Towards Law-Aware Semantic Cloud Policies with Exceptions for Data Integration and Protection

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Legal Informatics, School of Law
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Motivations

1. Current cloud infrastructures do not provide enough automatically self-managed services.

2. In order to seek technology innovation on Software-as-a-service (SaaS), we apply semantic web technologies for cloud computing.

3. Automatically self-managed SaaS is not only for automatic allocation of cloud resources, but also for enforcing security and privacy policies.

4. Law-as-a-Service (LaaS) further enhances security and privacy policy representation and enforcement in the cloud.
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1. How to empower semantic technologies for cloud computing to provide law-aware semantics-enabled cloud policies?
2. How to accomplish data protection while enforcing data integration?
3. How to use semantic legal policies to interpret laws and ensure the legality of data sharing and protection across jurisdictions?
4. How to unify semantic policies and allow defeasible reasoning of a policy's exceptions handling?
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2. Semantic legal policies for data integration and protection are designed and enforced in a super-peer architecture.
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A Law-Aware Semantic Policy Infrastructure

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- Trusted Legal Domain (TLD)
- Trusted Virtual Domain (TVD)
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A Law-Aware Semantic Policy Infrastructure (conti.)
Logical Cage Model vs. Legal Cage Model

- A TVD is a *logical cage* model, which consists of a set of distributed virtual machines (VMs), storage for the VMs, and a communication medium interconnecting the VMs [6].
- A TLD is a *legal cage* model, which determined by a specific law, to regulate virtual legal boundary of data disclosure and usage.
- TLD concepts are modeled as a taxonomy of laws, where a type of law and an effective judicial domain are two factors to decide whether a data request is allowed.
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Semantic Legal Policies as Logical Theories [5]

- Semantic legal policies are expressed as logical theories for information queries, and context are sets of ground facts that fed into policies for outputs.
- Semantic legal policies are mapping from a data usage context to access control decisions, such as permit, deny, and error.
- A data usage context comprises a user’s role along with his/her personal properties, resources metadata, access time, access location, purpose, and action, etc.
- Once a user’s data usage context is satisfied with the domain policy of a TLD, the semantic legal policies of this TLD are identified and executed.
- Semantic legal policy outputs (or query answers) are also encoded as logical formulas for authorization.
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Related Work

Several categories are related to this study:

- **Multi-tenant cloud services**: Abbadi [1], Cabuk [6], Eberhart [13], Foresti [16], Haase [20], Hu [25].
- **Peer data management**: Beneventano [3], Calvanese [7], Halevey [21] [22], Hu [27], Madhavan [31].
- **Semantic policies for data sharing and protection**: Clifton [10], Hu [24] [26].
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- A Peer Data Management System (PDMS) is the best way to achieve wide-scale data integration over the Internet.
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Possible semantic mappings from local schemas to global schema:
- Global-As-View (GAV): expressing each concept in the global schema as queries over the data sources.
- Local-As-View (LAV): expressing each concept in the data sources as a query (or view) over the global schema.
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Principles of Data Protection Laws

Three principles of data protection laws for cloud computing:

- *Registration* principle: location of service provider registration, which enables data collection services.
- *Nationality* principle: nationality of the data owner whose data are being used.
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Applying semantic technologies in the trusted virtual cloud infrastructure to:

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A super-peer data cloud system is a set of super-peer domains \( \Pi = \{ \pi_1, ..., \pi_n \} \), where

- Each super-peer domain \( \pi_i \) corresponds to a TLD.
- Grouping a set of peers into a super-peer domain and organize them into a two-level architecture: peers and super-peer.
- The super-peer is a guardian, which integrates all of its local peers’ ontologies into a global ontology through ontology mapping, alignment, and merging.
- Semantic global mappings are also possible from the current Super-peer \( \alpha \) to interlink with another Super-peer \( \beta \).
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A super-peer domain $\pi_\alpha \in \Pi$, corresponding to a $TLD_\alpha$, can be defined as a tuple $(P_\alpha, SPD_\alpha, GS_\alpha, LS_{peer_i}, M_\alpha, DS_\alpha)$:

- A super-peer $sp_\alpha$ is the only node in a super-peer domain $\pi_\alpha \in SPD_\alpha$, which allows an agent $\alpha$ to enforce semantic legal policies.
- Through local LAV mapping assertions, a global schema $GS_\alpha$ provides an integrated view for a set of peers from $P_\alpha = \{peer_1, ..., peer_n\}$.
- A set of peers from $P_\alpha$ are mediators. A peer $p_i \in \pi_\alpha$ maps its local ontology schema, $LS_{peer_i}$, to a set of relational data sources, $ds_i$, from $DS_\alpha = \{ds_1, ..., ds_m\}$.
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Semantics of Multiple TLDs

A super-peer domain $\pi_\alpha$ for $TLD_\alpha$ is related to another super-peer domain $\pi_\beta$ for $TLD_\beta$ through:

- A set of super-peer’s GLAV semantic mapping assertions

\[ CQ_{\pi_\beta}(sp_\beta) \rightsquigarrow CQ_{\pi_\alpha}(sp_\alpha) \]

where $CQ_{\pi_\beta}(sp_\beta)$ and $CQ_{\pi_\alpha}(sp_\alpha)$ are conjunctive queries over the super-peer $sp_\beta$ and super-peer $sp_\alpha$.

- A Datalog rule is a mapping assertion of GLAV:

\[ H \leftarrow B_1 \land B_2 \land \cdots \land B_n \]

where $H$, query results (or views) are from the source of $sp_\alpha$’s global ontology schema, and rule antecedent $B_i$, is a pattern matching specification from target $sp_\beta$’s global ontology schema.
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\[
CQ_{\pi_\beta}(sp_\beta) \leadsto CQ_{\pi_\alpha}(sp_\alpha)
\]

where \( CQ_{\pi_\beta}(sp_\beta) \) and \( CQ_{\pi_\alpha}(sp_\alpha) \) are conjunctive queries over the super-peer \( sp_\beta \) and super-peer \( sp_\alpha \).

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A semantic legal policy is created from a policy language, and a semantic legal policy language is shown as a combination of ontology language and rule language.

A semantic legal policy is composed of ontologies and rules, where ontologies are created from an ontology language and rules are created from a rule language.

Currently, OWL-DL is used for policy ontology and stratified Datalog with negation, e.g., $Datalog^\neg$, rules are used for defeasible rules reasoning.

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Policy Ontology for a Super-Peer Domain

Semantics of a super-peer data cloud includes two modular concepts:

1. **super-peer domain**
2. **domain policy and data policy**
Semantics of a super-peer data cloud includes two modular concepts:

1. super-peer domain
2. domain policy and data policy
Balancing policy expressive power and computational complexity from integration of ontologies and rules.

OWL-DL with positive unary and binary datalog rule from SWRL is not capable for a policy’s exceptions handling.

How about using different species of DL-Lite, e.g. $DL - Lite_A$, $DL - Lite_F$, $DL - Lite_R$ integrated with extended Datalog, $Datalog^{+-}$, for a semantic legal policy enforcement?

Consider seriously about policy enforcement criteria in terms of computational complexity, such as undecidable vs. decidable, intractable vs. tractable, etc.
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Semantic Legal Policies
A Domain Policy’s Ontology

A PARTIAL ONTOLOGY FOR A DOMAIN POLICY

```
hasTLD.DomainPolicy(dmp), hasTLD⁻.TLD(tld).
hasCondition.DomainPolicy(dmp),
hasCondition⁻.Condition(dmc).
hasPartOf.Condition(dmc),
hasPartOf⁻. Purpose(checkIn),
hasPartOf⁻. DataUser(airlineStaff),
hasPartOf⁻. Action(read).
hasPartOf⁻. Location(TW),
hasPartOf⁻. Consent(⊤).
= 1 hasSuperPeer⁻. Super⁻ Peer(sp),
∃ hasPeers.Peer(p),
∀ registerAt.Peer(p),
∃ registerAt⁻. Super⁻ Peer(sp).
```
Semantic Legal Policies (conti.)
A Domain Policy’s Rules (conti.)

**LINK BETWEEN TLD AND SPD**

\[
\text{DomainPolicy}(?\text{dmp}) \land \text{hasTLD}(?\text{dmp}, ?\text{tld}) \land \text{correspondTo}(?\text{tld}, ?\text{spd}) \land \text{SPD}(?\text{spd}) \rightarrow \text{domainPolicyForSPD}(?\text{dmp}, ?\text{spd}) \leftarrow (1)
\]

**REQUEST FOR AN SPD**

\[
\text{Request}(?r) \land \text{hasCondition}(?r, ?c) \land \text{Condition}(?c) \\
\land \text{DomainPolicy}(?\text{dmp}) \land \text{hasCondition}(?\text{dmp}, ?\text{dmc}) \land \text{Condition}(?\text{dmc}) \\
\land \text{isSubsumed}(?c, ?\text{dmc}) \land \text{domainPolicyForSPD}(?\text{dmp}, ?\text{spd}) \\
ightarrow \text{getInTo}(?r, ?\text{spd}) \leftarrow (2)
\]
Semantic Legal Policies (conti.)
A Domain Policy’s Rules (conti.)

**Link between TLD and SPD**

\[
\text{DomainPolicy}(\text{?dmp}) \land \text{hasTLD}(\text{?dmp}, \text{?tld}) \land \text{correspondTo}(\text{?tld}, \text{?spd}) \land \text{SPD}(\text{?spd})
\]
\[\rightarrow \text{domainPolicyForSPD}(\text{?dmp}, \text{?spd}) \leftarrow (1)\]

**Request for an SPD**

\[
\text{Request}(\text{?r}) \land \text{hasCondition}(\text{?r}, \text{?c}) \land \text{Condition}(\text{?c})
\land \text{DomainPolicy}(\text{?dmp}) \land \text{hasCondition}(\text{?dmp}, \text{?dmc}) \land \text{Condition}(\text{?dmc})
\land \text{isSubsumed}(\text{?c}, \text{?dmc}) \land \text{domainPolicyForSPD}(\text{?dmp}, \text{?spd})
\]
\[\rightarrow \text{getInTo}(\text{?r}, \text{?spd}) \leftarrow (2)\]
Semantic Legal Policies
A Data Policy’s Ontology (conti.)

A PARTIAL ONTOLOGY FOR A DATA POLICY

isBelongedTo.DataPolicy(dap),
isBelongedTo\!.DomainPolicy(dmp).
hasPII.Data(da), hasPII\!.PII,
hasPFlightInfo.PII(pii),
hasPFlightInfo\!.PersonalFlightInfo(fInfo).
hasPartOf.PersonalFlightInfo(finfo),
hasPartOf\!.Name(name),
hasPartOf\!.PassportNo.(pano),
hasPartOf\!.Nationality(citizenship),
hasPartOf\!.FlightNo.(fno),
hasPartOf\!.Date(date).
hasPartOf\!.Address(addr).
hasPartOf\!.PhoneNumber(pono).
Semantic Legal Policies (conti.)
A Data Policy’s Rules (conti.)

**SUPER-PEER HAS ITS OWN PEERS**

\[ SPD(?spd) \land \text{hasSuperPeer}(?spd, ?sp) \land \text{Super} - \text{Peer}(?sp) \land \text{hasPeers}(?spd, ?p) \land \text{Peer}(?p) \land \text{registerAt}(?p, ?sp) \rightarrow \text{hasOwnPeers}(?sp, ?p) \]  
\[ \leftarrow (3) \]  

**SUPER-PEER IS ALLOWED TO DISCLOSE PII**

\[ \text{Super} - \text{Peer}(?sp) \land \text{hasOwnPeers}(?sp, ?p) \land \text{Peer}(?p) \land \text{canFind}(?p, ?da) \land \text{Data}(?da) \land \text{hasPII}(?da, ?pii) \land \text{PII}(?pii) \rightarrow \text{hasDisclosedFor}(?sp, ?pii) \]  
\[ \leftarrow (4) \]
Semantic Legal Policies (conti.)
A Data Policy’s Rules (conti.)

**Super-peer has its own peers**

\[
\text{SPD}(spd) \land \text{hasSuperPeer}(spd, sp) \land \text{Super} - \text{Peer}(sp) \land \text{hasPeers}(spd, p) \land \text{Peer}(p) \land \text{registerAt}(p, sp) \rightarrow \text{hasOwnPeers}(sp, p) \leftarrow (3)
\]

**Super-peer is allowed to disclose PII**

\[
\text{Super} - \text{Peer}(sp) \land \text{hasOwnPeers}(sp, p) \land \text{Peer}(p) \land \text{canFind}(p, da) \land \text{Data}(da) \land \text{hasPII}(da, pii) \land \text{PII}(pii) \rightarrow \text{hasDisclosedFor}(sp, pii) \leftarrow (4)
\]
Semantic Legal Policies (conti.)
A Data Policy’s Rules (conti.)

A DATA POLICY FOR AN SPD

\[
\text{DataPolicy}(\text{dap}) \land \text{isBelongedTo}(\text{dap}, \text{dmp}) \land \text{DomainPolicy}(\text{dmp}) \\
\land \text{domainPolicyForSPD}(\text{dmp}, \text{spd}) \rightarrow \text{dataPolicyForSPD}(\text{dap}, \text{spd}) \leftarrow (5)
\]

REQUEST CAN USE PII

\[
\text{Request}(\text{r}) \land \text{getInTo}(\text{r}, \text{spd}) \land \text{satisfy}(\text{r}, \text{dap}) \land \text{DataPolicy}(\text{dpa}) \\
\land \text{dataPolicyForSPD}(\text{dap}, \text{spd}) \land \text{SPD}(\text{spd}) \land \text{hasSuperPeer}(\text{spd}, \text{sp}) \\
\land \text{hasDisclosedFor}(\text{sp}, \text{pii}) \rightarrow \text{canUse}(\text{r}, \text{pii}) \leftarrow (6)
\]
Semantic Legal Policies (conti.)
A Data Policy’s Rules (conti.)

A DATA POLICY FOR AN SPD

\[
\text{DataPolicy}(\text{dap}) \land \text{isBelongedTo}(\text{dap}, \text{dmp}) \land \text{DomainPolicy}(\text{dmp}) \\
\land \text{domainPolicyForSPD}(\text{dmp}, \text{spd}) \rightarrow \text{dataPolicyForSPD}(\text{dap}, \text{spd}) \leftarrow (5)
\]

REQUEST CAN USE PII

\[
\text{Request}(\text{r}) \land \text{getInTo}(\text{r}, \text{spd}) \land \text{satisfy}(\text{r}, \text{dap}) \land \text{DataPolicy}(\text{dpa}) \\
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We manually unify two types of semantic legal policies, translated from privacy protection law and national security law.

Privacy protection law $\alpha$ and national security law $\beta$ are unified at $\text{Super} - \text{peer}_{\alpha \cap \beta}$ at $TLD_{\alpha \cap \beta}$, where $TLD_{\alpha \cap \beta}$ is in the intersection of $TLD_{\alpha}$ and $TLD_{\beta}$ jurisdiction.

Database is in compliance with a data protection law $\alpha$ from one jurisdiction but data centers hosting database are possibly in compliance with national security law $\beta$ from another jurisdiction.
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Unifying Two Types of Policies
Privacy Protection and National Security

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Unifying Semantic Legal Policies at $Super - peer_{\alpha \cap \beta}$
Query at Intersection of TLDs

Two types of queries are available: subject-based and pattern-based:

1. At Super – peer$_{\alpha \cap \beta}$, only provides pattern-based queries, at Super – peer$_\alpha$ and Super – peer$_\beta$ we provide both.

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Defeasible Reasoning for Policy Exceptions

Stratum One Exception:
A Data Owner’s Consent

**NO DATA DISCLOSURE UNLESS A DATA OWNER’S CONSENT**

\[ Ab1 \rightarrow \text{hasPartOf.} \text{Condition}(Ab1) \]
\[ \text{hasPartOf.} \text{Condition}(Ab1), \]

\[ Ab1 = \left\{ \begin{array}{l}
\text{hasPartOf}^{-}.\text{Purpose}(\neg \text{nationalSecurity}) \\
\text{hasPartOf}^{-}.\text{DataUser}(\neg \text{securityOfficer}) \\
\text{hasPartOf}^{-}.\text{Consent}(\top)
\end{array} \right\} \]
Stratum Two Exception:  
Without a Data Owner’s Consent

**DATA DISCLOSURE WITHOUT A DATA OWNER’S CONSENT**

\[ Ab2 \rightarrow \text{hasPartOf.\text{Condition}}(Ab2) \]
\[ \text{hasPartOf.\text{Condition}}(Ab2), \]
\[ Ab2 = \begin{cases} 
\text{hasPartOf}.\text{Purpose} (\text{nationalSecurity}) \\
\text{hasPartOf}.\text{DataUser} (\text{securityOfficer}) \\
\text{hasPartOf}.\text{Consent} (\bot) 
\end{cases} \]
Stratum Three Exception:
Citizenships are the Criteria

Deny data disclosing if not a local citizen

\[ Ab3 \rightarrow \text{hasPartOf.Condition}(Ab3). \]
\[ \text{hasPartOf.Condition}(Ab3), \]

\[ Ab3 = \begin{cases} 
\text{hasPartOf.Condition}(Ab2) \\
\cdots \\
\text{hasPartOf}^- \cdot \text{Nationality}(\neg TW \cdot \text{citizenship}) 
\end{cases} \]
A Policy’s Exceptions Handling in $SPD_{\alpha \cap \beta}$
Complying with two type of laws

\[
\text{Request}(\texttt{?r}) \land \text{hasCondition}(\texttt{?r, Ab1}) \land \text{Condition}(\texttt{Ab1}) \\
\land \text{DomainPolicy}(\texttt{?dmp}) \land \text{hasCondition}(\texttt{?dmp, ?dmc}) \land \text{Condition}(\texttt{?dmc}) \\
\land \text{isSubsumed}(\texttt{Ab1, ?dmc}) \land \text{domainPolicyForSPD}(\texttt{?dmp, ?spd}) \\
\rightarrow \text{getInTo}(\texttt{?r, ?spd})
\]
Conclusion

A semantic privacy preserving model provides legalized data integration and protection services in semantic cloud.

Law-as-a-Service (LaaS) overcomes legal obstacles when Cloud Service Providers (CSPs) intend to deploy their cloud resources and services.

Semantic web technologies are applied for semantic legal policy representation to enable data integration and protection.

Semantic legal policies, as a combination of ontologies and stratified Datalog rules with negation, are enforced and a semantic legal policy’s exceptions are handled through defeasible reasoning.
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Future Work

- Exploring defeasible reasoning of a policy’s exceptions handling from different hybrid integration of DL-Lite species’ ontologies and stratified Datalog rules with negation.
- Exploiting expressive power and computational complexity of semantic legal policy enforcement under different ontologies and rules integration.
- After direct mapping from a RDB’s tables to modular ontologies, through fragmentation and encryption techniques to ensure the data protection criteria of outsourcing in the cloud.
- Using tremendous amount of RDB data sets as ontology’s data sources to verify sustainability of LaaS.
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LaaS System Demo and Q&A

- LaaS System Demo.
- Q&A
LaaS System Demo and Q&A

LaaS System Demo.

Q&A
## Communicable Disease Control Medical Network SPD

### Ent Lab. at NCCU in Taiwan

#### Communicable Disease Control Medical Network SPD

**L. J. Lin (logout)**

**Center of Disease Control in Taiwan**

**Notification Unit** | **Report Number** | **Law Verify**
---|---|---
National Taiwan University Hospital | 1 | Law/Life

#### a/II domain

**National Taiwan University Hospital**

<table>
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<th>Birthday</th>
<th>Nationality</th>
<th>Gender</th>
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<td>M</td>
<td>K14569758</td>
<td>National Taiwan University Hospital</td>
<td>005</td>
<td>H1N1</td>
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</table>

**Show XML**

**Show XML**

### a/I domain

**The Government of Taipei**

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<th>Name</th>
<th>Birthday</th>
<th>City</th>
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<tr>
<td>Wu Yi-zhong</td>
<td>19681114</td>
<td>Taipei City</td>
<td>Rm. 1, 2F, No. 34-2, All. 3 Ln., 12, Minshin W. Rd., Dating Dist.</td>
<td>K14569758</td>
<td>M</td>
<td>Wu Lingley</td>
<td>Wo</td>
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</table>

**Show XML**

**Show XML**

### Reference

**Prevention, Protection, Act C1.3**

**Article Content**

- Where it is to prevent harm on the life, health, freedom, or property of the Party,

**Enforcement Rules of the Communicable Disease Control Act**

**Article Content**

- In accordance with regulations of Paragraph 4, Article 39 of the Act, require medical institutions, pharmacies, or forensic medicine physicians to provide within a definite time, relevant information of patients of communicable diseases.
### National Security Bureau

#### Welcome! Li(logout)

Search: @ID
- ReportNumber
- Name

Key: K145698758

### National Taiwan University Hospital

<table>
<thead>
<tr>
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<th>BirthDay</th>
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### NationalSecurity_I

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<td>Exception</td>
<td>Personal Information Protection Act_C1-5_5</td>
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<tr>
<td>Law</td>
<td>The Constitution of The Republic of China_137_4</td>
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</table>
Self-managed services conceptual model in trustworthy clouds’ infrastructure.

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*Legal Theory: Sources of Law and the Semantic Web*.

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Data management in peer-to-peer data integration systems.

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What you always wanted to know about Datalog (and never dared to ask).

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