Programming for Autonomy

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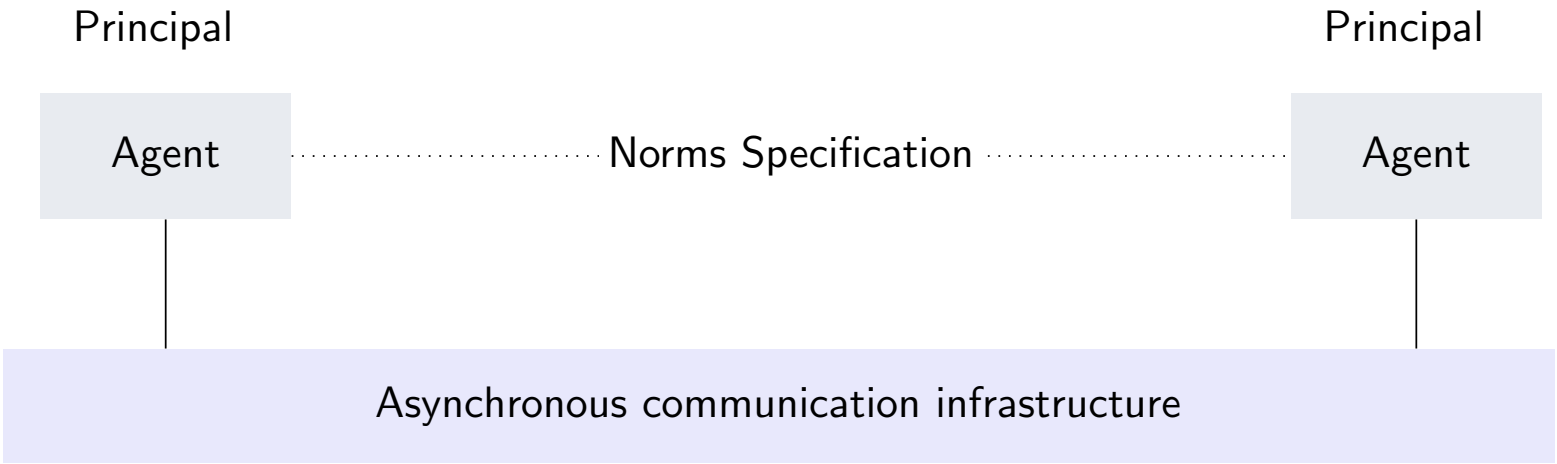
Decentralized System of Autonomous Principals

Finance, health, business,. . .



- Autonomous principals
  - Exercise independent decision making
  - Engage via arms-length communications
  - Subject to *norms* (expectations)
    - Correctness of engagements
    - E.g., as specified in agreements
  - Principals may violate norms

Commitment: Exemplar Norm Kind

Cupid (With M. P. Singh, AAAI 2015)

```
base events
  quote(S, B, ID, item, price)
  accept(S, B, ID, item, price, addr)
  pay(S, B, ID, item, price, amt)
  deliver(S, B, ID, item, price, addr, status)

commitment PurchaseCom S to B
  create quote
  detach (accept and pay) within quote + 5d
     where amt >= price
  discharge deliver within detached(PurchaseCom) + 10d
```

Operationalizing Commitments via Protocols

Decentralized computation of commitment events

- Who effects an event and when?
- Who observes an event and when?
- Who may generate (bind) a piece of information?

```
base events
  quote(S, B, ID, item, price)
  accept(S, B, ID, item, price, addr)
  pay(S, B, ID, item, price, amt)
  deliver(S, B, ID, item, price, addr, status)

commitment PurchaseCom S to B
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  discharge deliver within detached(PurchaseCom) + 10d
```

Information Protocols in BSPL

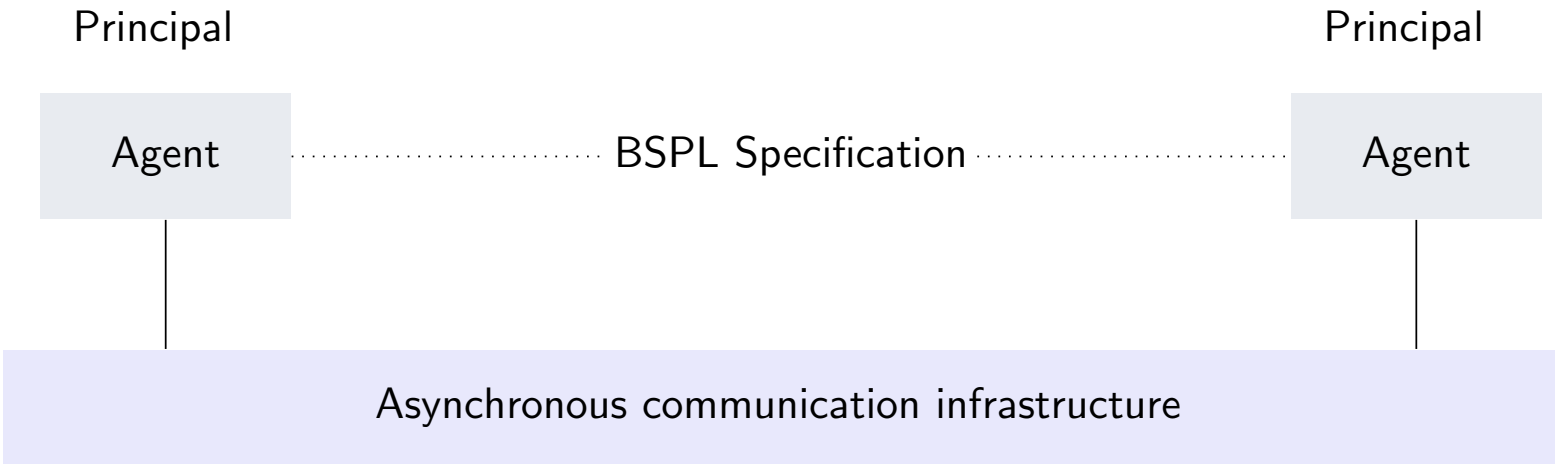
Explicitly specify causality and integrity (M. P. Singh, AAMAS 2011-12)

```
Purchase {
  role B, S
  parameter out ID, out item, out price, out addr, out amt, out
      status

  S ↦ B: quote[out ID, out item, out price]
  B ↦ S: accept[in ID, in item, in price, out addr]
  B ↦ S: pay[in ID, in item, in price, out amt]
  S ↦ B: deliver[in ID, in item, in price, in addr, out status]
}

    AltPurchase {
      ...
      B ↦ S: accept[out ID, out item, out price, out addr]
    }
```

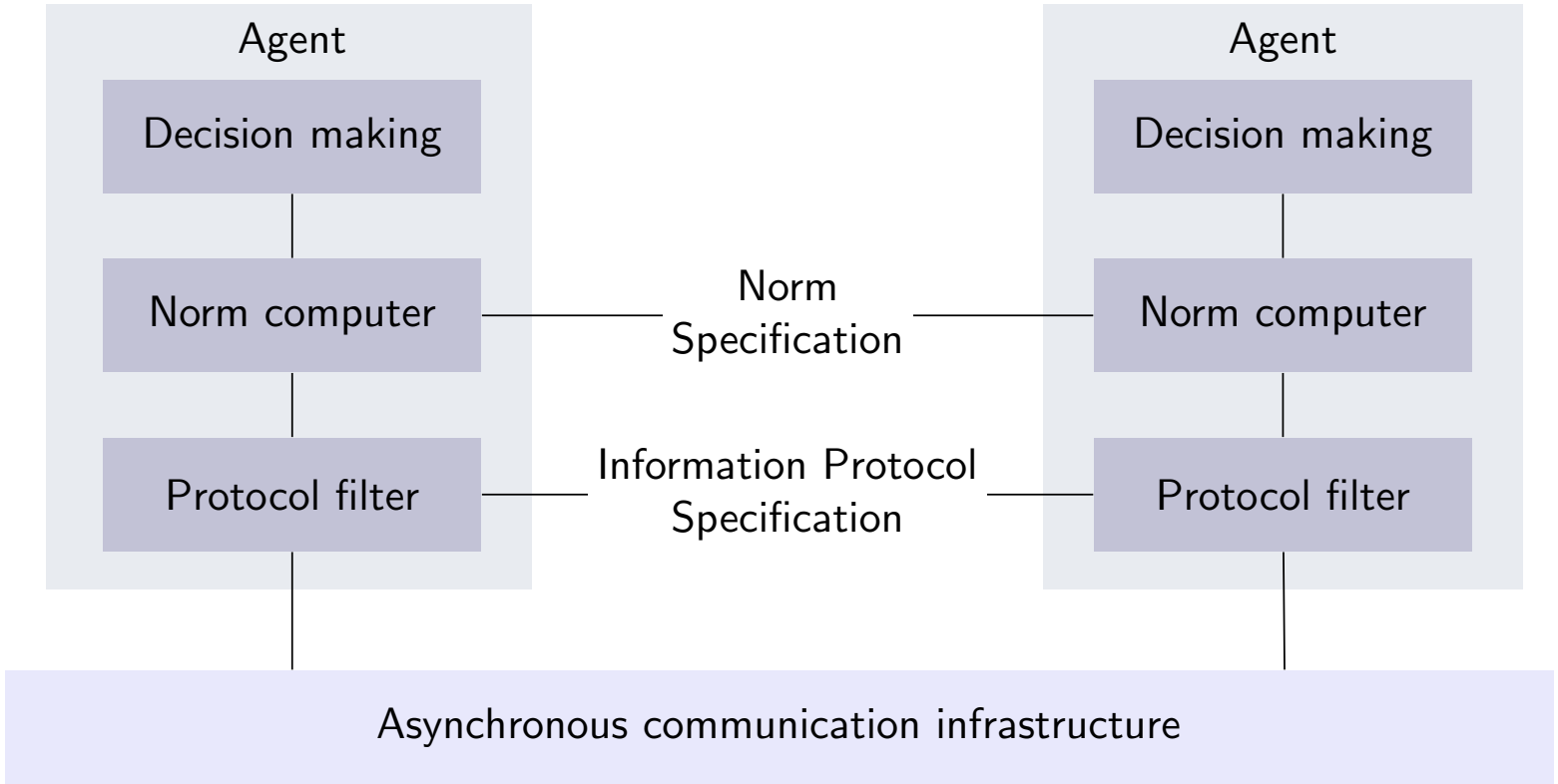
BSPL, Architecturally



- Agents communicate asynchronously
  - Nonblocking emissions
  - Nondeterministic receptions
- Agents require no message ordering guarantees
- Agents ensure emissions are locally correct
- Receptions are guaranteed correct!
  - No agent required to do . . . ?m. . .

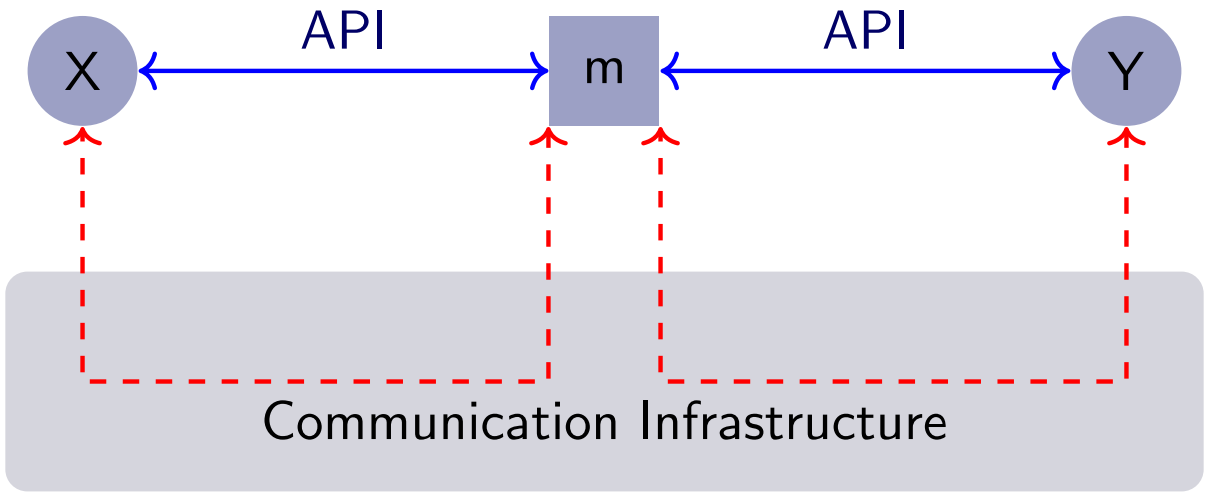
Autonomy-Oriented Architecture

Interaction-oriented architecture



Traditional Software Engineering: Machine-Oriented

No representation of norms



Takeaways

- Autonomy means decentralized system
- Autonomy *requires* norms *requires* information protocols
  - Application: Agreement-based systems
- Protocol specifies how to compute a decentralized information object
  - Via causality and integrity constraints
  - Never worry about asynchrony or ordering again :)

Acknowledgments

- Munindar P. Singh, North Carolina State University
  - Social abstractions and their decentralized computation
  - Information protocols (BSPL)
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