Introduction to Collaborative Signal Processing

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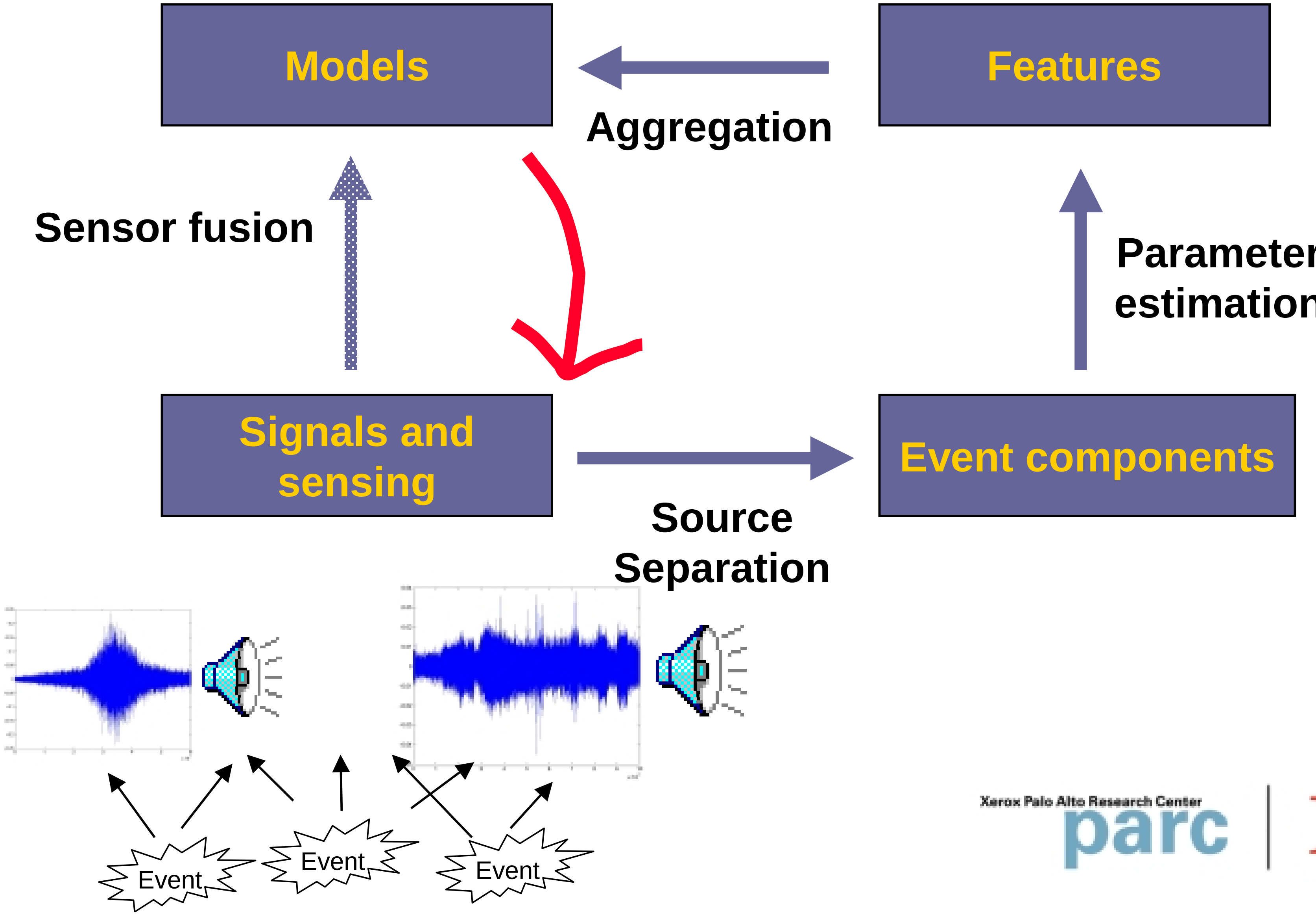
Model-Directed Sensing and Estimation

Insight: Model provides spatio- temporal priors to focus sensing and signal processing!



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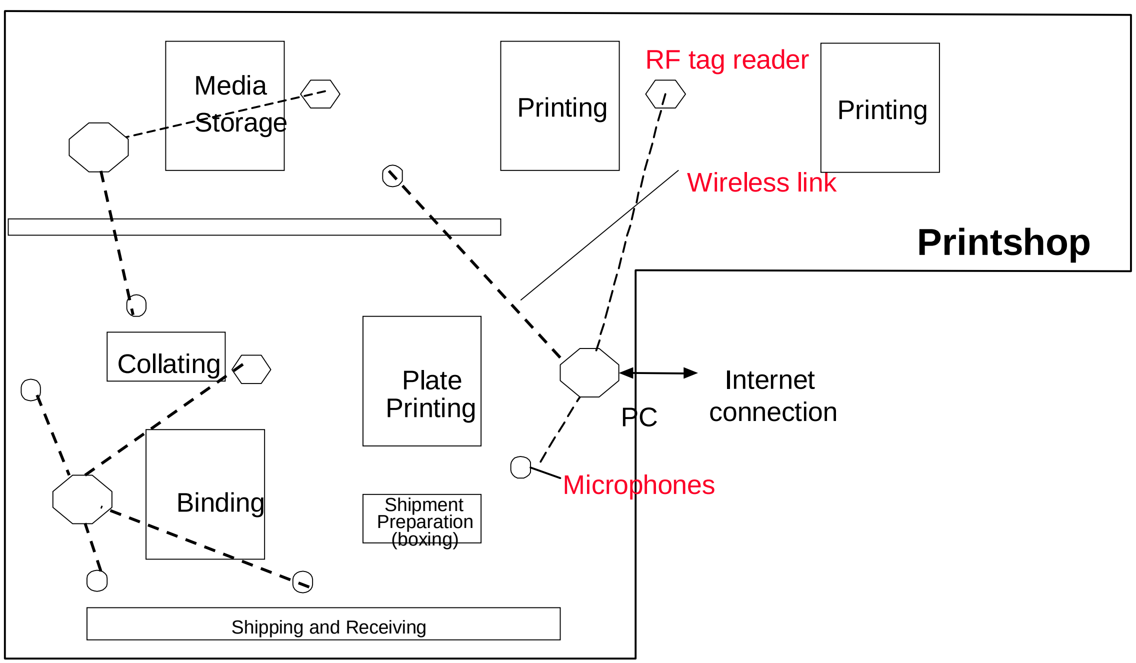
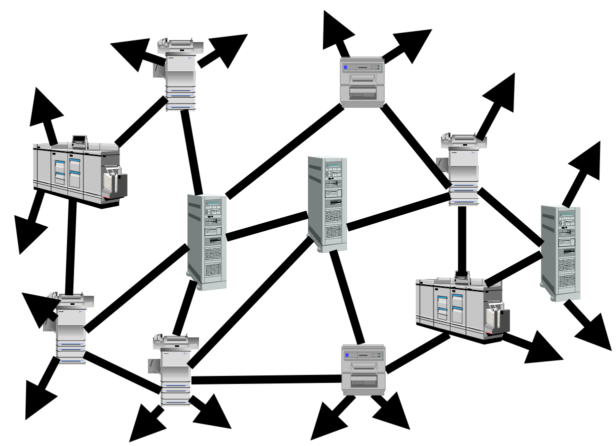
Tracking job flow in a printshop

- **The problem**: Identify *workflow* of printshops consisting of multiple machines
  - Determine job initiation, duration, and component conditions
  - Optimize the shop operations using the information
- **Requirement:** Minimal disruption to existing printshop operation and intrusion to customer networks (security)
- **Approach:** Use distributed microphones and RF tags to locate/track job flows





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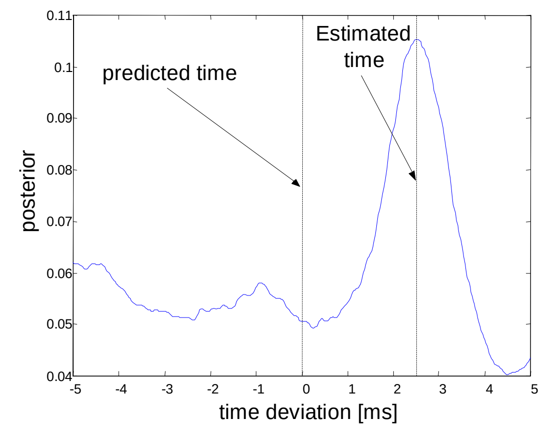
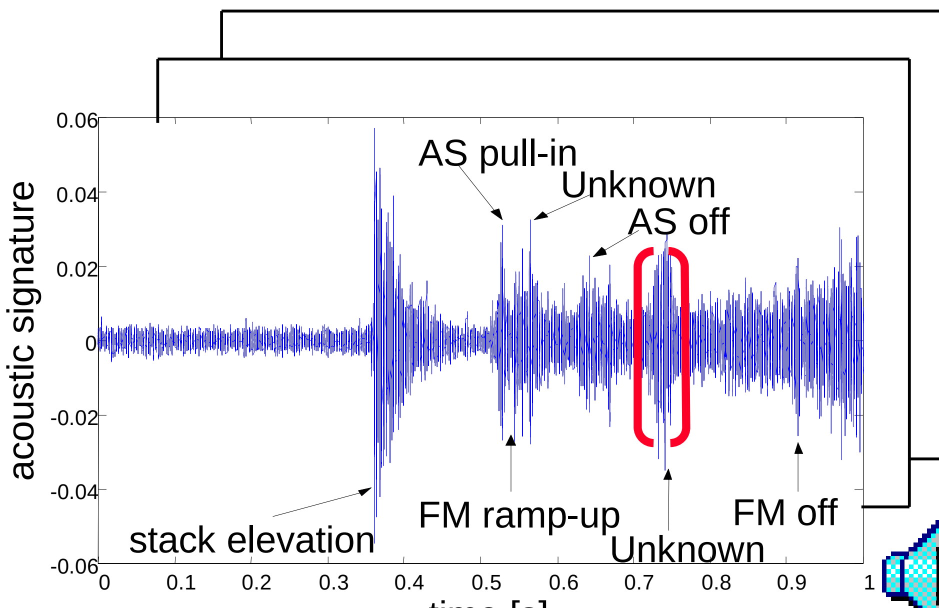
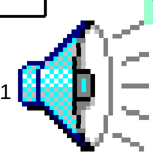
Idea: Event model as a temporal prior in distributed monitoring

- As in speech processing, identify grammar and inter-word constraints
- Use a Petri net event model to constrain the search for next “word”





Multi-channel data streams



(1) Prediction: $P(e^t) = M(e^{t-1}, e^{t-2}, \cdots)$

(2) Source separation:

$$\begin{bmatrix} z_1^t \\ \vdots \\ z_n^t \end{bmatrix} = \begin{bmatrix} \alpha_{11}\delta(t-\tau_{11}) & \cdots & \alpha_{1m}\delta(t-\tau_{1m}) \\ \vdots & & \\ \alpha_{n1}\delta(t-\tau_{n1}) & \cdots & \alpha_{nm}\delta(t-\tau_{nm}) \end{bmatrix} * \begin{bmatrix} s_1^t \\ \vdots \\ s_m^t \end{bmatrix}$$

Likelihood function:

$$P(\overline{\mathbf{z}}^t \mid \alpha, \tau) = k_1 \cdot \exp\left[-\tfrac{1}{2}(\mathbf{r}^t)^T \Sigma^{-1} \mathbf{r}^t\right]$$

(3) Update: $P(e^t \mid \overline{\mathbf{z}}^t) = k_2 \cdot P(\overline{\mathbf{z}}^t \mid e^t) \cdot P(e^t)$

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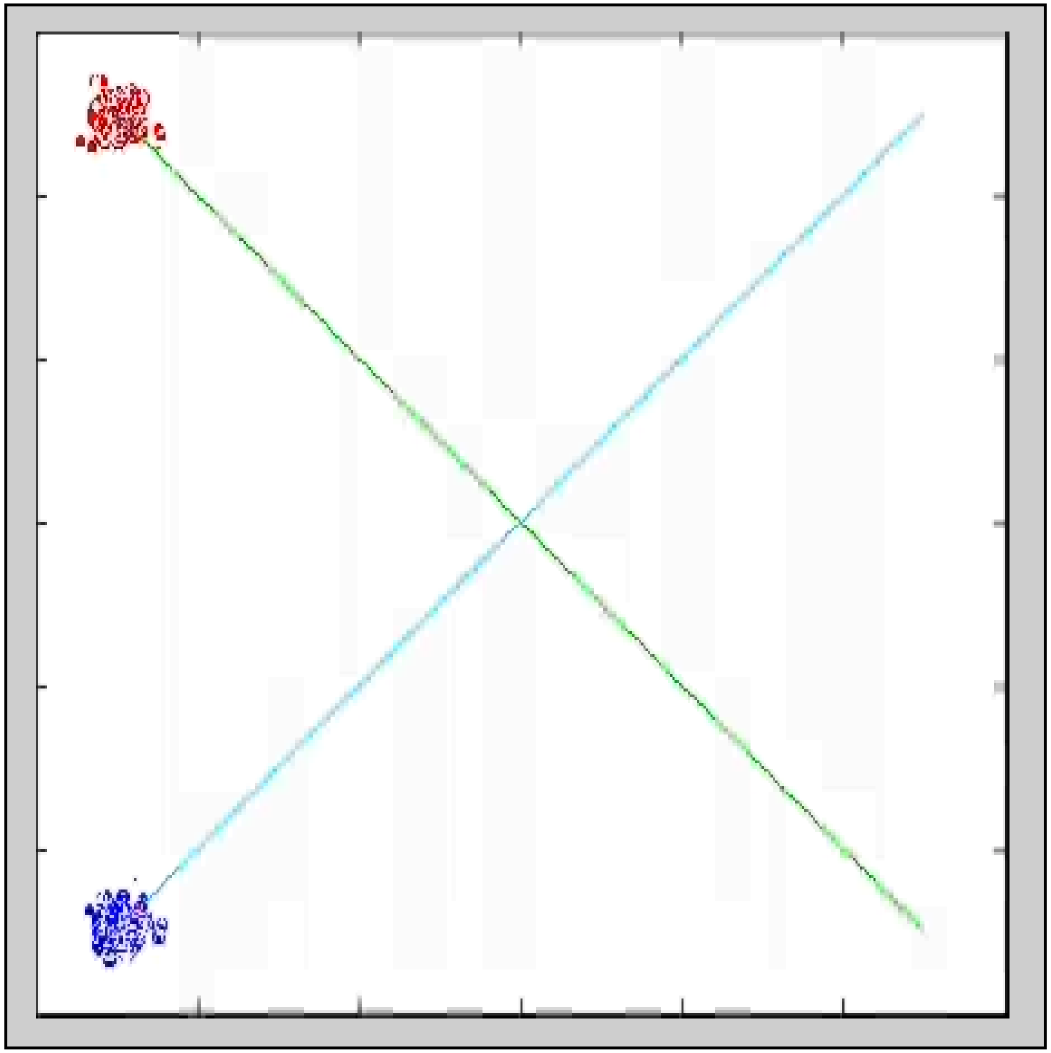
Dynamics as a prior in multiple target tracking



Two vehicle targets cross over

Particle Filter (Condensation) as an implementation for Bayesian Filtering

- Multi-modal, non-Gaussian distribution
- Uniform representation

$P(S_{k-1} | Z_{k-1})$ Probability distribution at k-1

$P(S_k | S_{k-1})$ Prediction

$P(Z_k | S_k)$ Observation

$P(S_k | Z_k)$ Probability distribution at k

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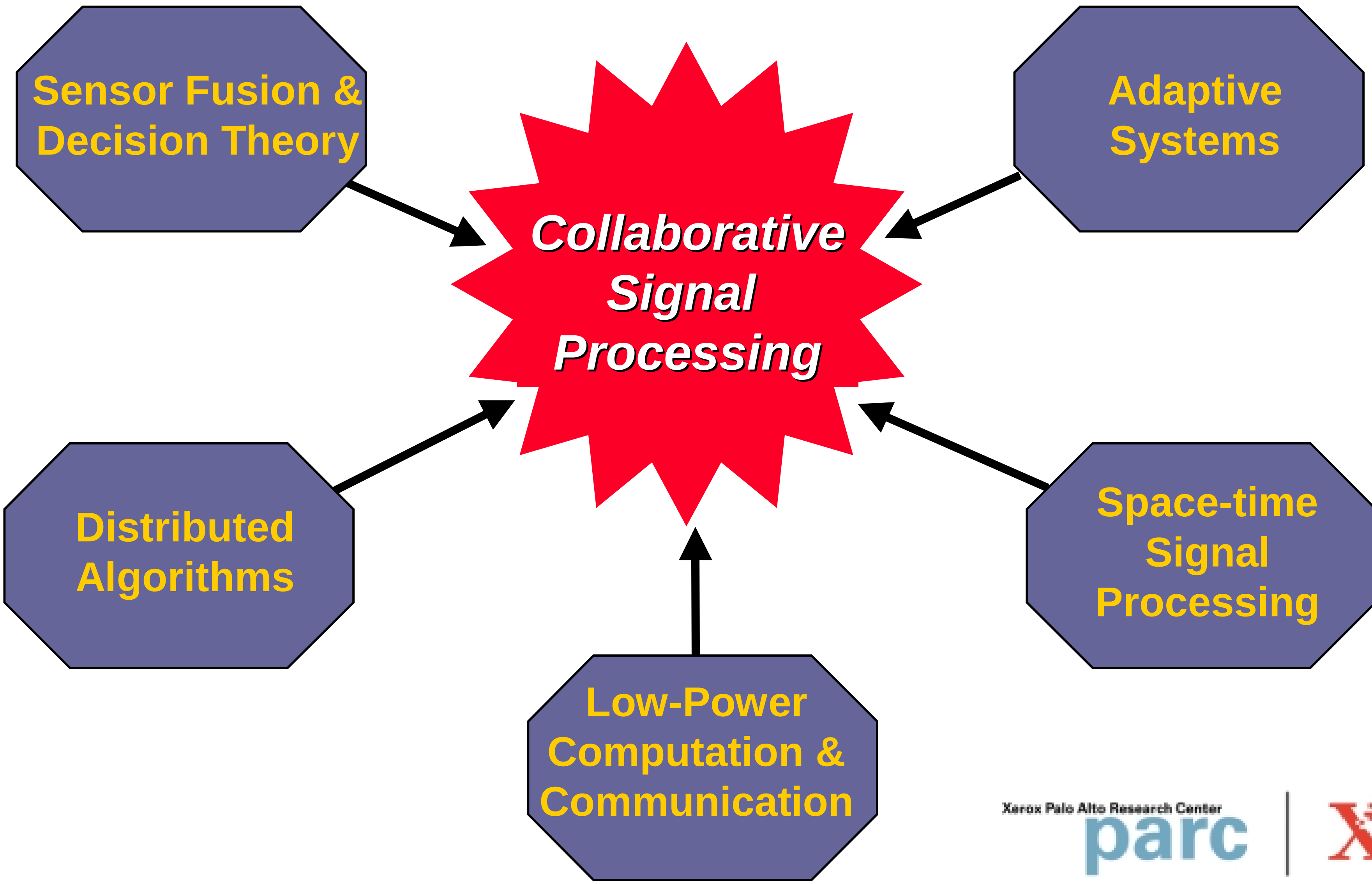
A few issues in distributed implementation

- Distribute hypotheses and models
- Transmit results v.s. raw data
- Exchange and combine data with great variability in latency and quality
- Dense small nodes vs. sparse large nodes
- Track pixels v.s. predicates
- Sensor wakeup and cueing
- Taxonomy of application scenarios

Emerging Discipline



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