A Framework for Monitoring Agent-Based Normative Systems *

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Outline of Talk

- Requirements for monitoring
- Overview of monitoring framework
- Representation and processing of norms for monitoring
- Agreements on what observations count as norm statuses and trusted observers
- Implementation and use case
- Conclusions and future work

Requirements for monitoring normative systems

- Norms (obligations, prohibitions, permissions) used to regulate and coordinate agent behaviours

- Autonomous agents may violate norms

  ⇒ enforcement mechanisms (sanctions) required to motivate compliance

  ⇒ monitoring of agent behaviours to determine compliance / violation

- Example obligation on purchaser P of goods G from a supplier S:

  If P is notified by S that goods G are in stock, then unless S is declared bankrupt, either P must
  • cancel the order within 7 days of receipt of notification,
  or;
  • accept the order and pay within 7 days of receipt of notification.

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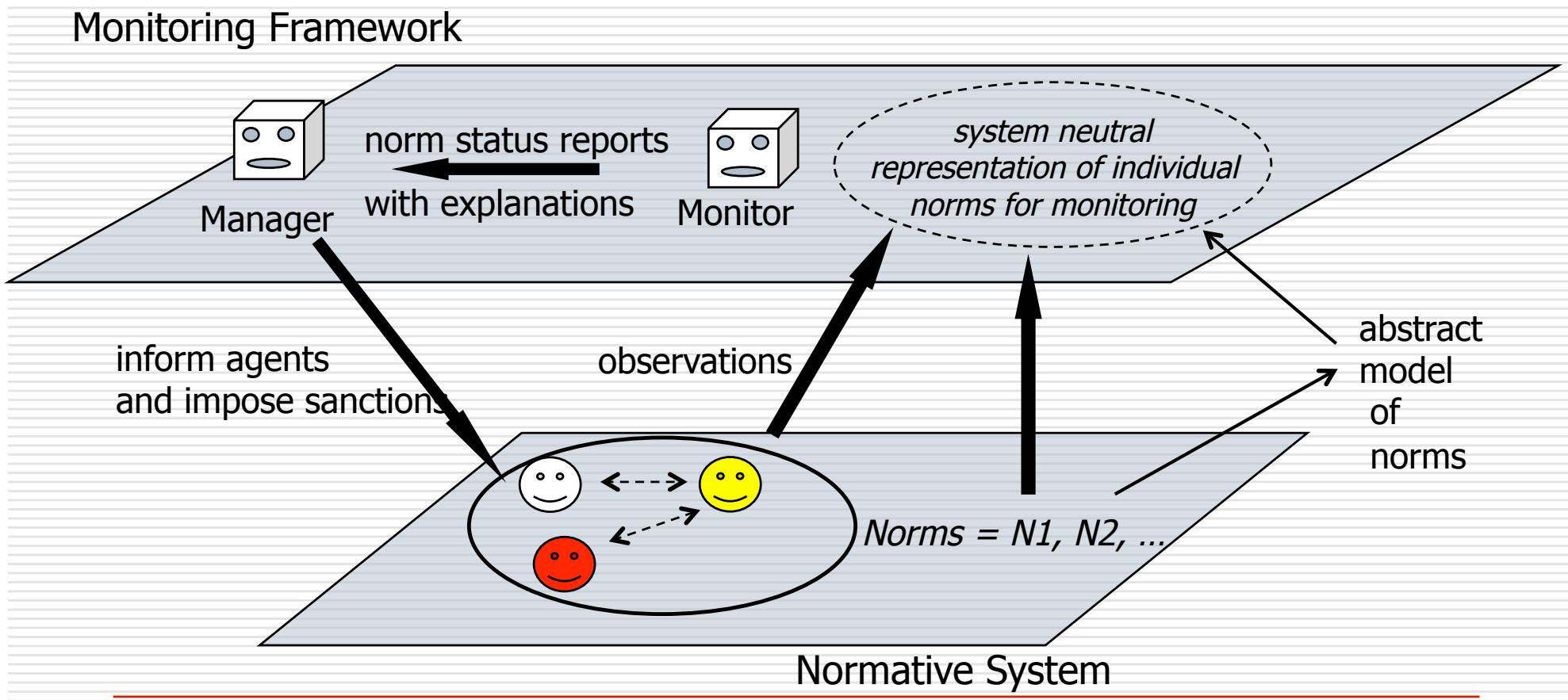
General Framework for Monitoring Normative Systems



An abstract model of norms for monitoring

- Norms describe complex behaviours and world states brought about by (groups of) agents, e.g., consider following obligation:

If P is notified by S that goods G are in stock, then unless S is declared bankrupt, either P must :

- *cancel the order within 7 days of receipt of notification,*

or;

- *accept the order and pay within 7 days of receipt of notification.*

(*Type, Target, Activation, Condition, Expiration*)

Type ∈ {*obligation*, permission, prohibition},

Target = agents whose behaviour is governed by the norm (*P*)

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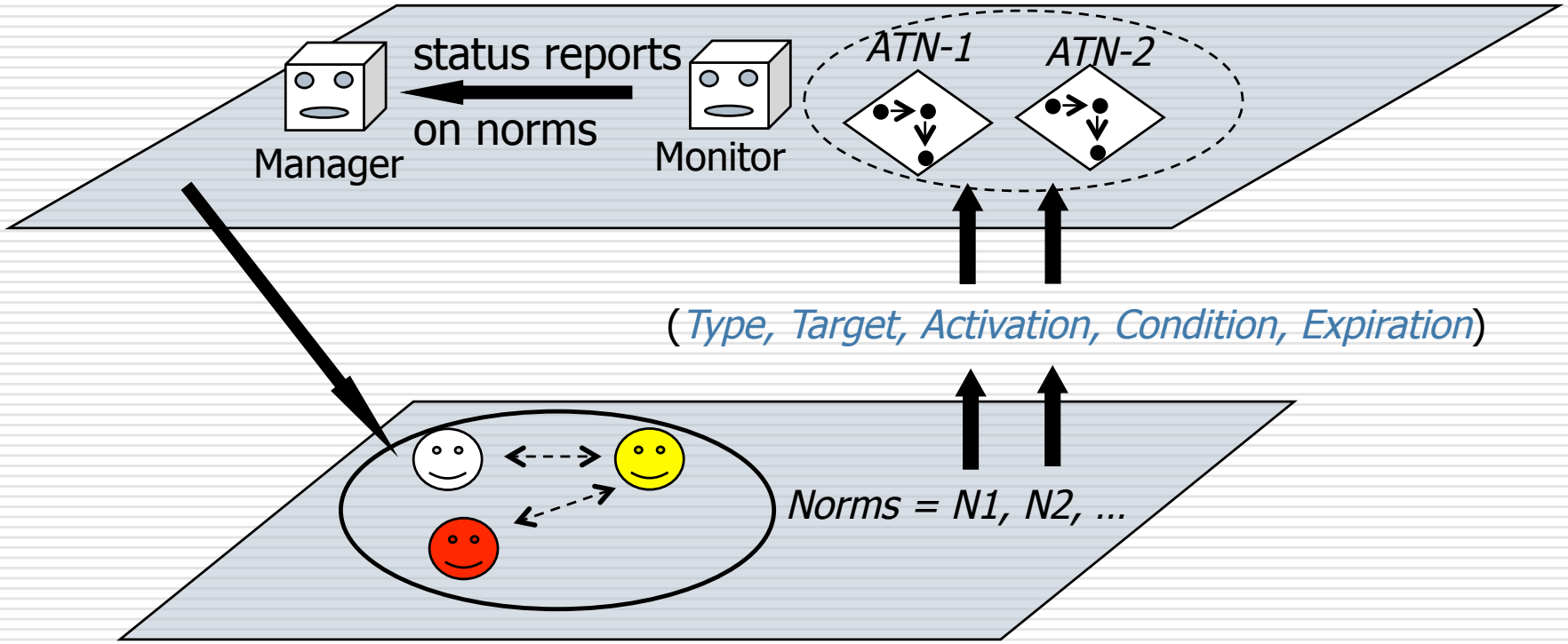
Activation = conditions under which norm applies to ***Target***

Condition = state that must be (obligation) may be (permission)
or must not be (prohibition) realised by ***Target***

Expiration = conditions under which norm no longer applies

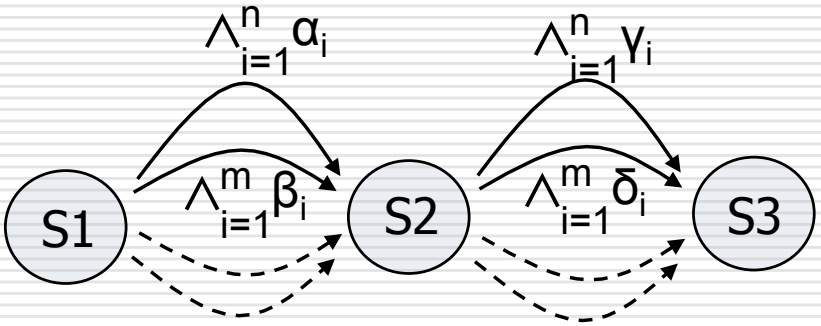
Representing norms for Monitoring

- Norms in many normative systems conform to abstract model
  => norms can be mapped to *Augmented Transition Networks* (*ATNs*) that reference elements of model and are used for monitoring status of norms



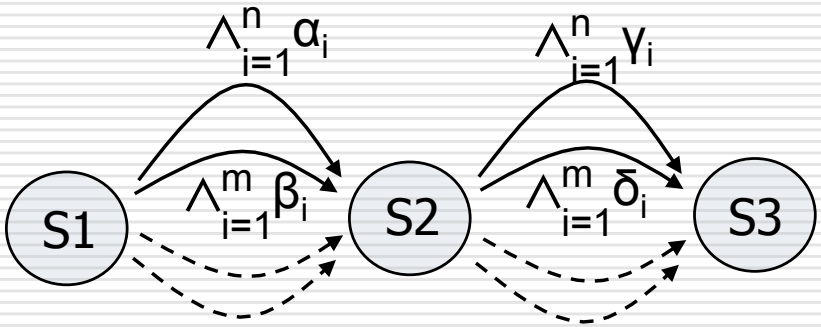
Processing ATN representations of norms

- ATNs are directed labelled graphs that transition from node to node based on satisfaction of connecting arcs' labels
- DNF representations of *Activation* = $(\alpha_1 \wedge \ldots \wedge \alpha_n) \vee (\beta_1 \wedge \ldots \beta_m) \vee \ldots$ and *Condition* = $(\gamma_1 \wedge \ldots \wedge \gamma_n) \vee (\delta_1 \wedge \ldots \delta_m) \vee \ldots$ map to labels of *ATN*



- If *Expiration* does not hold, and:
  - ATN in S1 (norm not active) and at least one arc label satisfied then transition arc to *activation* state S2
  - ATN in S2 and at least one arc label satisfied then transition arc to *fulfillment* state S3 (if obligation/permission) or *violation* state S3 (if prohibition)
  - Obligation ATN in S2 and *time window* elapses then obligation *violated*

Processing *ATN* representations of norms



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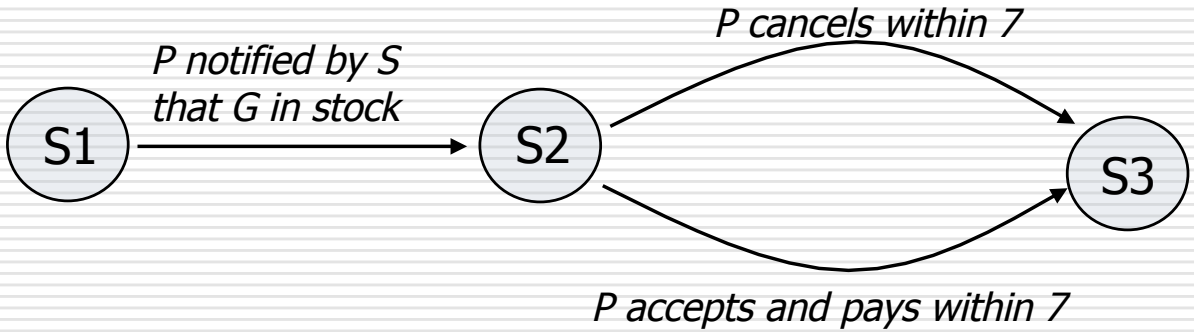


- If *NormExpiration* does not hold, and:

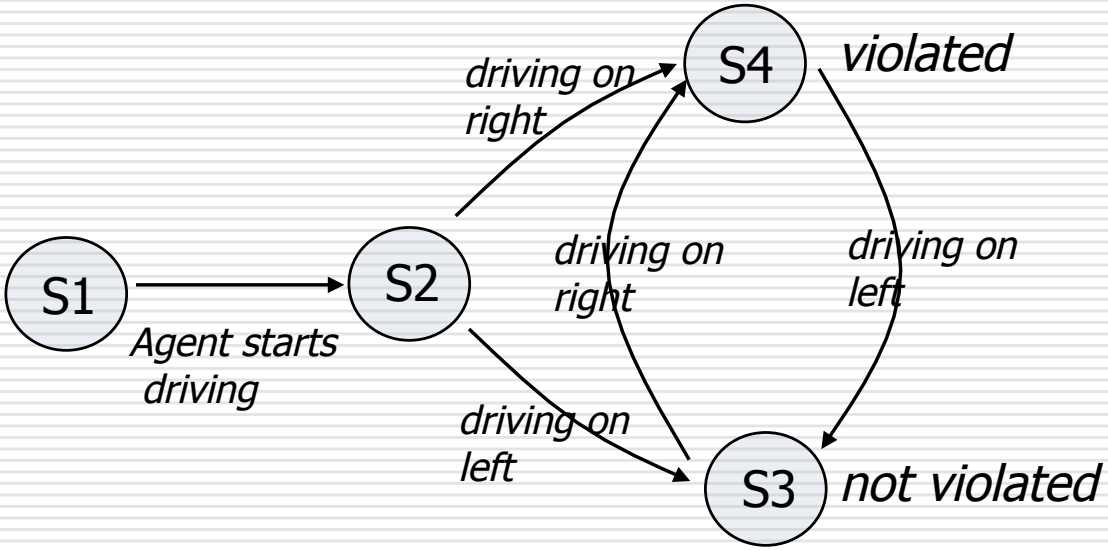
- *P* notified by *S* that *G* in stock at time *T* then transition to *S2* and norm activated (in force w.r.t. *P*)

- If *P* cancels at *T1* (*T1* ≤ *T* +*7*) or
  P accepts at *T2* (*T2* ≤ *T* +*7*) and pays at *T3* (*T3* ≤ *T* +*7*)
  then transition corresponding arc to fulfillment node S3

- If current time *T'* greater than time window *T* + *7* and *ATN* in S2 then obligation violated

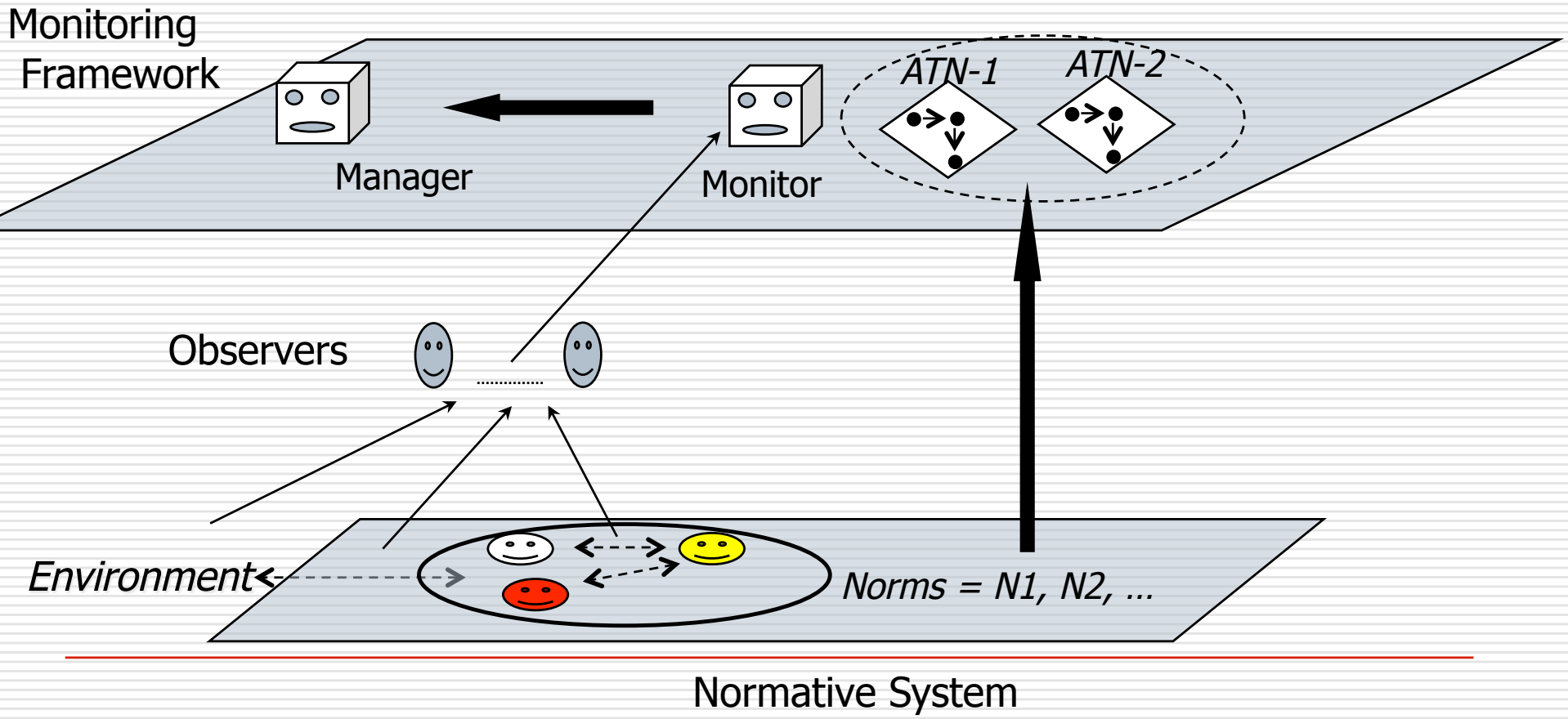
Processing *ATN* representations of *maintenance* norms

- 3 node *ATN*s for *achievement* norms
- 4 node *ATN*s for *maintenance* norms that may toggle between violated and not violated (e.g. *obligation to drive on left*)



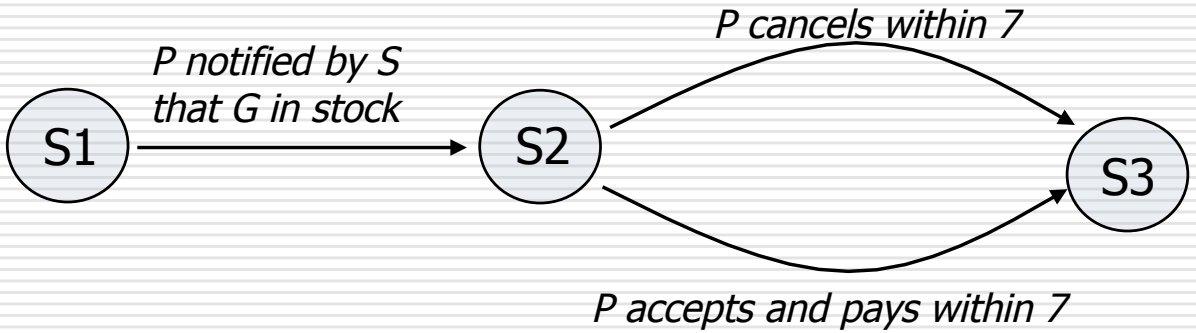
Matching observations with *ATN* labels

- Monitors match observations of world states and agent behaviours with *ATN* labels => transition *ATN*s across corresponding arcs



Counts as agreements and trusted observers

- Choice of observations (brute facts) that *count as* *Activation*, *Condition*, *Expiration* *and* choice of observers responsible for observations
  => important for motivating agent participation in normative systems since these choices impact on agents' confidence that sanctions applied appropriately



- What observed brute facts should count as *P paying S* and who should make and report these observations ?

Counts as agreements and trusted observers

- Observed message sent from *P* to *S* notifying *S* of payment -
  sent message counts as *P* pays *S*

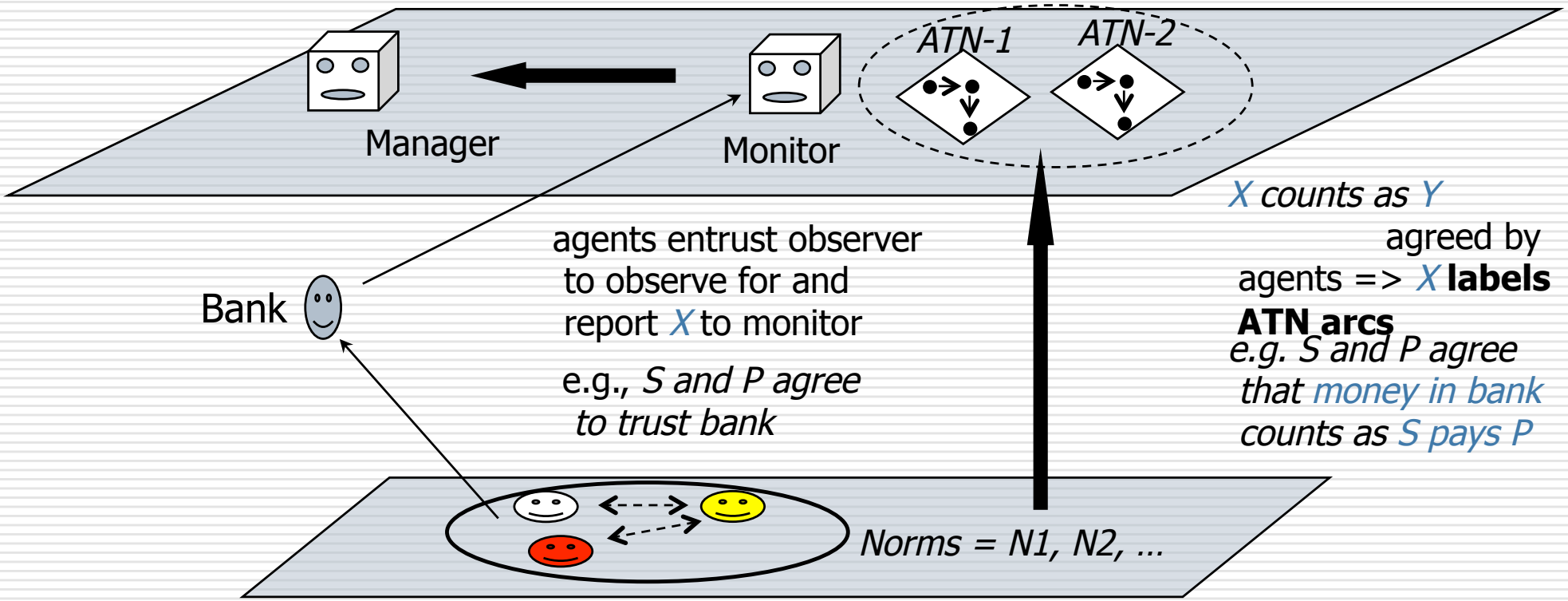
  => P may send message without actually paying and so avoid sanction
  => S not motivated to participate

- *S* sends notification message to monitor (i.e., *S* acts as observer) that money deposited in bank -
  money in bank counts as *P* pays *S*

  => money may be in bank but *S* does not notify and so sanction inappropriately imposed on *P* (resulting in some gain for *S*)
  => *P* not motivated to participate

Counts as agreements and trusted observers

- Agents agree on what brute facts count as *Activation*, *Condition*, and *Expiration and* agree on observers responsible for observing and relaying facts to monitor



Implementation and Use Case *

- Jason implementation of interacting aerospace agents governed by electronic contract

- Examples of contract normative clauses:

  - Service site obliged to repair engine for airline operator within 7 days

  - Service site prohibited from sourcing parts from part manufacturer

- JAVA implemented monitor processes observed messages exchanged between aerospace agents, together with ATN representations of norms

  Norm status reports visualised in GUI proxy for manager

* F. R. Meneguzzi, S. Modgil, N. Oren, S.Miles, M. Luck, N. Faci, C. Holt, M. Smith. Monitoring and Explanation of Contract Execution: A Case Study in the Aerospace Domain. To appear in: AAMAS 09,Industry and Applications Track, Hungary, 2009.

Conclusions and Future Work

- General framework for monitoring individual norms in underlying normative systems

  - Monitors process *ATN* representations of norms labelled by observed facts agreed by system agents as *counting as* statuses of norms
  - Facts relayed to monitors by observers explicitly entrusted by agents
  - Monitors create status reports on norms

- Implementation of monitor validated on electronic contract

- Future Work:

  - predictive monitoring whereby recognition of *danger* states (encoded as additional nodes in *ATN*s) signals danger of normative violations

  - enhanced explanations of normative violations