Reflections about Judea Pearl and his Contributions

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Special UAI Session: Recognizing Judea Pearl's Turing Award

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It's an honor to have been invited to share reflections about Judea Pearl and his contributions. Being asked to talk about Judea in front of this home audience is an interesting request as most people here understand and appreciate Judea's work—and many of you know him well personally.

Judea has been the heart and soul of a revolution in the use of probabilistic representations in AI and in computer science more broadly. His intellectual contributions and clear writing have also provided other disciplines with insights and building blocks, with influences in econometrics, statistics, and the philosophy of science.

Many of us know Judea as a whirlwind of curiosity, intellect, and humor—and someone who has passionately and optimistically pursued answers to questions about human and machine intelligence—questions on the computational foundations of intelligence. Over the years, I've heard him ask: "How can we emulate mental phenomena on a machine?" "What is it about human intelligence that a computer cannot do?" "What human qualities might be attributed to programs?" "How can we imbue robots with human intuitions about cause and effect?"

Such essential questions and motivations have become too rare as folks push on their favorite subproblems and present their results at UAI, AAAI, and NIPS. Judea has continued to call out core questions at the center of AI—and he has referred to AI as a "daring paradigm"—and "an aspiration."

As a bit of history, the UAI conference itself was first hosted by Judea 27 years ago, at UCLA in July 1985. That summer was a time of peaking interest in AI where methods based on the

chaining of rules in production systems were being viewed as game changers in industry. Several thousand people flocked to the co-located IJCAI meeting.

As a new graduate student interested in automated reasoning under uncertainty, I had learned that the larger AI community had overall come to treat uncertainty as a nuisance—and probability as a foreign antigen. Probabilistic methods were viewed by many as flat, unstructured numerical methods—a throwback to numerically intensive OR methods—with little relevance to the rich symbolic reasoning of the form that people did, nor to the exciting ideas that founding fathers like Herb Simon reflected about in their examination of human problem solving and in their pursuit of mechanized intelligence.

I have vivid memories of Judea's presentation at UAI 85. He went up to a freestanding blackboard and wrote down several graphical structures with chalk, and spoke passionately about "networks of belief," and he shared his recent excitement about the power of updating procedures built on network data structures. I recall that Judea had so much to say, that he could not convert his ideas into words fast enough and used gestures to fill in the gaps. He used his hands and the chalked networks to express his intuitions, speculating about the role of these kinds of structures or analogs in human intelligence, saying something like, "These networks—these networks of belief—this kind of thing is the way we think, how our own minds work," and that "we must be doing something like this," to capture relevance and irrelevance in a tractable manner. The discussions continued throughout the meeting, and, for a few of us, at a very memorable evening pool party at Judea's home that week, where we were joined by several colleagues including as I recall Nils Nilsson and Hans Berliner.

Today, probabilistic graphical models, and numerous ideas emanating from the work of Judea and colleagues play a central role in AI. If we were to be magically transported from the UAI meeting in 1985 to a current AAAI or IJCAI meeting, our thought would be: "Wow, UAI has become a much larger conference!" And we'd be essentially right.

To be fair, many people have contributed to the probabilistic revolution in AI, including numerous people in this lecture hall today. However, most would agree that Judea is the heart

and soul, the intellectual core of our influential community, and his contributions have led the way for over 30 years.

Each of Judea's main bodies of work has boosted the science of AI, and provided the community with new insights and tools. In 1986, I was invited to write a review of Judea's book on intelligent search strategies. In the course of preparing these reflections, I re-read that review on the AAAI archive, and re-experienced my excitement about the work when I had just read the book. The work centered on probabilistic analyses of heuristic strategies, and included methods for generating new heuristics for solving hard search and planning problems.

Judea's second book is a tour de force—a bible on probabilistic graphical models, pulling together and extending a string of contributions, some of which had been published here at UAI and at AAAI. With this book, Judea explicitly aimed at bridging concepts and communities. He said in its preface, "AI researchers can take an earnest look at probability theory, now that it is phrased in their language, and probabilists should be challenged by the new issues that emerge from the AI experiment."

In the book, Judea clearly laid out Bayesian networks as data structures encoding independence relationships, and described qualitative patterns of reasoning, including intercausal reasoning and notions of "explaining away"—and definitions, proofs, and conjectures, covering I-maps, I-equivalence, P-maps, and d-separation—and he presented key methods for doing inference, including distributed message-passing procedures, and methods for tackling harder inference problems when there were network cycles, including likelihood weighting and cutset conditioning.

Judea's third book on causal representations and reasoning, and on adding "doing" to perceiving and inferring has been another pillar---a synthesis that unifies and extends efforts to understand causality and intervention.

Judea's writings are a fun read. I've loved his mix of technical ideas with simple examples that one might encounter on a day in suburban LA : home alarms, earthquakes, burglars, and radio reports; wet pavement on sunny days, sprinklers, and perhaps a bit of anomalous rain. Beyond

theory and fun examples, he has shared his passion, curiosity, and motivations. He apologizes in his second book for shifting gears to speculate, telling the reader that he doesn't want to "deny the reader the sense of excitement that led him to the explorations."

So Judea's thinking has influenced many people's research, and, more generally, lives and careers--and projects and programs. We would not be where we are today with the science of AI without his leadership and contributions.

As a final note, I'm confident that Alan Turing would be most proud to have his name associated with Judea Pearl and his contributions. A few years ago I read a beautiful annotated version of Turing's original paper on computability, where he introduces the Turing machine—of course it was not called that just yet. Turing's unique analysis was based on taking an algorithmic perspective on challenging problems in mathematics—casting, and then viewing the problems through the eyes of a computing system. Turing appears to seek to understand how a well-defined automated observer could come to understand and prove foundational properties about number systems. In a similar manner, Judea Pearl has examined probability theory, and probabilistic representations and inference through the eyes of computation. Judea has mentioned that the lens of computer science has been very important in thinking about probability. In the preface to his book on graphical models, he states that he has embarked on "a computation-minded interpretation of probability theory, an interpretation that exposes the qualitative nature of this centuries old formalism, its solid epistemological foundation, its compatibability with human intuition, and most importantly, its amenability to network representations, and to parallel and distributed computation." Like Turing, Judea has carefully probed mathematical challenges through the lens of computation—of mechanization—to uncover new truths. And through that lens he's refined the science of engineering systems that can perceive, believe, learn, and act in the world. We are all grateful for the journey that Judea has taken. He is an Alan Turing of our time.