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From PGD to iPGD

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From PGD to iPGD

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Today many problems in science and engineering remain intractable, in spite of the impressive progresses attained in mechanical modelling, numerical analysis, discretization techniques and computer science during the last decade, because their numerical complexity is simply unimaginable. We can distinguish different challenging scenarios for efficient numerical simulations:

- The first one concerns models that are defined in high dimensional spaces, usually encountered in quantum chemistry and kinetic theory descriptions of complex fluids.
- The second problem category involves time-dependent problems whose spectrum of characteristic times is so large that standard incremental techniques fail.
- Real time simulators are needed in many applications. Control, malfunctioning identification and system reconfiguration also need to run in real time.
- In problems defined in degenerate geometrical domains (beams, plates, shells ...) standard grid-based discretization methods fail because the extremely fine meshes.
- Many problems in process control, parametric modeling, inverse identification, and process or shape optimization require the solution of many direct problems.
- A new paradigm in the field of Applied Sciences and Engineering has emerged in the last decade. *Dynamic Data-Driven Application Systems* (DDDAS) allow the linkage of simulation tools with measurement devices for real-time control of simulations.
- Augmented reality requires efficient (fast and accurate) simulations. The idea is supplying in real time appropriate information to the reality perceived by the user.
- Light computing platforms (e.g. smartphones) are appealing alternatives to heavy computing platforms.

Our main objective is to address the modeling and simulation of “real” models encountered in science and engineering with all their complexity from the geometrical and constitutive points of view, some of them never until now solved because their computational complexity. These models should be solved very fast, in some cases in real time, by using light computing platforms. Classical simulation techniques fail to fulfill the above requirements. An appealing alternative consist of considering *off-line* solutions of parametric models, in which all the sources of variability – loads, boundary conditions, material parameters, geometrical parameters, etc. - will be considered as extra-coordinates. Thus, by solving only once the resulting multidimensional model, we have access to the solution of the model for any value of the parameters considered as extra-coordinates. Now, from this general solution computed only once and off-line we could perform on-line real time post-processing, optimization, inverse analysis, analysis of sensibilities, stochastic analysis ... by using very light computing platforms as for example smartphones. We could also adapt the model on-line while its simulation is running within the framework of dynamic data-driven application systems – DDDAS. The price to be paid is the solution of parametric models defined in high dimensional spaces that could involve hundreds of coordinates. The use of the Proper Generalized Decomposition that we recently proposed and we are intensively developing, allows such solution, because thanks to the separated representation of the unknown fields the computational complexity scales linearly with the dimensionality, instead of growing exponentially which is characteristic of mesh-based discretization techniques [1-7]. This off-line-on-line Proper Generalized Decomposition Based Dynamic Data-Driven Application Systems could constitute a new paradigm in computational sciences.

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