Optimal Remote Estimation: Managing A Human Operator's Workload.

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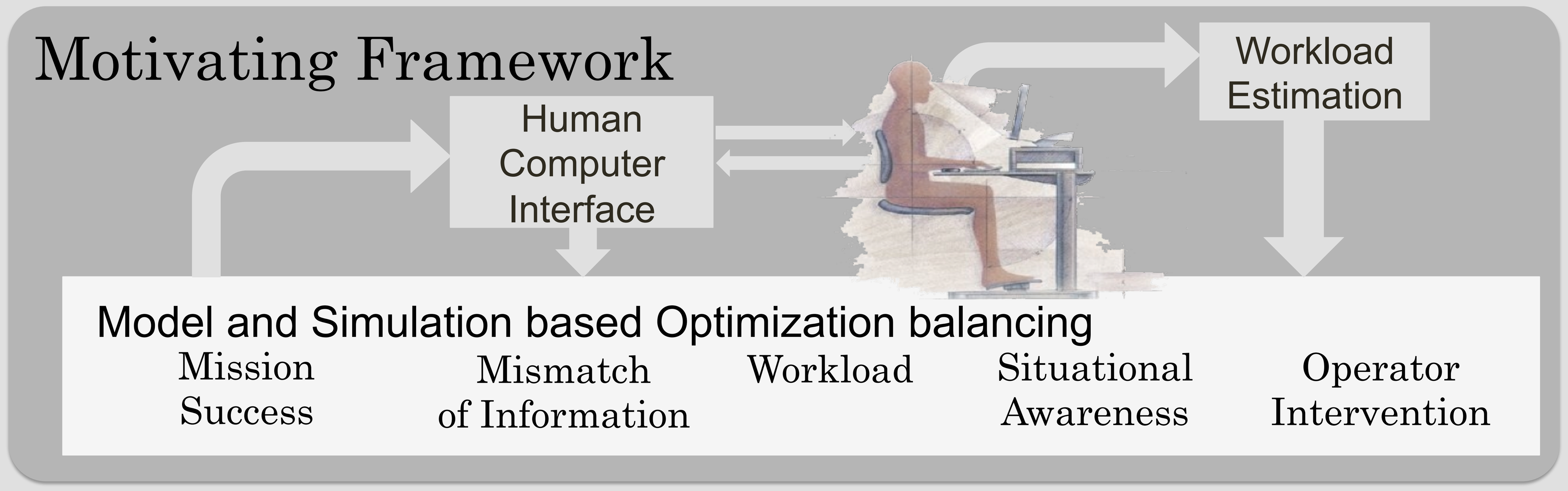
Research Aims

Our goal is to develop new design methods, principles and analysis to facilitate dynamic collaboration of human operators and autonomous agents.

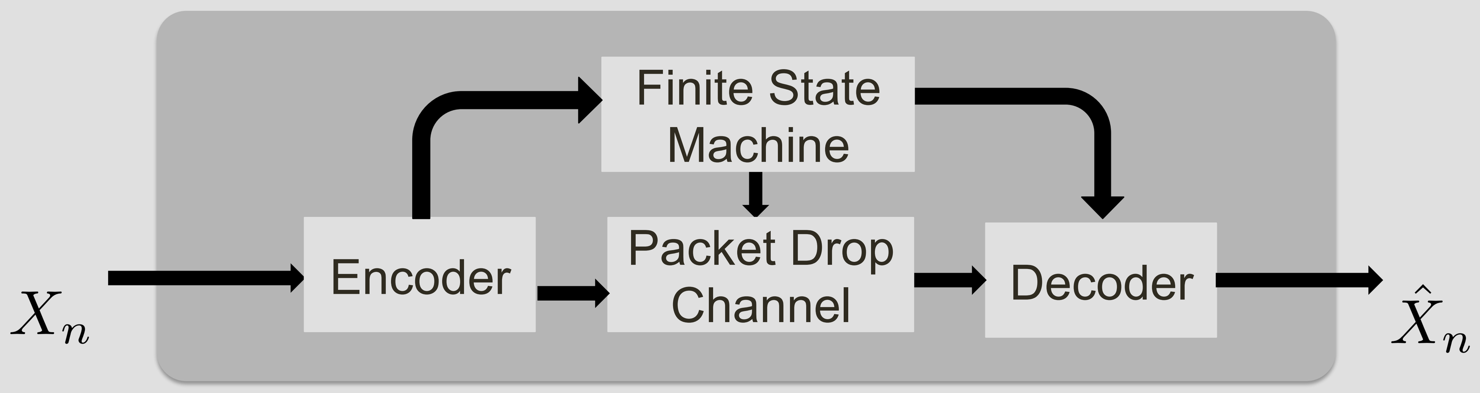


Future directions

- In collaboration with Naval Air Systems Command, we are in process of designing experiments that utilize this research in the scenario of a Unmanned Vehicle Operator splitting their attention between target localization tasks and planning tasks. In this case, the operator ignoring a localization task is a packet drop and the operator's current workload determines the probability that the operator ignores the localization task.
- Extending the remote estimation results over a packet drop channel to X_n that is not white and Guassian
- In collaboration with Naval Air Systems Command, adapting the results below for different costs that are more appropriate for specific experiments and verifying these models empirically.

Remote Estimation over channels influenced by channel use

Estimation over a Packet Drop Channel whose statistics change with channel use.



The Finite State Machine state determines the packet drop probability due to channel use.

Cost:

$$\sum_{n=1}^{N} E\left[(X_n - \hat{X}_n)^2\right]$$

Results:

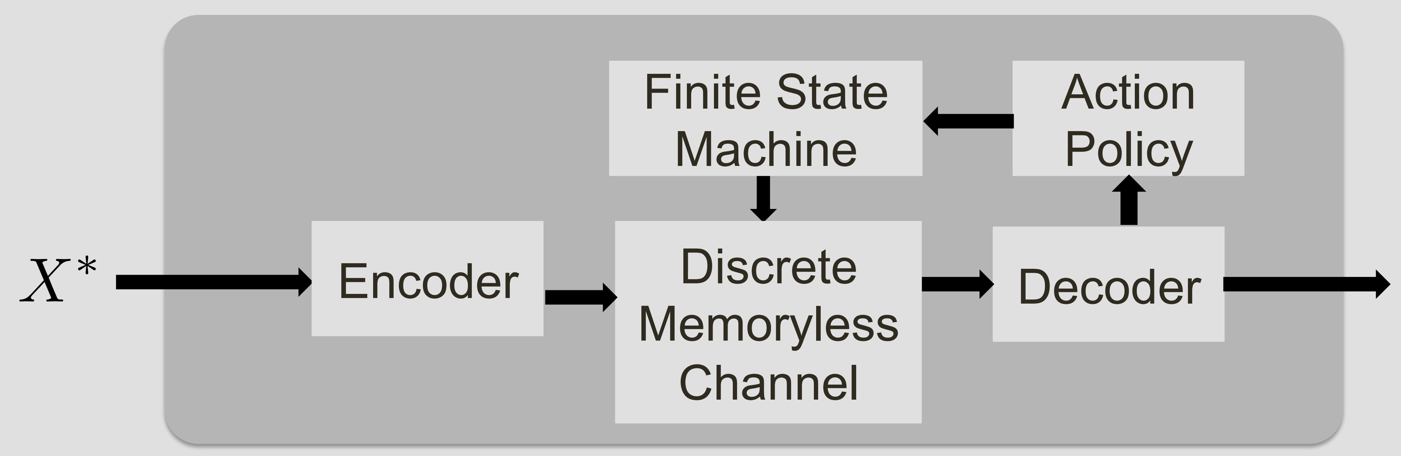
- The optimal symmetric transmission policy is a symmetric threshold transmission policy.
- If X_n is white and Guassian, the optimal transmission policy is a threshold transmission policy. In general this threshold policy will not be symmetric.

Definition: $\mathcal{G}$ is a threshold policy if for a and b it is of the form

$$\mathcal{G}(x) = \begin{cases} 1 & \text{if } a \le x \le b \\ 0 & \textit{Otherwise.} \end{cases}$$

Ward, D.; Martins, N.; Sadler, B., "Optimal Remote Estimation over a Class of Action Dependent Switching Channels," American Control Conference (ACC), 2015.

Estimation over a Discrete Memoryless Channel whose statistics change with use.



The Finite State Machine state, q, determines the Discrete Memoryless Channel, p(y|x,q).

Cost:

$$H(X^*|Y^N)$$

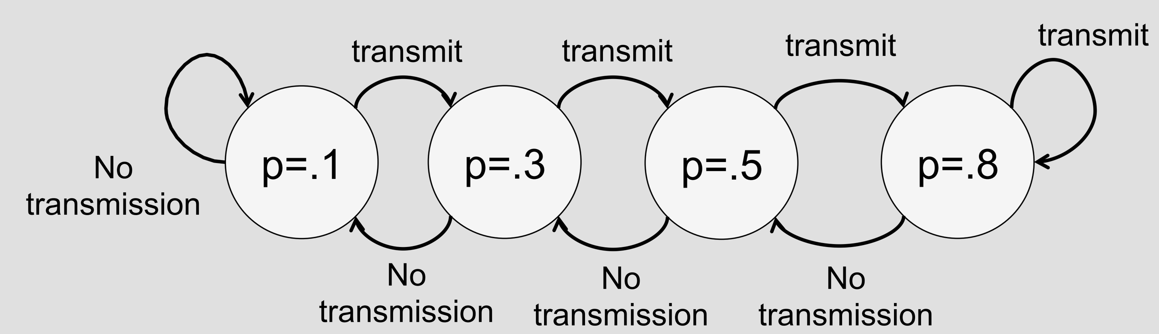
Results:

- There are optimal action feedback policies for which the input to the finite state machine is a deterministic sequence that does not depend on the channel output.
- When the Discrete Memoryless Channel is a Binary Symmetric Channel, the optimal action policy and optimal encoding policy can be designed separately.

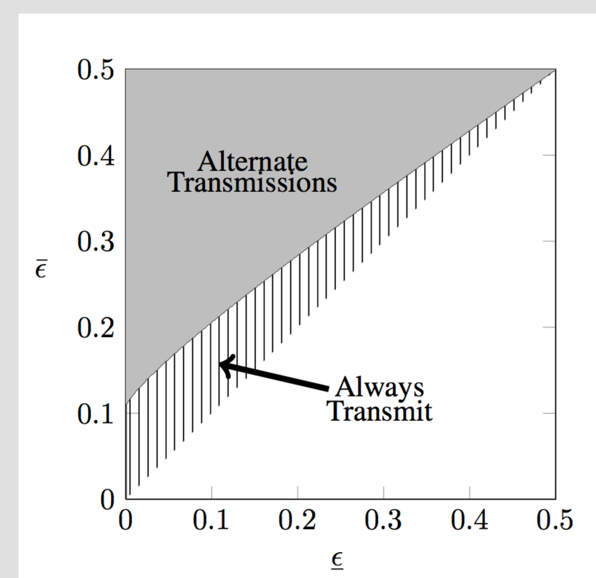
Ward, D.; Martins, N., "Optimal Remote Estimation over Use-Dependent Packet Drop Channels: Modeling and Managing Human Operator's Task Shedding," submitted to the Conference on Decision and Control (CDC), 2015.

Modeling human operator phenomena modeled by the memory in the channel

Workload modeled by a finite state machine for the packet drop channel.



The figure below depicts optimal transmission regions for a Binary Symmetric Channel with cross-over probabilities governed by a Finite State Machine similar to the chain shown above. Note $\bar{\epsilon}$ and $\underline{\epsilon}$ are the largest and smallest drop probabilities in the Finite State Machine chain as shown above.



Other operator phenomena can be modeled by the Finite State Machine such as sequential biasing.

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