2018 Ulf Grenander Prize in Stochastic Theory and Modeling
Citation
Judea Pearl

The 2018 Grenander Prize in Stochastic Theory and Modeling is awarded to Judea Pearl for the invention of a model-based approach to knowledge representation that is at once both stochastic and highly structured, for the discovery of innovative tools for inferring these models from observations, and for the development of novel computational methods for the practical applications of these models.

Grenander sought to develop general tools for constructing realistic models of patterns in natural and man-made systems. He believed in the power of rigorous mathematics and abstraction for the analysis of complex models, statistical theory for efficient model inference, and the importance of computation for bridging theory and practice. Judea Pearl has relied on these very same principles, bringing to it an energy and creativity that is remarkably reminiscent of the scientific life of Ulf Grenander.

In the 1980s, through a series of seminal papers and the landmark book *Probabilistic Reasoning in Intelligent Systems*, Pearl demonstrated how reasoning systems based on probabilities could address the principle shortcomings of the rule-based systems that had dominated decades of AI research. He argued that properties of classical logic make it difficult for rule-based systems to cope with reasoning under uncertainty, and proposed that graphical models of conditional independence, also known as Bayesian networks, can make this type of inference tractable in practice. Pearl's arguments prevailed, and by the early 1990s Bayesian networks and other graphical models had become the preferred framework for much of AI research and a rich source of challenging and important problems in mathematical statistics and computer science.

Mindful of the considerable computational challenges surely to be encountered in practice, Pearl proposed the belief propagation algorithm in Bayesian networks, which recast the problem of computing posterior distributions given evidence as a scheme for passing local messages between network variables. Although exact computations through dynamic programming are possible, Pearl recognized that in most problems of interest this would not be feasible and in fact belief propagation turned out to be remarkably effective in many applications.

Pearl's primary goal in adopting Bayesian networks for formulating structured models of complex systems was his conviction that Bayesian networks would prove to be the right platform for addressing one of the most fundamental challenges to statistical modeling: the identification of the subset of correlated variables that derive from truly causal relationships. In a series of papers in the 1990s, Pearl clearly showed that statistical and causal notions are distinct and how graphical causal models can provide a formal link between causal quantities of interest and observed data. In order to determine whether a proposed directed acyclic graph on a given set of observable variables represents a causal Bayesian network, Pearl invented his remarkable "do-calculus" for reasoning about causal and associated probabilities, interventions and observations. Given a collection of Bayesian networks that are consistent with the joint statistics of a set of observable variables, Pearl's calculus provides a systematic and provably correct plan of experimentation to distinguish the causal from non-causal interactions. These contributions are beautifully presented in his influential book "Causality." Whereas many challenges arise, for example involving data collection and counterfactual interventions, and the story is by no means over, Pearl's "do-calculus" has been widely adopted and is perhaps the most convincing and constructive of the existing approaches to causality.

Pearl has had a sweeping impact on the theory and practice of statistics and machine learning, and his ideas continue to engage mathematicians, statisticians and many other scientists with challenging analytic and algorithmic problems that are at the heart of modern AI.