

A SEMANTIC PRIVACY-PRESERVING MODEL FOR DATA SHARING AND INTEGRATION

Yuh-Jong Hu Jiun-Jan Yang
{hu, 98753036}@cs.nccu.edu.tw

Emerging Network Technology(ENT) Lab.
Department of Computer Science
National Chengchi University, Taipei, Taiwan

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Part I

RESEARCH GOALS



Motivations

- Large enterprises spend a great deal of time and money on data sharing and integration [3].
- Semantic web technologies provide a possible solution.
- But it is a very complicated research problem because [11]:
 - heterogeneity of the data sources
 - relation between the global schema and the data sources
 - limitations on the mechanisms for access the data sources
 - queries processing expressed on the global schema
- We further exploit data protection issue besides data sharing.



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Research Goals and Achievements

- 1 Providing a virtual platform for data sharing and protection in multiple servers with relational database systems.
- 2 Representing and enforcing semantics-enabled policies as a combination of ontology and rule.
- 3 Using a combination of semantics-enabled policies for data sharing and protection in multiple servers.
- 4 Ensuring soundness and completeness of query rewriting services in a semantic privacy-preserving model.



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Related Work

CITED PAPERS

- Data integration for relational DB
A. Halevy, et al. [18] [19] [27]
- Data integration with Description Logic (DL)
D. Calvaneses et al. [8] [9] [10]
- Privacy-preserving data integration and sharing
C. Clifton et al. [12]
- Data usage control model
J. Park and R. T. Sandhu [32]
- Access control policies and languages in open environments
S. Jajodia et al. [22]
- A privacy policy model for enterprise
G. Karjoth [24] [25]
- A KRDB perspective for the semantic web
F. Goasdoué and M.-C. Rousset [15]

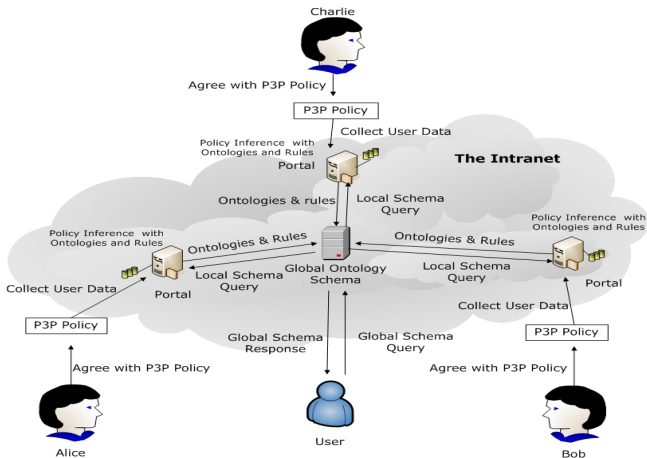


Part II

A PRIVACY-PRESERVING MODEL



A Semantic Privacy Protection Model



Formal Privacy Protection Policy

- 1 A formal policy (\mathcal{FP}) is a declarative expression executed in a computer system for a human legal norm without semantic ambiguity.
- 2 An \mathcal{FP} is created from a policy language (\mathcal{PL}), and \mathcal{PL} is shown as a combination of ontology and rule languages.
- 3 An \mathcal{FP} is composed of ontologies \mathcal{O} and rules \mathcal{R} , where ontologies are created from an ontology language and rules are created from a rule language.
- 4 A formal protection policy (\mathcal{FPP}) is an \mathcal{FP} that aims at representing and enforcing resource protection principles, where the structure of resources is modeled as ontologies \mathcal{O} but the resources protection is shown as rules \mathcal{R} .

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Semantic Mapping from Local to Global Schema

DEFINITION (SEMANTIC MAPPING: GAV, LAV, AND GLAV)

- Global-As-View(GAV): Each concept in the global schema is expressed in terms of query over the data sources.
- Local-As-View(LAV): Defining each concept in the data sources as a view over the global schema [10] [26].
- Global-Local-As-View(GLAV): Allowing flexible schema definitions independent of the particular details of the data sources [14] [30].



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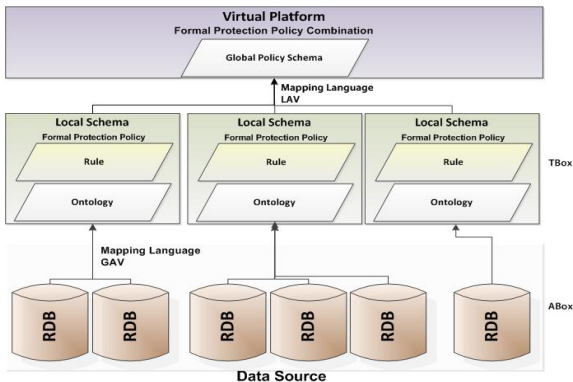
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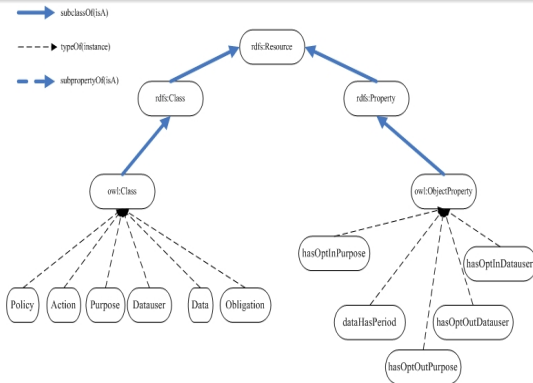
A Semantic Privacy-Preserving Model



A Partial Ontology of FIPs

PROPERTY AND CLASS IN FIPs ONTOLOGY

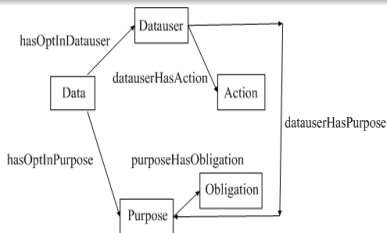
- $T \sqsubseteq \forall \text{hasOptInPurpose}.\text{Data}$, $T \sqsubseteq \forall \text{hasOptInPurpose}^{\perp}.\text{Purpose}$
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Data Request Services

SWRL RULES FOR DATA REQUEST

- FIP's five attributes ($?d, ?p, ?du, ?a, ?o$) for each data request service
- An initial feasible parameter input set is $\mathcal{FS} = input(?du, ?r, ?p)$, and output dataset is $output(?d, ?o)$ for pattern-matching and subject-based data requests
- $hasOptInPurpose.Data(?data) \wedge hasOptInPurpose^-.Purpose(?purpose)$
 $\longrightarrow hasOptInPurpose(?data, ?purpose) \longleftarrow (1)$
- $hasOptInDatauser.Data(?data) \wedge hasOptInDatauser^-.Datauser(?datauser)$
 $\longrightarrow hasOptInDatauser(?data, ?datauser) \longleftarrow (2)$



Formal Privacy Protection Policy (conti.)

- 1 A privacy protection policy shown as an \mathcal{FPP} is a combination of ontologies and rules, where DL-based ontologies provide data sharing, while LP-based rules provide data query and protection.
- 2 A formal policy combination (\mathcal{FPC}) in a global policy schema (\mathcal{GPS}) allows data sharing as an integration of \mathcal{FP} from a variety of servers.
- 3 a formal protection policy combination (\mathcal{FPPC}) allows data sharing and protection from \mathcal{FPC}

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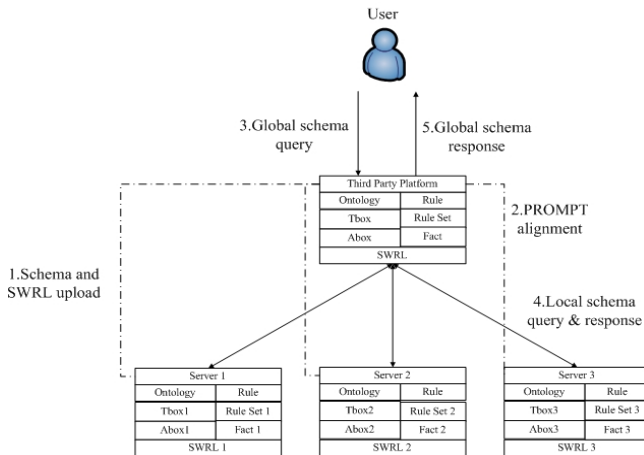


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A VP for Ontology Merging and Rule Integration



A Perfect Ontology Alignment

DEFINITION (A PERFECT ONTOLOGY ALIGNMENT)

- A perfect ontology alignment between \mathcal{T}_i in \mathcal{O}_i and \mathcal{T}_j in \mathcal{O}_j via a mapping (uid, e_i, e_j, n, ρ) and merging satisfied the following:
 - $e_i \in \mathcal{T}_i$ and $e_j \in \mathcal{T}_j$ entity names are either for describing the root class or for property which corresponding to the privacy protection concepts and relations.
 - A numeric confidence measure n is always equal 1.
 - ρ is either equivalence (\equiv) or subsumption (\sqsubseteq) between entity names of \mathcal{T}_i and \mathcal{T}_j schemas.
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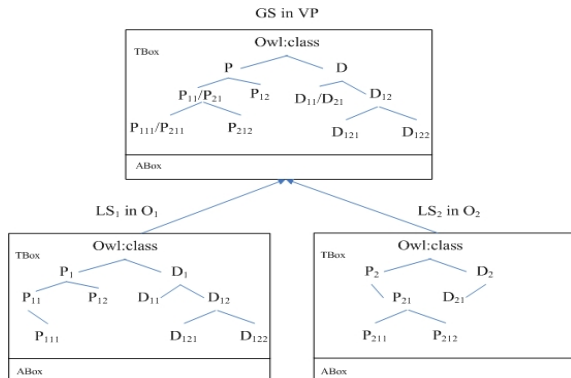


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Class Alignment for Ontology Merging



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DEFINITION (A PERFECT RULE INTEGRATION)

- A datalog rule is a CQ of the form:
 $v_i \leftarrow conj_i(\vec{x}_i)$ [9].
- A datalog rule r_i in the \mathcal{R}_i of \mathcal{FP}_i is:
 $\mathcal{H} \leftarrow \mathcal{B}_1 \wedge \mathcal{B}_2 \wedge \dots \wedge \mathcal{B}_n$, where \mathcal{H} , the query results (or views).
- A perfect datalog rules integration is:
 $\exists r_i \in \mathcal{RS}_i$ in \mathcal{FP}_i , for data sharing and protection without causing rules conflict with $\exists r'_i \in \odot_i \mathcal{R}_i$, $\lambda_i \in \diamond_i \mathcal{O}_i$.
- Avoid conditions as: (*Incomplete*) $\exists r_i \models \lambda_i \Rightarrow \exists r'_i \not\models \lambda_i$ and
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Part III

AN EHRs SHARING AND PROTECTION SCENARIO



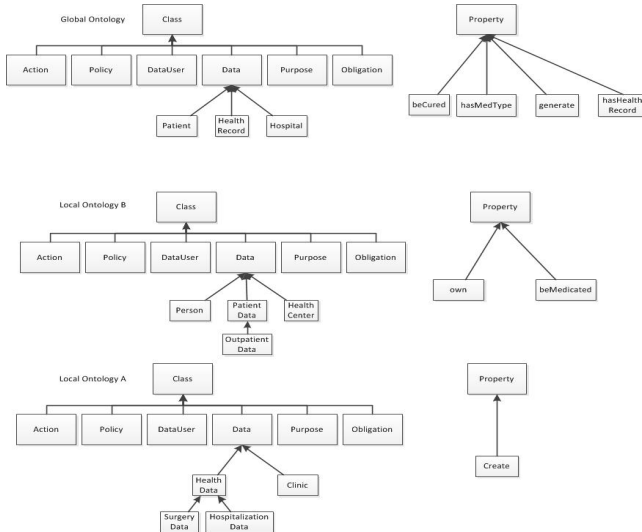
An EHRs Sharing and Protection Scenario

EXAMPLE (SCENARIO DESCRIPTION)

Under the data protection law, two hospitals, A and B, have allowed to share their patients' Electronic Health Records (EHRs) after patients give their consents for the medication purpose. A patient was hospitalized in the hospital A for a surgery. After that, this patient went to the hospital B for an outpatient medication. A physician in the hospital B was authorized to query this patient's sharable EHR at the \mathcal{VP} collected from hospital A and hospital B's RDB data sources.



An EHRs Sharing and Protection Scenario(conti.)



An EHRs Sharing and Protection Scenario(conti.)

THE HOSPITAL A'S LOCAL ONTOLOGY SCHEMA

- Class: **C**linic and **H**ealthData with subClass **S**urgeryData and **H**ospitalizationData
- Property: **c**reate with domain **H**ospital and range **H**ealthData
- $T \sqsubseteq \forall \text{create.Hospital}$
- $T \sqsubseteq \forall \text{create}^{\neg}.\text{HealthData}$

THE HOSPITAL B'S LOCAL ONTOLOGY SCHEMA

- Class: **P**erson, **H**ealthCenter, and **P**atientData with subClass **O**utPatientData
- Property: **o**wn, **b**eMedicated with domain and range:
- $T \sqsubseteq \forall \text{own.Person}$, $T \sqsubseteq \forall \text{own}^{\neg}.\text{PatientData}$.
- $T \sqsubseteq \forall \text{beMedicated.Person}$,
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An EHRs Sharing and Protection Scenario(conti.)

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An EHRs Sharing and Protection Scenario(conti.)

THE \mathcal{VP} 'S GLOBAL ONTOLOGY SCHEMA:

- Class: **P**atient, **H**ospital, **S**urgery, and **H**ealthRecord
- Property: **beCured**, **hasHealthRecord**, **generate**:
- $T \sqsubseteq \forall \text{beCured.Patient}$, $T \sqsubseteq \forall \text{beCured}^{\neg}.\text{Hospital}$
- $T \sqsubseteq \forall \text{hasHealthRecord.Patient}$, $T \sqsubseteq \forall \text{hasHealthRecord}^{\neg}.\text{HealthRecord}$
- $T \sqsubseteq \forall \text{generate.Hospital}$, $T \sqsubseteq \forall \text{generate}^{\neg}.\text{HealthRecord}$

An EHRs Sharing and Protection Scenario(conti.)

VIEWS AT THE \mathcal{VP} FROM HOSPITAL A'S LOCAL SCHEMA:

- $\text{def}(V1_{\text{Clinic}}) = \text{Hospital}$
- $\text{def}(V2_{\text{HealthData}}) = \text{HealthRecord}$
- $\text{def}(V3_{\text{SuregeryData}}) = \text{HealthRecord} \wedge \forall \text{hasMedType.Surgery}$
- $\text{def}(V4_{\text{HospitalizationData}}) = \text{HealthRecord} \wedge \forall \text{hasMedType.Hospitalization}$
- $\text{def}(V5_{\text{create}}) = \text{generate}$

VIEWS AT THE \mathcal{VP} FROM HOSPITAL B'S LOCAL SCHEMA:

- $\text{def}(V6_{\text{Person}}) = \text{Patient}$
- $\text{def}(V7_{\text{HealthCenter}}) = \text{Hospital}$
- $\text{def}(V8_{\text{PatientData}}) = \text{HealthRecord}$
- $\text{def}(V9_{\text{OutPatientData}}) = \text{HealthRecord} \wedge \forall \text{hasMedType.OutPatient}$
- $\text{def}(V10_{\text{beMedicated}}) = \text{beCured}$
- $\text{def}(V11_{\text{own}}) = \text{hasHealthRecrod}$

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An EHRs Sharing and Protection Scenario(conti.)

A DATALOG QUERY q AT THE \mathcal{VP} :

Patient(?x) \wedge beCured(?x, ?y) \wedge hasHealthRecrod(?x, ?r)
 \wedge HealthRecord(?r) \wedge hasMedType(?r, Surgery) \wedge generate(?y, ?r)
 \rightarrow sqwrl : select(?x, ?r)

An EHRs Sharing and Protection Scenario(conti.)

q_{va} USES VIEWS DEFINED AT THE \mathcal{VP}

$V6_{Person} \wedge V10_{beMedicated} \wedge V11_{own} \wedge V9_{OutPatientData} \wedge V5_{create}$
 $\rightarrow sqwrl : select(?x, ?r) \leftarrow (q_{va})$

q_{va} IS REWRITTEN AS A QUERY:

$B : Person(?p) \wedge B : beMedicated(?p, ?c) \wedge B : own(?p, ?d)$
 $\wedge B : OutPatientData(?od) \wedge A : create(?h, ?hd)$
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An EHRs Sharing and Protection Scenario(conti.)

q_{vb} USES VIEWS DEFINED AT THE \mathcal{VP}

$V6_{Person} \wedge V10_{beMedicated} \wedge V11_{own} \wedge V3_{SuregeryData} \wedge V5_{create}$
 $\longrightarrow sqwrl : select(?x, ?r) \longleftarrow (q_{vb})$

q_{vb} IS REWRITTEN AS A QUERY:

$B : Person(?p) \wedge B : beMedicated(?p, ?c) \wedge B : own(?p, ?d)$
 $\wedge A : SuregeryData(?sd) \wedge A : create(?h, ?hd) \longrightarrow sqwrl : select(?p, ?sd)$

An EHRs Sharing and Protection Scenario(conti.)

q_{vb} USES VIEWS DEFINED AT THE \mathcal{VP}

$V6_{\text{Person}} \wedge V10_{\text{beMedicated}} \wedge V11_{\text{own}} \wedge V3_{\text{SuregeryData}} \wedge V5_{\text{create}}$
 $\longrightarrow \text{sqwrl} : \text{select}(\text{?x}, \text{?r}) \longleftarrow (q_{vb})$

q_{vb} IS REWRITTEN AS A QUERY:

$B : \text{Person}(\text{?p}) \wedge B : \text{beMedicated}(\text{?p}, \text{?c}) \wedge B : \text{own}(\text{?p}, \text{?d})$
 $\wedge A : \text{SuregeryData}(\text{?sd}) \wedge A : \text{create}(\text{?h}, \text{?hd}) \longrightarrow \text{sqwrl} : \text{select}(\text{?p}, \text{?sd})$

Part IV

SOUNDNESS AND COMPLETENESS



Soundness of Query Rewriting

THEOREM (SOUNDNESS OF QUERY REWRITING)

After a perfect ontology alignment and a perfect rule integration with \mathcal{FPFC} , $\exists \mathcal{GPS} = (\diamond_i \mathcal{O}_i, \odot_i \mathcal{R}_i)$ at the \mathcal{VP} , Under a particular feasible parameter input set \mathcal{FS}_i , if $\lambda_j \in \mathcal{O}_i$ is protected by a \mathcal{FPP}_i at each server i , $\forall i$, i.e., $\forall i, r_i \in \mathcal{R}_i \not\models \lambda_j$, then $r'_i \in \odot_i \mathcal{R}_i \not\models \lambda_j$ for the same \mathcal{FS}_i , where λ_j is a protective data set in \mathcal{O}_i .

PROOF

(Sketch) If $q(x)$ is a query over $\odot_i \mathcal{O}_i$ at the \mathcal{VP} and $q_{s_i}(x)$ is a query over \mathcal{O}_i in a server i , then we need to prove the statement $\forall x \cdot q(x) \rightarrow \bigcup_i q_{s_i}(x)$. This statement is equivalent to the original argument: If $r_i \in \mathcal{R}_i \not\models \lambda_j$, then $r'_i \in \odot_i \mathcal{R}_i \not\models \lambda_j$. The CQ $q(x)$ is a query containment of datalog rule r'_i and the CQ $q_{s_i}(x)$ is a query containment of datalog rule $r_i \in \mathcal{R}_i$. The statement $\forall x \cdot q(x) \rightarrow \bigcup_i q_{s_i}(x)$ is true because the local as view (LAV) schema mapping only allow the protected concept λ_j in each server i to be connected to the global schema. After using a perfect ontology alignment and a perfect rule integration with a perfect mapping language \mathcal{ML} , we avoid the condition: $\exists r_i \not\models \lambda_j \Rightarrow \exists r'_i \models \lambda_j$. □

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After a perfect ontology alignment and a perfect rule integration with $\mathcal{FP}PC$, $\exists \mathcal{GPS} = (\diamond_i \mathcal{O}_i, \odot_i \mathcal{R}_i)$ at the \mathcal{VP} , Under a particular feasible parameter input set \mathcal{FS}_i , if $\lambda_j \in \mathcal{O}_i$ is shareable by a \mathcal{FPP}_i at each server i , $\forall i$, i.e., $\forall i, r_i \in \mathcal{R}_i \models \lambda_j$, then $r'_i \in \odot_i \mathcal{R}_i \models \lambda_j$ for the same \mathcal{FS}_i , where λ_j is a shareable data set in \mathcal{O}_i .

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Part V

CONCLUSION AND FUTURE WORK



Conclusion

CONCLUSION

- 1 A semantic privacy-preserving model provides authorized view-based query over a widespread of autonomous multiple servers.
- 2 Semantics-enabled privacy protection policies empower the data sharing and access control at the virtual platform.
- 3 The policy combination is shown as ontology mapping/merging and rule integration.
 - The ontology mapping and merging algorithm creates a global ontology schema at the virtual platform by integrating multiple local ontology schemas for data sharing.
 - The perfect datalog rule integration enforces the data query and protection services.
- 4 The soundness and completeness of data sharing and protection criteria are ensured to support the validity of policy combination.



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Future Work

FUTURE WORK

- Modularize and reuse of ontologies for data sharing and protection
- Semantics-enabled policies and framework to enforce information sharing and protection in the cloud: national security vs. privacy protection

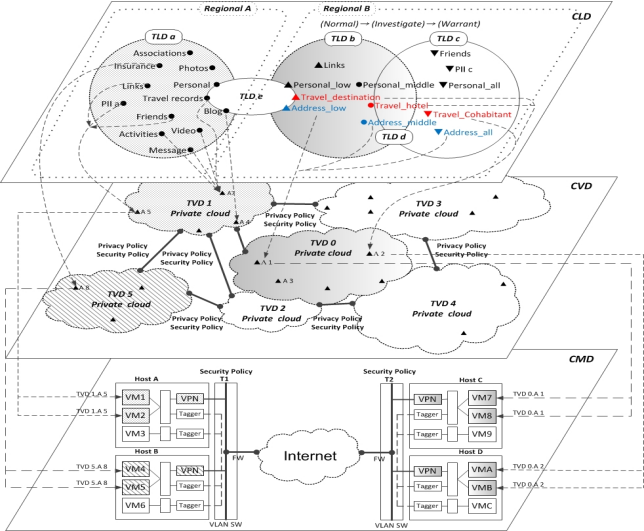


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A Semantics-enabled Policy Framework in the Cloud



System Demo and Q&A

SYSTEM DEMO. AND Q&A

- System Demo.: Jiun-Jan Yang
- Q&A

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SYSTEM DEMO. AND Q&A

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