CEME. The problem on applying AD during the zig process is to answer to "how can we achieve suitable DPs?".

It is important to notice that the zig process follows the reverse direction stated on Equation 1: FRs are known and the designer needs to find the DPs in the Physical Domain. Therefore, at each level of decomposition it is necessary to test a set of DPs in order to know if they fulfil the corresponding FRs.

The theorems of AD give a great benefit in performing this task, helping to formulate the problem, as well as to evaluate and to select a concept.

This paper proposes a way to help defining the DPs, therefore highlighting the box of Fig. 2 named "defining and selecting sub-DP".

The FRs' metrics are defined trough equations, making their values possible to vary over time or change according to the stage of the system.

This paper proposes two conditions at which a system can operate: the "nominal condition" (NC) and "actual condition" (AC). FRs may have different nominal conditions which occur when FRs reach their engineering maxima. In engineering, a maximum is usually defined in probabilistic terms, regarding to the conditions the system will work. Examples of these maximums are the cooling load of a building that depends on the weather, the strength of a ship that depend on the sea conditions, or the forces in a metallic structure that are a combination of loads, wind and seismic actions. Actual conditions are all the conditions at which a system needs to perform during the working period, which includes the nominal conditions.

To reach the design equation it is necessary:

- Define or calculate the DPs that fulfil the FRs at the defined engineering "nominal condition";
- Evaluate the interdependencies between the FRs and the proposed DPs in the actual conditions;

- Check the influence of the tolerances of the DPs, and noise effects on the functional domain, and evaluate the probability of success of the design;
- Evaluate back at the same level of decomposition if the FRs are CEME.

Therefore at one level of decomposition, the designer first raises a design equation at nominal conditions and only after obtains the design equation at actual conditions, the so called DE. Thus, the design equation might have the elements defined during the study of the design at nominal conditions.

Hilario Oh [18] expressed the design Equation 1 by the following Equation 2, equal to a set of non-linear equations, where $\{DP\}$ is the root vector of the equation

$$f\{DP\}-\{FR\}=0 \quad (2)$$

The solution of a set of non-linear equations can be achieved by the Newton-Raphson iterative process, starting at any proposed $\{DP_k\}$, according to Equation 3.

$$\{DP_{k+1}\}=\{DP_k\}-[J]^{-1}\cdot\{f\{DP\}-\{FR\}\}=0 \quad (3)$$

Where $[J]$ is the Jacobian matrix of the transformation of $\{DP\}$ into $\{FR\}$, therefore being the design matrix $[A]$. This equation is strictly valid if the Jacobian matrix exists and if this matrix is invertible [18]. The formulation of Equation 3 has the advantage of showing the need of a sequence of DPs to achieve the root of the equation.

Using the formulation of Hilario Oh it is possible to show the evolution of the design from the nominal conditions to the actual conditions. The design team usually starts to define what the nominal conditions are. Thus, it allows defining and computing the DPs, the design equation and the corresponding DM at nominal conditions $[A_{NC}]$. Equation 4 shows the corresponding design equation:

$$\{FR_{NC}\}=f_{NC}\{DP_{NC}\} \quad (4)$$

At actual condition, the DPs need to change by ΔDPs, performing FR by adding a f_1 equation.

$$\{FR_{AC}\}=f_{NC}\{DP_{NC}\}+f_1\{DP_{NC}+\Delta DP\} \quad (5)$$

Expressing the second term of Equation 5 as a first order Taylor series, Equation 5 becomes:

$$\{FR_{AC}\}=f_{NC}\{DP_{NC}\}+f_1\{DP_{NC}\}+[J]\{\Delta DP\} \quad (6)$$

Or:

$$\{FR_{AC}\}=f_{AC}\{DP_{NC}\}+[J]\cdot\{\Delta DP\}=A_{AC}\cdot\{DP_{AC}\} \quad (7)$$

Equation 7 is the so-called design equation, which shows that the DM may be obtained by the sum of two DMs.

The design team may use the DM $[A_{NC}]$ mainly for evaluation purposes and the $[A_{AC}]$ for evaluation of performance and control purposes.

Achieving the DPs is not as straightforward as Equation 2 might show, but is a sequence of conceptual trial-and-error experiments. Therefore, the zig representation is not a process, but the final representation of a sequence of processes.

Figure 3 depicts the “defining and selecting the DPs” at a level of decomposition, explaining the way to perform the process represented in Figure 2. The inputs of the process IN_1 come from the previous zag, bringing the DPs, CNs, CS of the higher level and the FRs at nominal conditions (FR_{NC}). Then, the design team proposes a set of DPs to perform the FR_{NC}, evaluates the DM (A_{NC}) and comes back to the functional domain in order to check if the FR_{NC} are fulfilled. During this process, DPs and DE may change, being possible the need to modify the set of FRs and evaluate if they are CEME. The process of checking if the FRs are CEME is not shown in Figure 3, as it would be required to relate the FRs with the parent FRs. The design team may conclude that the design has no solution (No Sol.), so that they have to go back to the previous level of decomposition.

During this first stage, the design team looks for the main important relations between each FR and the DPs, by estimating the value of the elements of the design matrix. In other words, all the $\left|\frac{\partial FR}{\partial DP}\right|$ which values are lower than a certain threshold are discarded.

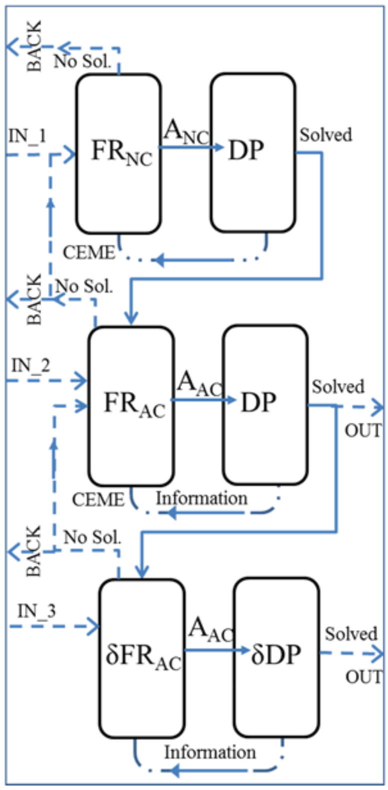

Fig. 3. Defining and selecting the DPs at a specific level of decomposition.

If there is a solution, the process needs a new input (IN_2), regarding the metrics of the FRs when the system works at the actual conditions. In addition, the new input brings the range of acceptance of the FRs, making possible to evaluate the information of the system. In many engineering applications the range of the FRs is defined as the "higher the better".

The information is accounted by the probability of the system to fulfil the FRs, when undergoing all possible situations in time, taking into account all interactions defined by the DM and the DPs at typical values. This is a first approach to the information that may be acceptable for existing designs, or similar.

At this stage of definition of DPs, the design team once more raises a new design matrix, the A_{AC}, check the fulfilment of the FRs and evaluate back if the FRs are CEME, trying at the same time to reduce the couplings between the FRs. If the FRs cannot be fulfilled, the design team may need to revaluate the nominal conditions, or to decide to go back to the previous level of decomposition. According to the diagram depicted in the previous Figure 2 of section 1.1, if the solution is accepted, the design may need to be tuned, or if the design is coupled it may need to undergo a decoupling process or an optimization process.

The design team may want to check the performance of the accepted solution, needing the input of the variation of the FRs (input IN_3 at Fig. 3). This allows the design team to check the tolerances of the DPs and to evaluate the information of the system at any situation in time. The design team also checks the system behaviour, taking into account the interactions defined by the DM and the effects of tolerances in the DPs.

Once more, the process may go back to redefine the FRs and DPs at the actual condition stage, or go back to the previous level of decomposition. Otherwise, it follows the aforementioned process for an accepted solution.

3 Example of the zig process

The following example helps us to show the existence of the two design equations during the zig process at the second level of decomposition of a design.

The example is about an air conditioning system, the variable air volume system, which is working in cooling mode. In the air conditioning industry it is common to use the acronym HVAC that stands for heat, ventilation and air conditioning, and VAV for the variable air volume system. In working conditions, the VAV system may lack to deliver steadily the minimum amount of outside air (OA) into some spaces, while delivering more OA than necessary to other spaces [22].

To satisfy the CNs of any HVAC system, the design team needs to fulfil the first order FRs: "Remove the heat" and "Provide the indoor air quality (IAQ)" at each space. VAV systems are a class of HVAC systems that remove the heat by convection, making a stream of air to be supplied into the space at a lower temperature than the room set-point temperature. To accomplish this requirement, the sensible power to remove Q varies according to the $\dot{m}$, the mass airflow, and ΔT, the difference between the indoor comfort temperature and the supply air temperature into the room. Equation 8 shows the above mentioned relationship being cp the specific heat for air.

$$Q = \dot{m} \cdot cp \cdot \Delta T \qquad (8)$$

According to Equation 8, removing the heat load can be accomplished by maintaining the supply airflow and varying the temperature, or by maintaining the ΔT and varying the airflow. VAV systems use the second alternative.

In what concerns to the IAQ, it can be defined for any system according to the OA flow and computed tacking into account the number of persons and the floor area. Therefore, being q_p the OA per person, and q_s the OA to remove the contaminants of a space of floor area S, and np the number of persons, the needs of OA flow, q, may be expressed by Equation 9, an expression that sum both effects.

$$q = np \cdot q_p + S \cdot q_s \qquad (9)$$

Figure 4 depicts a sketch of a VAV serving two spaces, space 1 and any other space n, allowing one to see the differences of behaviour of the system between spaces without having to show all spaces. The Figure shows a single duct (item 1) VAV that supplies a variable amount of air through the VAV boxes (item 2), according to the temperature T of each room. The cooled air at a supply temperature (Ts) comes from the air-handling unit (AHU), which also intakes the building's needs of outside air (OA) and exhausts a similar amount of airflow extracted from the spaces. A part of the return air (RA) mixes with the OA, making the supply air to include a certain amount of stale air coming from the inside. Moreover, the amount of OA delivered at each room depends on the load of the room, as increasing the load increases the supply airflow and therefore the OA delivered in the room.

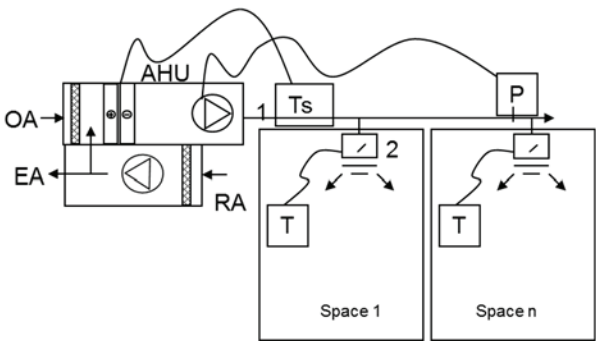

Fig. 4. VAV single duct system (box heaters and AHU dampers not shown).

The decomposition of FRs to DPs can help to define the major equipment of the VAV system at the design level of maximum load and maximum OA flow condition. The maximum load of the building allows the designer to define the cooling system of the AHU, and the maximum load at each space, the terminal equipment. Moreover, the total needs of OA of the building allow to define the OA of the AHU, and the OA needs of each space may be taken into consideration when defining the minimum position of the damper in the VAV box.

Equation 8 makes it possible to choose the VAV boxes, which size is determined by the airflow that is required to remove the maximum load at a certain supply temperature.

Table 1 shows the FRs and the DPs of the design decomposition until the second level of the design of a single duct VAV system [23]. Notice that there are no specific DPs for providing OA to each space, because the OA is mixed in the airflow supplied by the AHU.

Table 1. FRs and DPS of the VAV single duct in cooling mode.

FRs	DPs
FR1- Achieve indoor thermal comfort	DP1- Temperature control system
FR2- Provide IAQ	DP2- Outdoor air control system
FR1.1- Remove heat from space 1	DP1.1- 1's VAV box airflow
FR1.2- Remove heat from space n	DP1.2- n's VAV box airflow
FR1.3- Provide total airflow supply	DP1.3- AHU flow system
FR1.4- Adjust Ts of the AHU	DP1.4- AHU cooling coil system
FR2.1- Provide OA to space 1	
FR2.2- Provide OA to space *n*	
FR2.3- Provide building total OA flow	DP2.3- AHU OA system

Table 2 shows the design, at the aforementioned design level. Therefore "Remove the heat load", FR1.1 and FR1.2 depend on the airflow (DP1.1 and DP1.2) and on the air temperature difference, achieved at this level by the cooling system of the AHU (DP1.4).

Table 2. Design matrix at nominal conditions.

	DP1	DP2	DP1.1	DP1.2	DP1.3	DP1.4	DP2.3
FR1	X						
FR2	X	X					
FR1.1			X			X	
FR1.2				X		X	
FR1.3					X	X	
FR1.4						X	
FR2.3							X
FR2.1			X				X
FR2.2				X			X

Regarding the IAQ, DP2.3 fulfils FR2.3, computed the needs of OA for the all building according to Equation 9, which corresponds to the maximum amount of air that the building needs at nominal conditions. The position of the FR2.3 line was changed as to improve the readability of the design matrix.

The IAQ at each space (FR2.1 and FR2.2) varies according to the OA fraction in the supplied air, depending on the VAV box and on the OA delivered by the AHU. A common solution to this problem is to set a minimum position for the damper of the VAV box, in order to allow delivering at any time a minimum amount of air into the space [23].

Using the DM of Table 2 one can define the VAV box for each space and total OA of the AHU, as well as the airflow supply and the total cooling power. Some couplings arise in the design due to the fact that all VAV boxes are interconnected through a single duct, and because the airflow is a mix of OA and stale air.

At this time, all DPs are selected for maximum loads or OA needs, which occur at different times for all the building and for each space.

Table 3 shows the design matrix at the actual working conditions. Concerning to "removing the heat" (FR1.1 and FR1.2), anytime a dumper of a VAV box changes its angle, the pressure in the duct changes, forcing the adjustment of the other ones. Moreover, when a space has no load, then the minimum amount of air delivered by the VAV box may cause the space to overcool. There are two possible solutions for this problem: to adjust DP1.4 to another temperature on a trade-off between temperature and airflow; or to introduce a reheat coil in the VAV box that allows heating the airflow if necessary.

Regarding the IAQ, anytime the cooling load decreases at any space, then the airflow supply must be reduced and therefore the amount of OA also reduces. Moreover, the amount of OA in the supply air varies according to the airflow required by each VAV box, coupling the OA at each space to all the other spaces. This issue is represented by the squared block of "X" in the lines corresponding to FR2.1 and FR2.2 of Table 3.

Table 3. Design matrix at actual working conditions.

	DP1	DP2	DP1.1	DP1.2	DP1.3	DP1.4	DP2.3
FR1	X						
FR2	X	X					
FR1.1			X	X		X	
FR1.2			X	X		X	
FR1.3					X	X	
FR1.4						X	
FR2.3							X
FR2.1			X	X			X
FR2.2			X	X			X

To avoid a shortening of OA the VAV damper is set to a 30% minimum and the amount of OA for the building might increase by about 30% [23].

4 Discussion

In engineering design it is typical to define a solution at a certain level of decomposition and after simulate the behaviour of the design. Based on the experience of the authors, examples of this procedure happen when defining a fluid network, a metal structure, or a HVAC system.

In the higher-level representation of these designs, designers raise a sketch of the solution and discuss it. During this discussion, the design team often identifies the need for new DPs that may enforce them to go back and identify some forgotten FRs. After accepting a sketch, a similar process occurs during the calculation procedure.

Therefore the zig process at each decomposition level uses interdependent trial-and-error loops. Highlighting this concept supports linking the procedures of common good design in engineering to the approach of designing in the AD framework. In other words, the concept helps any expert designer to see the AD theory as a strong tool, instead of putting it aside because it seems difficult to apply.

The main benefits of AD to a design expert are the guidance to reach a solution, the evaluation of the design concept and the help in selecting the best solution.

5 Conclusions

The contributions of the AD community during last years mainly highlights the need of a more precise formulation of the functional requirements (FRs); the use of metrics and equations to express the design equation; and the epistemic classification of the decomposition process of zigzag between adjacent domains.

There was a previous work of Derick Tate regarding the zigzag process that explains how to interrelate the functional requirements (FR) of the design with the design parameters (DP). In what concerns to the zig process he proposed a roadmap depicted in Figure 2, with two main boxes: “define and select the DPs” and “setting the DPs values”.

The current paper is an attempt to explain the procedures needed to “define and select the DPs” at a certain level of the decomposition of the design. This procedure is a sequence of conceptual trial-and-error manoeuvres in order to solve the design equation.

There are two main proposals in this paper regarding the way to implement the box “define and select the DPs”: the definition of the design matrix (DM) performed in two stages; and the calculation of the information content of the design considering first the interactions of the system and thus the tolerances of the DPs.

Regarding the former, to achieve the DM the designer may define the “nominal conditions” when a maximum value for each FR occur in the sense of an engineering probabilistic value. The mapping from the functional domain to the physical domain allows the designer to define the design matrix at nominal conditions. Afterwards, the system is evaluated considering all interactions at different time conditions allowing to attain the DM. During this procedure the design team uses the concept of metrics for the FRs, variable with time or according to the different situations the system might perform. At each mentioned stage, FRs are checked for being “cumulatively exhaustive and mutually exclusive” regarding their parent FRs.

Attaining the DM makes it possible to define the tolerances of the DPs, and to check if the tolerances of the DPs fulfil the tolerances of the FRs.

Regarding the information content, it is possible to obtain the information of the system after defining the DM, by computing the probability of the system to perform within the ranges defined for the FRs. During this stage the designer worries at the time step about the behaviour of the system, considering the values for the typical value of the DPs. Afterwards, using the tolerances of the DPs it is possible to check the probability of success of the system at each situation or time step.

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