Fully Probabilistic Design of Multi-Agent System for Cloud Prediction

Shahram Azizi. Supervised by: Prof Anthony Quinn

1 Our context: Hierarchical FPD in Multiagent System

General Task: The optimal probabilistic design of multiagent system (MAS) for prediction of the unknown quantity of interest (χ) in large-scale system.

Agents = a set of sensors, a set of computer programmers, …

Agent's task: Each agent predicts χ and reports known distribution

Bayesian Moral Deliberator (I_0)'s task: Chooses the optimal distribution and proposes the uncertainty around their selection.

Deliberator's knowledge :

$$\boldsymbol{F} = \{f(\theta|K);\ E_{f(\theta|K)} D(g_l||h(x|\theta)) \le \beta_l\ , l = 1, \dots, s\}$$

The HFPD principle of optimization:

quantifies designer preferences

Kullback-Liebler divergence

The optimal hierarchical model (decision)

$$f^o \equiv \underset{f \in F}{\operatorname{argmin}}\, D[f(\theta|K)||f^I(\theta|K)]$$

The hierarchical solution:

optimal Kuhn-Tucker multipliers

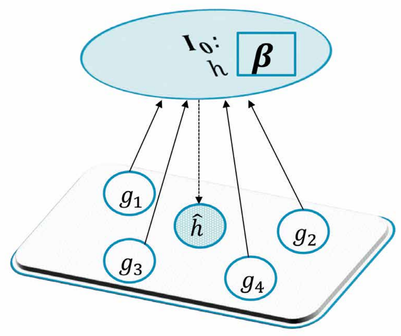
$$f^o(\theta|K) \propto f^I(\theta|K)\exp(-\textstyle\sum_{l=1}^{s} \lambda_l D(g_l||h(x|\theta)))$$

The optimal predictor:

$$\hat{h}(x) = E_{f^o}[h(x|\theta)|K]$$

2 Some Competing Approaches

Schematic paradigm:



» **Logarithmic pool**

$$h_{lo}(x) \equiv \underset{h}{\operatorname{argmin}} \sum_{l=1}^{s} \alpha_l\, D[h(x)||g_l(x)] \propto \prod_{l=1}^{s} g_l{}^{\alpha_l}(x)$$

» **Linear pool**

$$h_{li}(x) = \underset{h}{\operatorname{argmin}} \sum_{l=1}^{s} \eta_l\, D[g_l(x)||h(x)] = \sum_{l=1}^{s} \eta_l g_l(x)$$

» **Dynamic Diffusion estimate**

$$h_i(x) \propto \prod_{j \in N_i} g_j{}^{\nu_{ij}}(x)$$

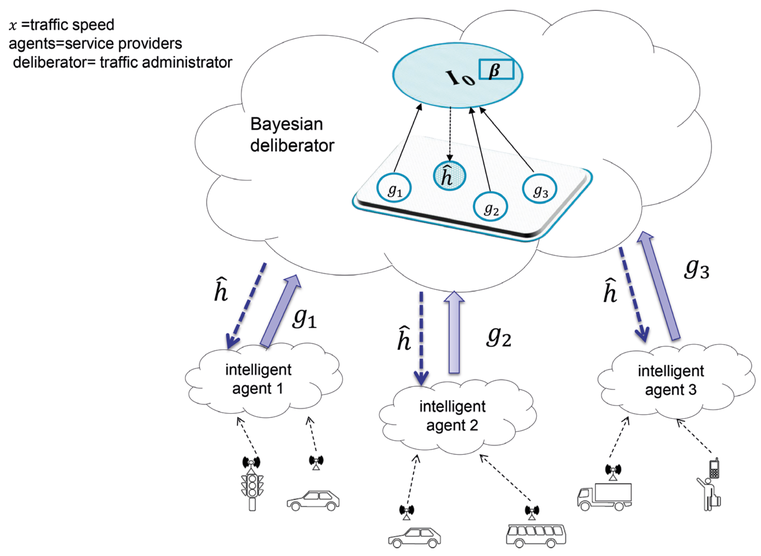
Challenging points:
In pervious approaches: How to choose α_l , η_l and ν_{ij}?
In our approach: How to design λ_l , β_l ?

Advantages of our approach

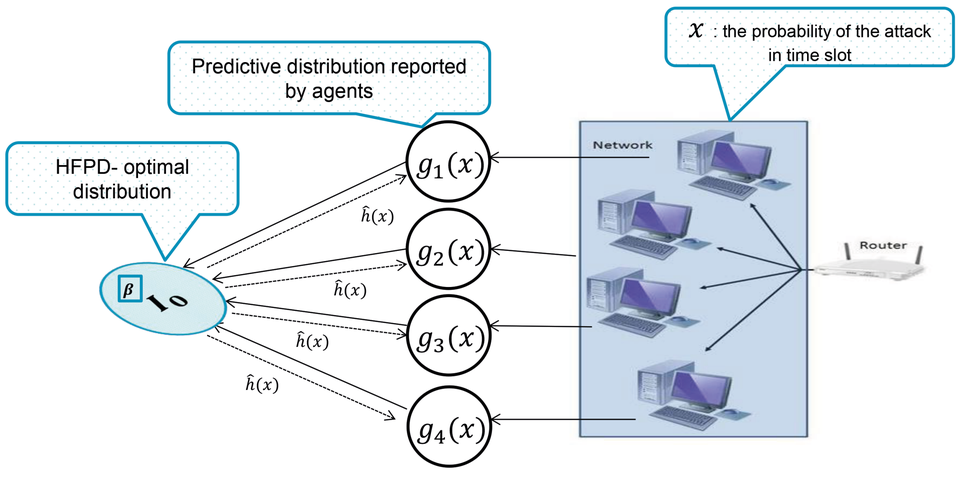
» Many parametric forms of h can be explored under this approach
» It is furnished with a measure of uncertainty around estimation of distribution, $\hat{h}(x)$

3 Possible application contexts

» **Traffic management**: traffic prediction

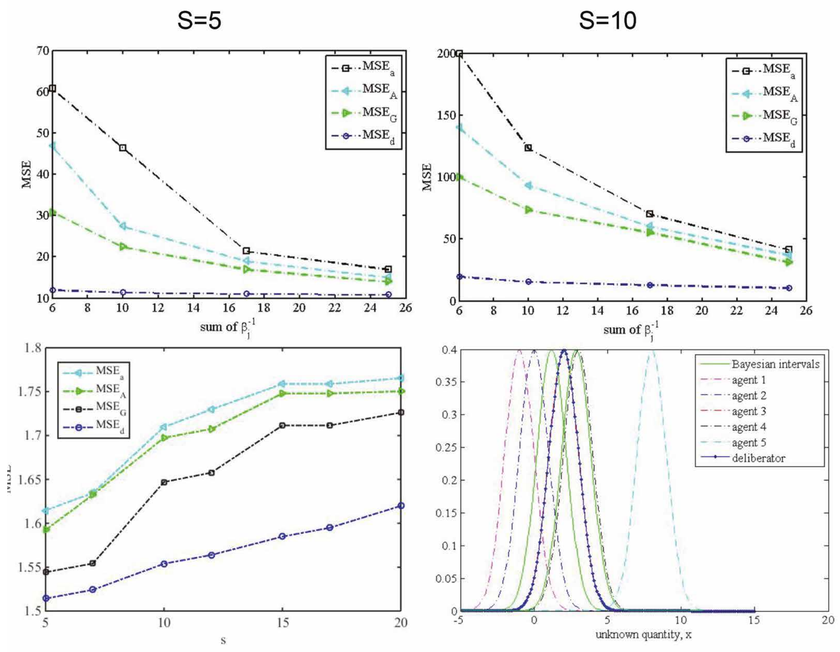


» **Monitoring network security:** prediction of potential security attack



4 Simulation Results

» MSE as a measure of performance:



Conclusion and Future work

» We propose a universal and consistent framework for how knowledge is expressed and shared in MAS regardless of the type of data.
» We set up fully tractable context for limited definition of the nature of the deliberator, we aim to relax this definition to more general case.
» How to express the deliberator's relationship with the agents.
» Extension of Hierarchical FPD to more general cases where agents have partially common support
» Adopting the proposed approach in the context of Bayesian filtering for tracking purposes

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