What is a sensor selection?
- Given a claim made by an agent in an environment, how do we verify it?
- Place sensors throughout the environment
- Which sensors do we select?

Rahmani et al.\(^1\) showed that minimum sensor selection is NP-Hard.

What is privacy?
- Information collected could be considered private, or sensitive
- Specify many itineraries with 2 types of constraints:
  - Positive: 2 itineraries, each of which must not be confused with the other
  - Negative: 2 itineraries, one of which must appear identical to the other
- Constraints taken together form the desired discernment (DD) graph
  - Positive constraints – undirected edges
  - Negative constraints – directed edges

Satisfying Sensor Selections
- For each (undirected) pair of itineraries in discrimination ⇒ no walks should have the same signature
- For each (directed) pair of itineraries in conflation ⇒ for each walk from the first itinerary there must be a walk in the second itinerary having the same signature

Implications for finding solutions
- Adding privacy constraints makes the sensor selection problem significantly harder!
- Thus, we understand that
  - Adding more discrimination requirements between itineraries is still NP-Hard
  - However, even one conflation requirement raises the complexity to PSPACE-Hard
- If P ≠ PSPACE, then our ability to solve large instances of this problem is impaired.

Hardness results
- With privacy (negative) constraints added, it is PSPACE-Hard to solve for the minimum sensor selection.
- Why? The following provides some intuition:
  - Signature automata replace the alphabet in the itinerary DFAs (i.e. the edges) with their respective labels which turns them into NFAs! Why?
  - 2 edges from the same node may have the same label
  - Some edges may have the empty symbol (no sensors)
- Conflation constraints involve language inclusion checks on these signature automata ⇒ known to be PSPACE-Complete
- The example shows how conflation constraints map:
  - Each Venn diagram shows regular languages over the specified alphabets
  - Note that there are no common strings (walks) for itineraries ending in the kitchen and bedroom
- Mapped over the active sensors, the set of their signatures turn out to be exactly equal

Observations
- Adding privacy may increase the number of sensors required to satisfy all constraints
- Merely minimizing selected sensor on discrimination requirements does not guarantee specific privacy

Modeling the problem
- A world graph is an edge-labelled, directed multigraph
  - Each edge on the world graph has a label associated with it
  - Any walk taken on the world graph leads to a so-called “signature” with the caveat that edges with empty labels don’t produce a symbol
  - Itinerary: A set of walks described by a DFA or regular expression

Decision Problem: Minimal sensor selection to accommodate a discernment designation in itineraries (MSSADDI)
 Input: A world graph G, a discernment designation D, and a natural number k ∈ N.
 Output: A satisfying sensor selection M ⊆ S for D on G with |M| ≤ k, or ‘INFEASIBLE’ if none exist.

Optimizations
- On the complete enumeration of sensor sets, we can cache signature automata or apply adaptive weights on constraints
- Adaptive weights led to a 87% improvement in time.