Most engineering structures encountered every day, such as cars, trains, ships, aircraft, and cranes, are subjected to fluctuating loading which is generated by the dynamic velocity alternation of vehicles and mass vibration of individual machine parts. Such loading can be extremely dangerous for a structure because it can initiate irreversible changes in the material microstructure that are difficult to detect at this stage. The locally initiated damage is accumulated during loading reversals, cycle by cycle, leading to a sudden drop in material stiffness, and finally, material failure. Enormous effort has been made by engineers and researchers to prevent such a situation, or at least, predict the life of the structure. However, owing to the high societal pressure on reducing vehicle energy consumption, attempts have been made to decrease the mass of the structure by optimizing the shape of the structural parts. In such a case, the optimization must include a reliable fatigue life prediction model to prevent unexpected failures. Owing to the highly complex fatigue material phenomenon, the most popular approaches are based on semi-empirical models. Such models are based on experimental tests conducted on standard material specimens to determine the basic relation between the fatigue life and applied uniaxial loading and verify the proposed fatigue criterion under multiaxial fatigue tests. Recently, the problem has appeared in an appropriate selection of the fatigue model for a given material state and loading conditions. This is a result of the unique fatigue behavior of different materials owing to the diversities in their microstructure, chemical composition, and machining. An inappropriate fatigue model selection can lead to inaccurate and nonconservative life predictions. Such predictions are undesirable because they can result in high financial costs and catastrophes including human lives. To avoid the model selection problem, recent attempts have been made to develop more general approaches with expanded applicability. However, these models are based on predefined functions identified and validated for the given test conditions, which limit their applications.

The current research project aims to develop an innovative approach based on machine learning and the Gaussian process (GP) for fatigue life prediction. The proposed GP-based fatigue model is a data-driven approach capable of accommodating each fatigue property of a material with the potential to replace the semi-empirical parametric models currently being used to predict the fatigue life. The GP for regression is classified as an artificial intelligence method and defines a nonparametric model with highly anticipated features in the fatigue life prediction problem. Its nonparametric nature ensures that some of the experimental data are automatically adjusted to the model’s ability to predict the fatigue life.

A wide experimental program, including uniaxial and multiaxial proportional and nonproportional loadings with different mean stresses, is planned to validate the pioneering proposal.

The project results are expected to change the view of the fatigue life prediction problem. The semi-empirical parametric functions used so far to create new models will be abandoned, and a new field of research in the area of fatigue damage mechanism, focusing on data-driven models based on GP, will be created.