Collaborative Human-AI

Decision-Making Systems

Serge Dolgikh, Oksana Mulesa

Solana Networks, Ottawa, Canada

National Aviation University, Kyiv

Uzhgorod National University, Uzhgorod, Ukraine

Example: High Cost of Diagnostics Errors in Public Health Care

- US economy: $750 Billion, annually
- Canada: 1 Million extra hospital-days, $750 Billion (decade)
- WHO study on Diagnostics Errors:

Sheikh A., Donaldson L., Westfall-Bates D. et.al.: Diagnostics errors. WHO Technical series on safer primary care

https://apps.who.int/iris/bitstream/handle/10665/252410/9789241511636-eng.pdf

Challenges

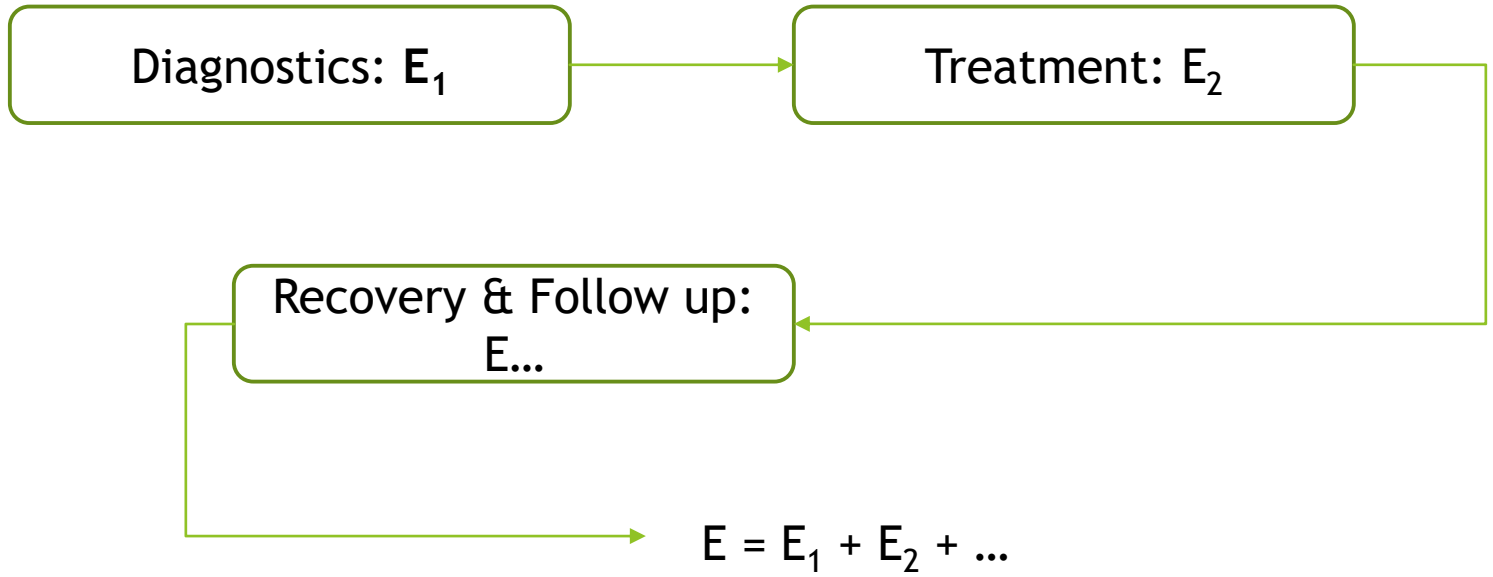
- **Human specialist:**
  - Performance affected by environment
  - Stress, burnout, distraction
  - Variation in education and experience
  - Competence
- **Machine system:**
  - Public perception
  - Track record or trust (lacking)
  - Insufficient understanding & confidence in learning quality

Synergy Potential

Human / AI	Strength	Challenge
Human	- *High intelligence* - *Associative capacity* - *Anomaly detection*	- *Influenced by environment* - *Stability: stress, burnout, distraction* - *Consistency: education, experience, competence*
Machine Intelligence	- *Stability and consistency* - *Efficiency and performance (e.g. throughput)* - *Accuracy (at and surpassing human)*	- *Perception (public trust)* - *Explainability (black box)* - *Operation record*

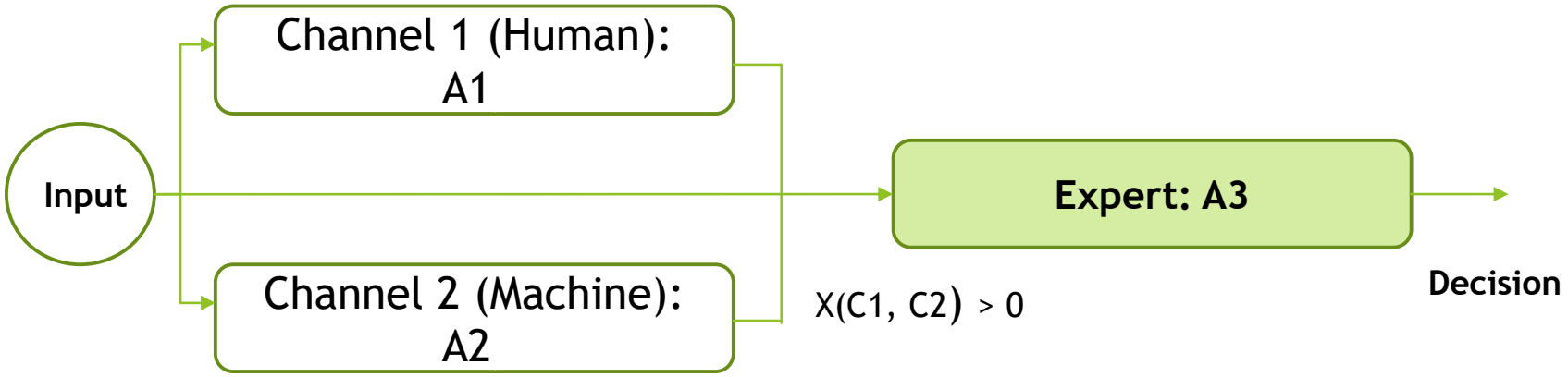
Challenge: combine advantages of human and machine intelligences while minimizing drawbacks

Single Chain Decision Making Model (Diagnostics)



- Errors accumulate, less effective outcome

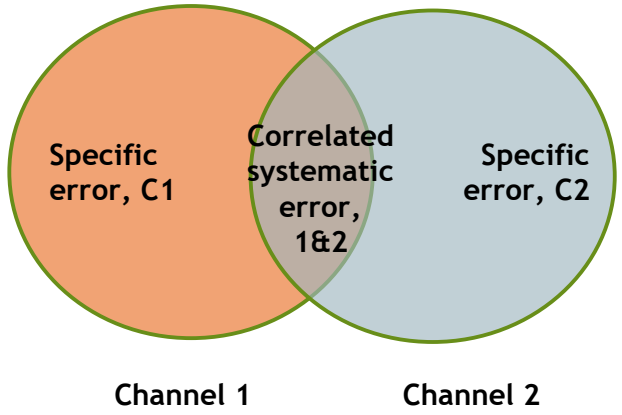
Multi-Channel Human-AI DMS



- Channels correct each other
- Expert decides in case of conflict between channels
- Reduced error, improved outcomes

Suppression of Error in a Multi-Channel System

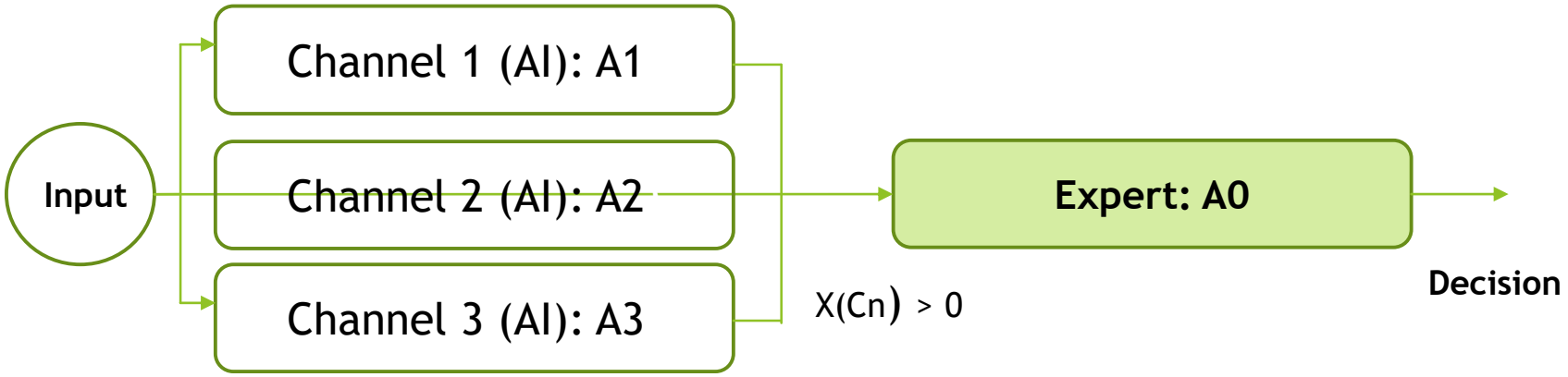
- Assumption: no significant source of Correlated Systematic Error
- $E_{sim} = E_1 \times E_2$
- $\mathbf{E_{total} = E_{sim} + (E_1 \text{ XOR } E_2) \times E_{exp}}$: errors in both channels suppressed!



Results, Multi-Channel Human-AI DMS (Diagnostics)

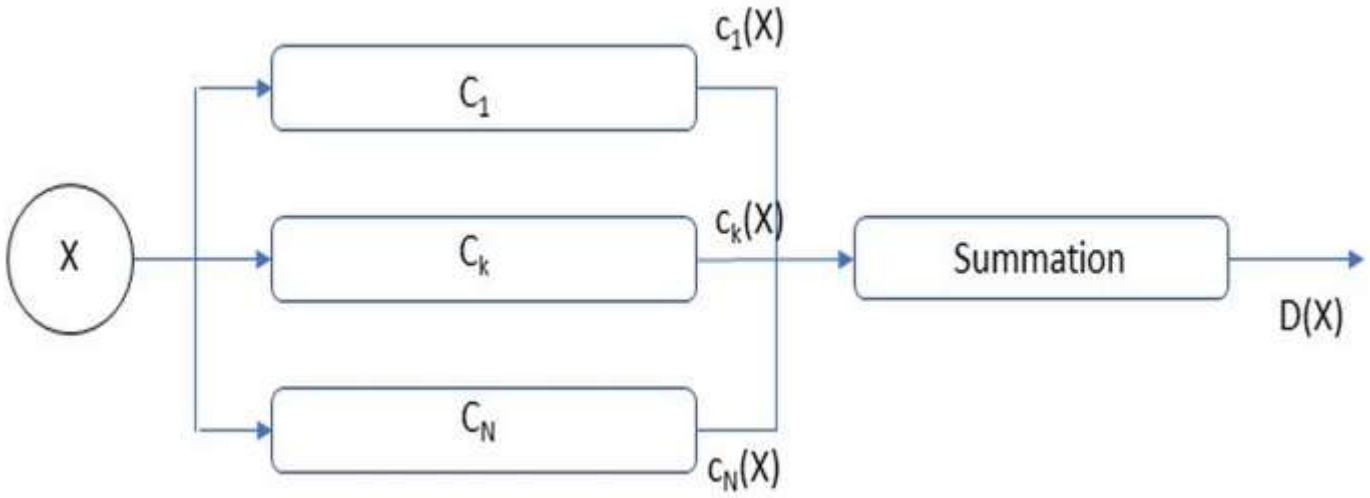
Condition	Single-Chain System	Multi-Channel Hybrid System	Gain, Accuracy
Internal	80%	92.8%	12.8%
Asthma	75%	88.1%	13.1%
Mammography	90%	98.1%	8.1%
Common	approx. 85%	95.2%	10.2%

Next Stage: Multi-Channel AI DMS with Human Arbiter



- AI channels independently trained
- Channel group error correction: reduced error, improved outcomes
- Human expert involved only in conflict: efficient use of resources

Single Stage Multi-Channel CHAI Systems



1. Minimizes the error of the decision function *D* on the set of possible inputs *{ X }*; and

2. Can be achieved within a time window shorter than operational time, t_m.

Single Stage Multi-Channel CHAI Systems

1. **Combined confidence**:

$$D = \begin{cases} True, \ if \ \sum\limits_{i=1,n:C_i=True} A_i \geq \sum\limits_{i=1,n:C_i=False} A_i; \\ False, \ otherwise. \end{cases}$$

The decision function is based on the sum of confidences of the channels that selected a decision, so that the decision with the highest confidence is selected.

2. **Difference of confidences**:

$$D = \begin{cases} True, \ if \ \max\limits_{i=1,n:C_i=True} A_i - \max\limits_{i=1,n:C_i=False} A_i \geq \Delta; \\ False, \ otherwise; \end{cases}$$

where $\Delta \in (-1, 1]$: const, confidence threshold.

3. **Voting**:

Let

$$\chi(C_i) = \begin{cases} 1, \ if \ C_i = True; \\ 0, \ if \ C_i = False. \end{cases}$$

Then the decision function

$$D = \begin{cases} True, \ if \ \sum\limits_{i=1}^{n} \chi(C_i) \geq \Delta; \\ False, \ otherwise; \end{cases}$$

where $\Delta \in (0, n]$: const, voting threshold.

Conclusions

Potential for Collaborative Human-AI (CHAI) Decision-Making Systems

- Significant gain in accuracy
- General, robust model
- Easily extends to new types of data, decision domains
- Highly efficient in operation
- Efficient utilization of limited resources
- Cost efficient

Potential for substantial improvement in both quality and operational performance of DMS in many areas of application!