Sequential sensitivity analysis for computer experiments with functional inputs

J. Fruth
TU Dortmund University

Affiliation: *Faculty of Statistics*, TU Dortmund University, Vogelpothsweg 87, 44227 Dortmund, Germany

Email: fruth@statistik.tu-dortmund.de – **URL**: http://www.statistik.tu-dortmund.de/1553.html

Master: TU Dortmund University

Ph.D. (2012-2015): TU Dortmund University

Supervisor(s): Prof. S. Kuhnt (Dortmund University of Applied Sciences and Arts) and Prof. O. Roustant (Ecole des Mines, Saint Etienne)

Abstract:

Sensitivity analysis [1] studies the influence of input factors of a computer experiment on a given output. A computer experiment usually simulates a real-life process which runs for a certain time. Input values are usually fixed at the beginning of the simulation as single input numbers and are not altered any more during the process. However, in various contexts, especially in mechanical processes, input values could indeed be varied during the process. Examples might be speed (e.g. of a car or a robot arm), the dose of a physical agent or temperature. Varying such factors during the process and analysing the functional sensitivity can strongly improve the understanding of the process and can lead to much more precise settings.

Our research is motivated by a sheet metal forming process [2], where two parameters, which were previously kept constant, can now be varied in time: the blankholder force, which keeps the sheet metal in place during the forming, and the friction between the tool and the sheet metal. See Fig. 1 (left) for a representation of a forming press. As output value the forming accuracy is measured in terms of springback, the amount of deformation of the flange after the forming. Two example runs can be seen in the table in Fig. 1 on the right. The first column shows the functional path of the parameter friction, the second the resulting springback value. The blankholder force is kept constant. For both runs, the friction mean over time is equal to 12.5, but the resulting springback values differ considerably. This emphasizes the possibilities that lie in a functional exploration.

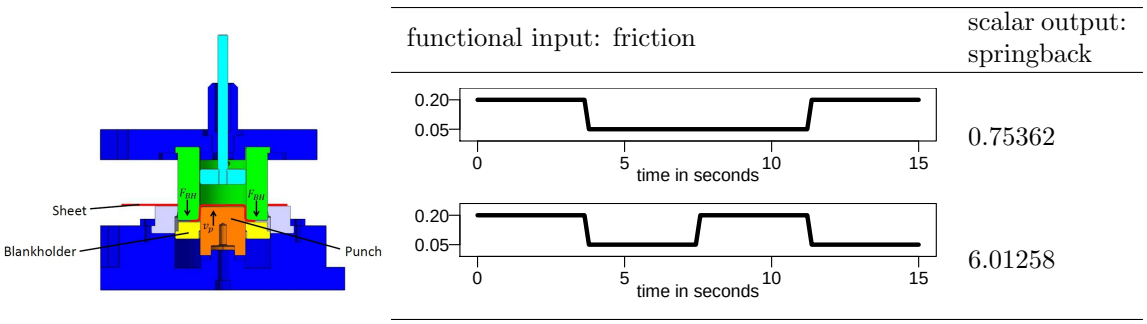

Figure 1: Representation of a sheet metal forming press (left). Two example runs with varying friction and constant blankholder force (right).

In the poster a very economical sequential approach for the sensitivity analysis of time-varying factors in computer experiments is introduced and developed. It does not only return a single influence value

per input, but instead gives the influence of each input over the whole time scale. This allows for a clear graphical representation of the functional influence. The idea is to reduce the dimension of the functional analysis problem [3] by exploring whole intervals of time and sequentially decreasing the interval size for interesting time spaces. A sequential design approach making use of ideas from group factor screening [4] is developed, resulting in very few runs necessary to explore the interesting time regions of the functional inputs. In addition the analysis and visualization of interactions between time regions is adressed.

In the sheet metal forming application five sequential steps have been performed taking only 40 runs in total. The size of the bars in Fig. 2 represents the linear influence of the time interval. A stronger influence of friction compared to blankholder force is noticeable as well as, for both inputs a clear difference between the first and second half of the punch time: in the first half the influence is mainly positive whereas in the second half it is strongly negative with the last time points showing the most influence. The results improved the engineers understanding of the time dependent influence. They have been validated afterwards in real forming experiments and also led to a better springback reduction.

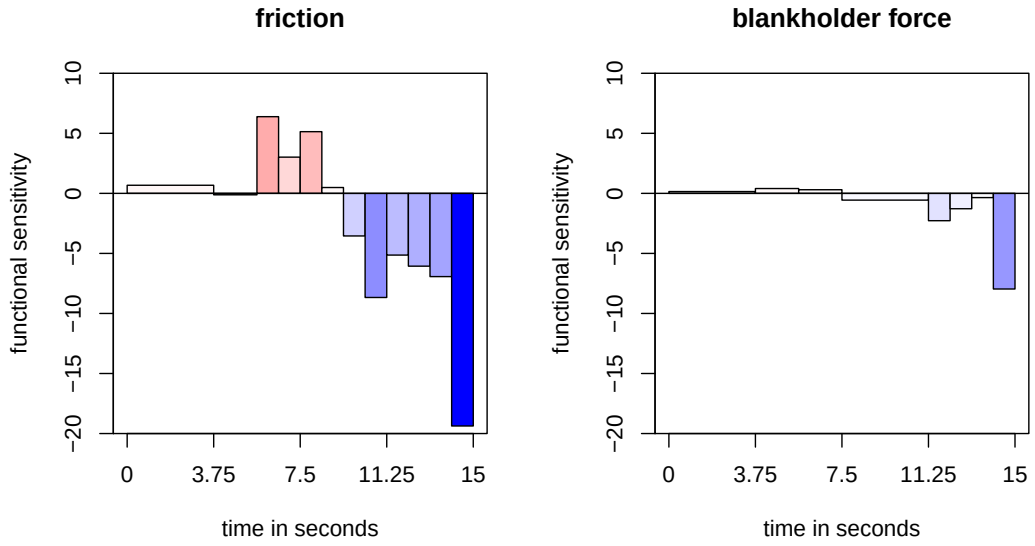

Figure 2: Graphical representation of the functional sensitivities of the input parameters friction and blankholder force in a sheet metal forming process.

[1] Saltelli, A., Chan, K., Scott, E. M. (2000): Sensitivity analysis. Chichester: Wiley.

[2] Hassan, H., Fruth, J., Guener, A., Tekkaya, A. E. (2013): Finite Element Simulations for Sheet Metal Forming Process with Functional Input for the Minimization of Springback. In: IDDRG conference 2013. Zurich, June 2-5, 393-398.

[3] Ramsay, J. O., Silverman, B. W. (2005): Functional data analysis. 2nd ed. New York: Springer.

[4] Morris, M. D. (2006): An overview of group factor screening. In: A. Dean und S. Lewis (eds.): Screening methods for experimentation in industry, drug discovery, and genetics. New York: Springer, 191-206.

Short biography – Jana Fruth did her Master of Statistics at TU Dortmund University in Dortmund, Germany. In her PhD thesis she works on sensitivity analysis methods for various situations in sheet metal forming, including interaction analysis, analysis of functional inputs, and derivative-based indices. The project is a cooperation with the TU Dortmund Engineering Department as part of the collaborative research centre SFB 708, funded by the Deutsche Forschungsgemeinschaft (DFG).