Towards a general framework of machine intelligence

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Predictive information science is widely applied across the technology markets, including financial, automotive, communications and business intelligence markets. The basic principle of predictive analysis is to identify and exploit biased data. Typical implementations of algorithms use basic probability principles, such as Bayes' law, to draw inferences from observed data. In my research program we build upon the basic design methodology of predictive information science towards a more generalized framework of machine learning and artificial intelligence.

This concept is large and multi-disciplinary. The applications are countless and increasingly important in our data driven society. My research will focus on the development of basic mathematical models to represent and implement intelligent engineering systems. Codes on graphs and related theory plays an important role in my basic development approach. In terms of applications, I focus on what I refer to as "gun control technology", which means technologies that are designed to prevent and mitigate events of guns violence, such as active shooter events at schools and universities. The idea is to augment existing and future digital surveillance systems with additional data inputs, and apply advanced predictive information and data automation science to develop pre-shot detection and prevention data to security systems operators.

Given a physical system governed by the probability law $P(X, Y)$, we suppose that X is observed data and that Y is unobserved data. We wish to infer the value or likelihood of the event Y given the observed data X. When $P(X, Y)$ is known, the well-known Bayes' rule yields the conditional probability of Y occurring given the observation X:

$$P(Y|X) = \frac{P(X,Y)}{P(X)}. \tag{1}$$

Thus the joint Probability Distribution Function (PDF) $P(X, Y)$ may be used to develop statistical estimates of the unobserved data given the observation data.

In our concept of gun control technology, the observed data is in the form digital surveillance data (such as of audio, video, and IR surveillance data), social engineering data, criminal background data, and other electro-magnetic spectrum sensing technologies, such as active RF and millimeter-wave scanning technologies and passive radioactive particle detectors. The hidden variables comprise weapons detection and tracking data, threat detection and estimation, and situational awareness data. This concept extends to Government/DoD interests in data automation for defense security awareness and tactical data environments.

My proposed research program will expand upon the basic principles of predictive information science towards large and arbitrary engineering systems. We envision a generalized framework of machine learning that is adaptable to specific problems of interest. We propose to develop a generalized framework for modeling and inference computation, utilizing graph-based models and inference on graphs theory. We will seek to realize engineering systems that are capable of automatically fitting models to arbitrary systems of data and then drawing inferences based on inherent bias of the system.

A Brief Introduction To Our Mathematical Approach

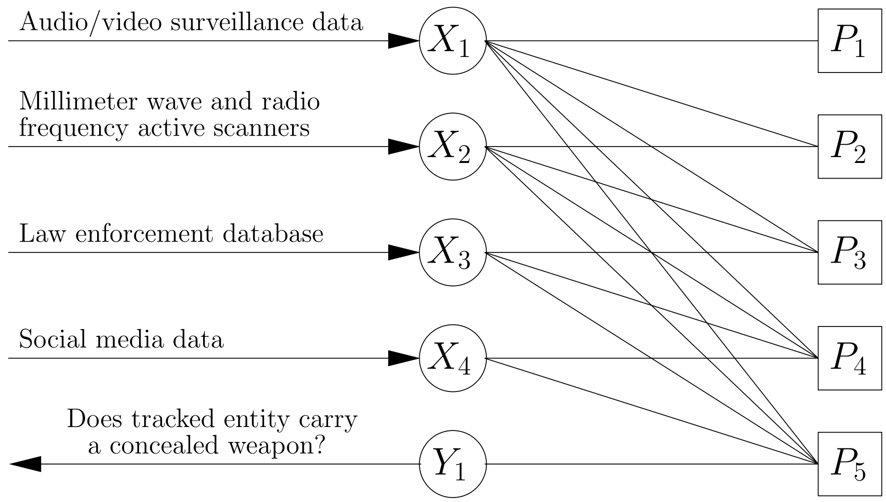

Figure 1: Tanner graph model of the joint probability distribution function $P(X_1, X_2, X_3, X_4, Y_1)$.

Figure 1 displays an input/output diagram with a graphical model (known as Tanner graph) representing the joint probability distribution function connecting the observed variables X_1, X_2, X_3, X_4 and unobserved variable Y_1. Without loss in generality the joint probability distribution function $P(X_1, X_2, X_3, X_4, Y_1)$ may be factored by the chain rule of probability:

$$P(X_1, X_2, X_3, X_4, Y_1) = P(Y_1|X_1, X_2, X_3, X_4)P(X_4|X_1, X_2, X_3)P(X_3|X_1, X_2)P(X_2|X_1)P(X_1). \quad (2)$$

In Figure 1, the five variables of the hypothetical system are represented by circles labeled X_1 through Y_1 and the five factors of Equation (2) are represented by the five squares labeled P_1 through P_5. For example, $P_5 = P(Y_1|X_1, X_2, X_3, X_4)$. An edge on the Tanner graph connects a square to a circle when the corresponding factor of Equation (2) is a function of the corresponding variable.

The graphical representation of Figure 1 serves as a framework for representing the overall probability distribution function of the system as well as a framework for computing the statistical quantities of interest, similar to Equation (1). Hence the Tanner graph is a general framework for algorithm implementation for predictive information processing.

What remains to be accomplished by the machine learning system is generating estimates of the component factors P_1 through P_5. This can be accomplished by use of training data sets in which the hidden variable is known or by use of abstract theoretical models for the variables of interest.

We are also keen on finding simplified representations of the system which might arise from alternative factorizations of the system PDF or conditional independence between variables of a given factor.

For example, if the identity of entity Y_1 is completely unknown, then law enforcement and social media database may not yield any statistically relevant information towards the goal of uncovering a concealed weapon. This corresponds to a conditional independence between the system variables and leads to a simplified graphical representation and algorithm implementation framework. For example, $P_5 = P(Y_1|X_1, X_2, X_3, X_4) = P(Y_1|X_1, X_2)$, etc. Hence, conditional independence among variables yields less edges on the Tanner graph system model and reduced complexity implementations.

Conclusion

I propose to develop a world class research and development program encompassing the subjects of predictive information science, machine learning and artificial intelligence. Our core theoretical foundations include probability theory, linear and nonlinear systems theory and information theory. We envision multi-disciplinary interactions between physical sciences, social sciences and defense security science and more depending on applications of study. The concepts developed are a top priority to Government and defense funding agencies.

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