A rigorous framework to describe margins

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Ph.D. expected duration: Nov. 2017 - Nov. 2020

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Abstract: The concept of margin is widely used in engineering fields, when the topic of design under uncertainty needs to be addressed. This notion has first been shaped by the intuition, but more rigorous definitions have been proposed in some engineering fields, as the practices were understood more precisely. Nevertheless, it appears that there is no *general* definition that would describe formally a margin independently from the field [2]. The goal of this work is to provide such a framework, encompassing a wide variety of current practices.

The margins that are investigated are those that can be described as *an amount of something included so as to be sure of success or safety.* Considering this definition, the margins in our scope are always taken to cover the consequences of some uncertainties. Our thesis is that it is always possible to measure this *amount of something included*, as a distance to a reference. However, this reference is not always a critical point to avoid or a point of performance to aim at and the distance does not always include all the variables of the problem.

The source of the uncertainty (lack of knowledge, truly aleatory phenomenon, unkown future design choices, unreliable partners...) and the consequences (limiting the design, improper prediction, safety concerns...) at stake in margins are numerous and diverse. In order to model it, it is assumed that it is possible to determine if the system is in an acceptable state by looking at some (random) variables of interest describing the system. More precisely, a state is acceptable if and only if the random variables of interest belong to an acceptance set $\mathcal{A}$. This acceptance set can be defined thanks to a risk threshold and a risk measure - i.e a function that maps random variables to a real value, interpreted as a "risk"-, similarly to the monetary risk measures introduced in [1].

We show that our framework gives a relevant interpretation of some well documented indicators from multiple engineering fields, the capability process C_p in statistical quality [7], the safety coefficients γ in probabilistic civil engineering [5], the gain GM and phase margin PM in control [6], among others. Some specific margins defined in previous frameworks [8], [4], [3] can also be defined in our formal system.

One of the possible applications of such a framework is to permit communication and exchange of margins between engineering disciplines, in the context of the design of a complex system. Another use could be an easier recording of the reason why a margin is imposed and an easier monitoring of its future evolution. The study of margin calibration, i.e focusing on how the minimum margin values are chosen, could be facilitated by the proposed margin definition. Last but not least, we hope that it will help to formalize some problems known as global margin allocation and margin accumulation, that would be solved by UQ techniques.

References

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Short biography – Adrien Touboul completed a Master's degree in applied mathematics at University Pierre et Marie Curie as well as an Engineer degree at École des Ponts ParisTech in 2017. He is now pursuing a PhD at the research institute IRT SystemX in a team gathering multiple industrial players, coming from PSA group, Renault and Airbus, among others. The academic support for the PhD is provided by the research center in applied mathematics CERMICS.