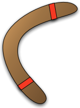
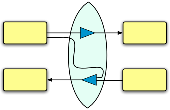
Updatable Security Views

Nate Foster
Benjamin Pierce
Steve Zdancewic

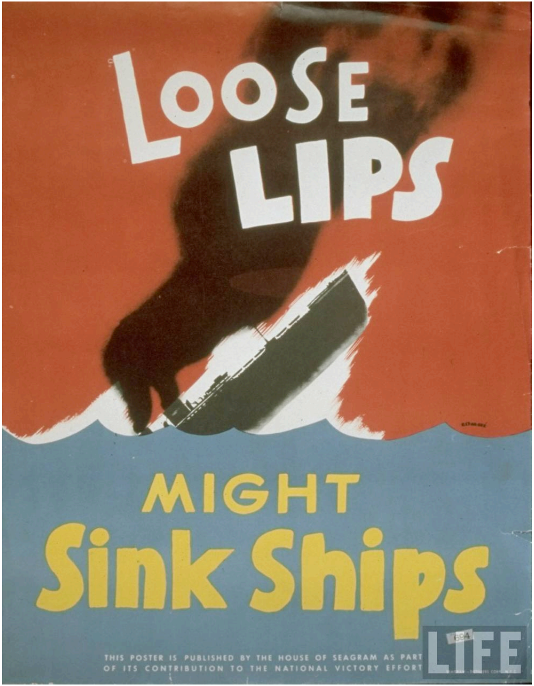
University of Pennsylvania

IBM PLDay '09






TOP SECRET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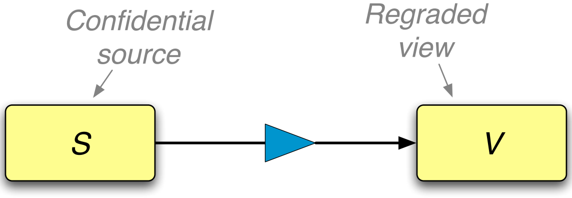
Security Views



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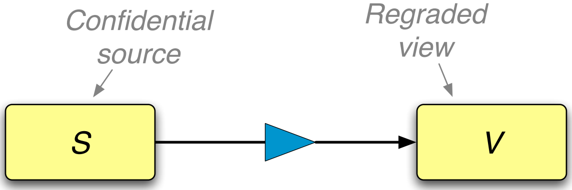
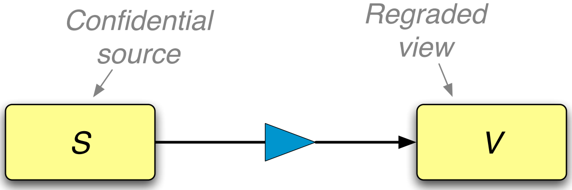


✔ Robust: impossible to leak hidden data

✔ Flexible: enforce fine-grained confidentiality policies

Security Views



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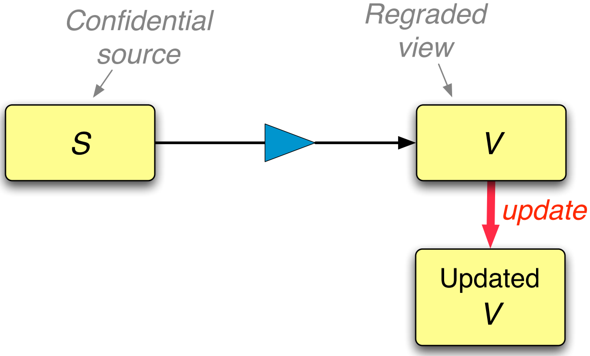
- ✔ Flexible: enforce fine-grained confidentiality policies
- ✗ Not usually updatable
- ✗ No separate specification of confidentiality policy

Updatable Security Views



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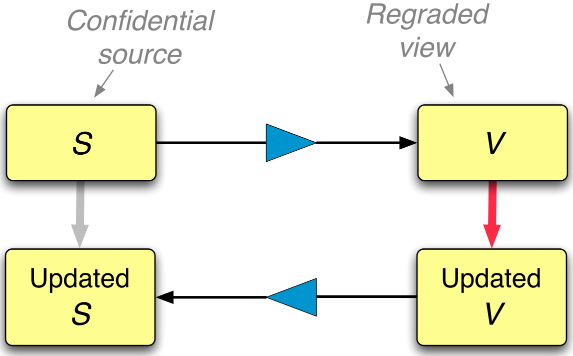

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This Talk

A generic framework for building updatable security views.

- Extends previous work on lenses.
- New non-interference laws provide additional guarantees about confidentiality and integrity.

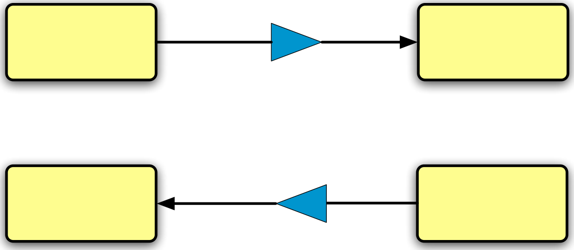
A concrete instantiation of these ideas in Boomerang, a language for writing lenses on strings.

- Annotated regular expressions express confidentiality and integrity policies.

Lenses

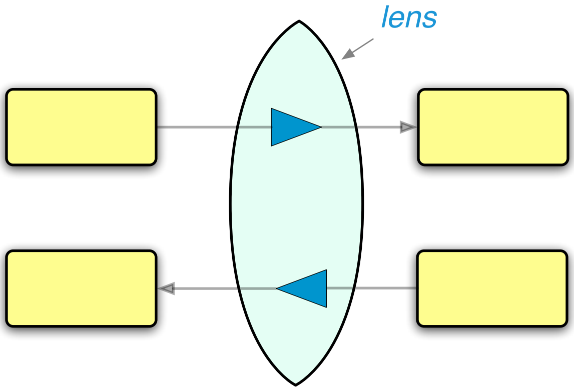
Bidirectional Transformations

For a view to be updatable, the program that defines it needs to be bidirectional.



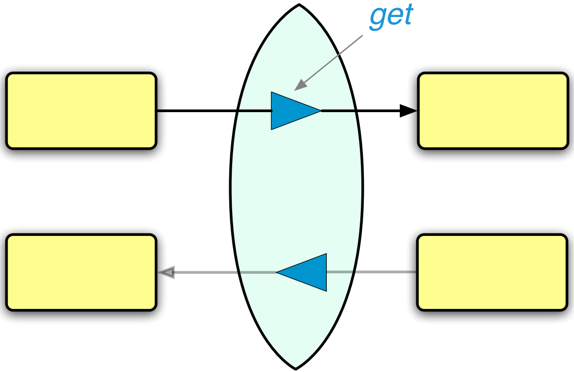
Lenses

In recent years, we have developed a number of bidirectional programming languages for describing certain well-behaved transformations called lenses.



Lenses: Terminology

In recent years, we have developed a number of bidirectional programming languages for describing certain well-behaved transformations called lenses.



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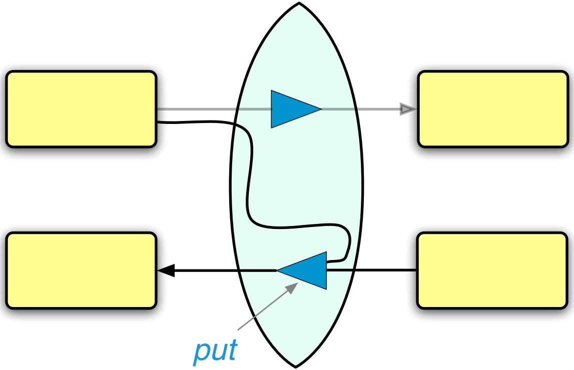


Semantics

A lens l mapping between a set S of sources and V of view is a pair of total functions

$$
\begin{aligned}
l.\mathbf{get} &\in S \rightarrow V \\
l.\mathbf{put} &\in V \rightarrow S \rightarrow S
\end{aligned}
$$

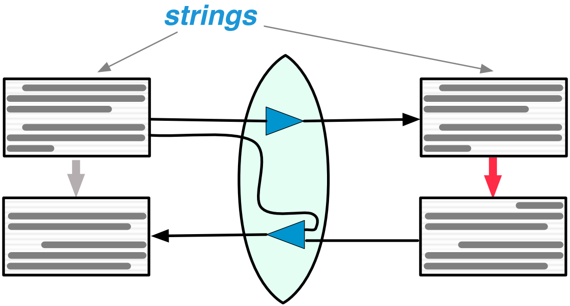
obeying "round-tripping" laws

$$l.\mathbf{get}\ (l.\mathbf{put}\ v\ s) = v \qquad (\textsc{PutGet})$$

$$l.\mathbf{put}\ (l.\mathbf{get}\ s)\ s = s \qquad (\textsc{GetPut})$$

for every $s \in S$ and $v \in V$.

Boomerang



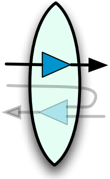
Data model: strings

Computation model: based on finite-state transducers

Types: regular expressions

Example: Redacting Calendars (Get)

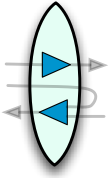
```
*08:30 Coffee with Sara (Starbucks)
 12:15 PLClu (Seminar room)
*15:00 Workout (Gym)
```



```
08:30 BUSY
12:15 PLClu
15:00 BUSY
```

Example: Redacting Calendars (Update)

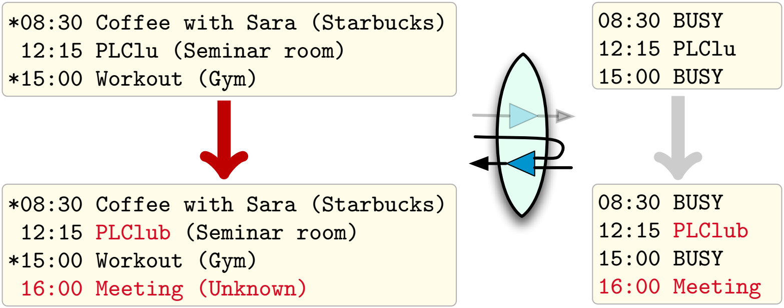
```
*08:30 Coffee with Sara (Starbucks)
 12:15 PLClu (Seminar room)
*15:00 Workout (Gym)
```



```
08:30 BUSY
12:15 PLClu
15:00 BUSY
```

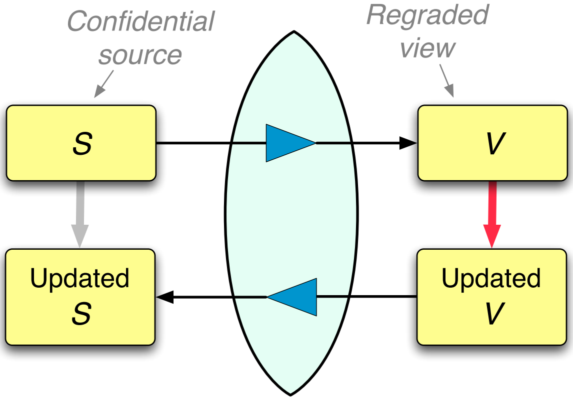
```
08:30 BUSY
12:15 PLClub
15:00 BUSY
16:00 Meeting
```

Example: Redacting Calendars (Put)



Secure Lenses

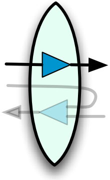
Requirements



1. Confidentiality: **get** does not leak secret data
2. Integrity: **put** does not taint endorsed data

Example: Redacting Calendars (Get)

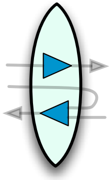
```
*08:30 Coffee with Sara (Starbucks)
 12:15 PLClu (Seminar room)
*15:00 Workout (Gym)
```



```
08:30 BUSY
12:15 PLClu
15:00 BUSY
```

Example: Redacting Calendars (Update II)

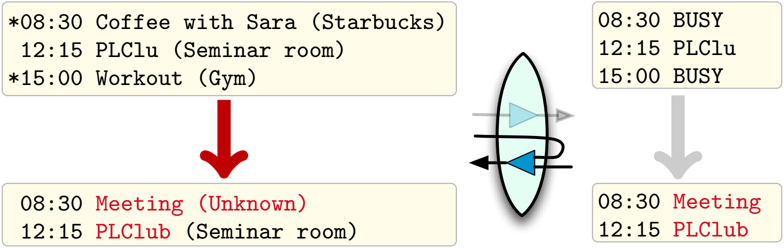
```
*08:30 Coffee with Sara (Starbucks)
 12:15 PLClu (Seminar room)
*15:00 Workout (Gym)
```



```
08:30 BUSY
12:15 PLClu
15:00 BUSY
```

```
08:30 Meeting
12:15 PLClub
```

Example: Redacting Calendars (Put II)



Observe that propagating the update to the view back to the source forces **put** to modify a *lot* of hidden source data:

- The entire appointment at 3pm.
- The description and location of the appointment at 8:30am.

Integrity

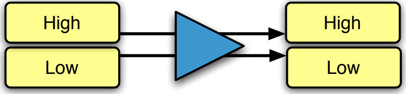
Question: should the (potentially untrusted) user of the view be allowed to modify hidden (potentially confidential) source data?

Answer: It depends $\rightarrow$ we need to be able to formulate and choose between integrity policies like

- "These appointments in the source may be altered"
- "These appointments in the source may not be altered (and so the view must not be modified in certain ways)"

Non-interference

Both requirements can both be formulated as non-interference.



A transformation is non-interfering if the low-security parts of the output do not depend on the high-security parts of the input.

Non-interference

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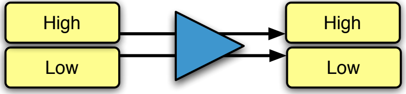
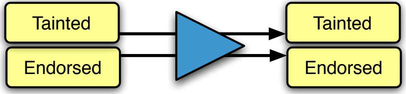


A transformation is non-interfering if the low-security parts of the output do not depend on the high-security parts of the input.

E.g., if the data contains "tainted" and "endorsed" portions



then non-interference says that the tainted parts of the input do not affect the endorsed parts of the output.

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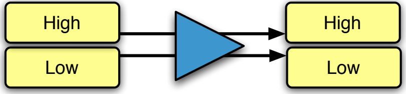
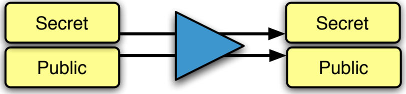


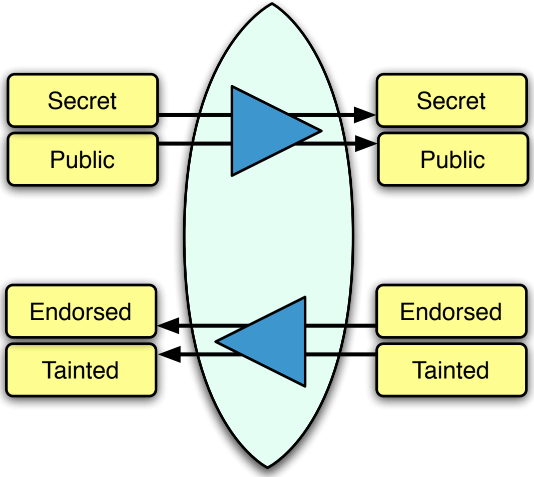
A transformation is non-interfering if the low-security parts of the output do not depend on the high-security parts of the input.

E.g., if the data contains both "secret" and "public" portions

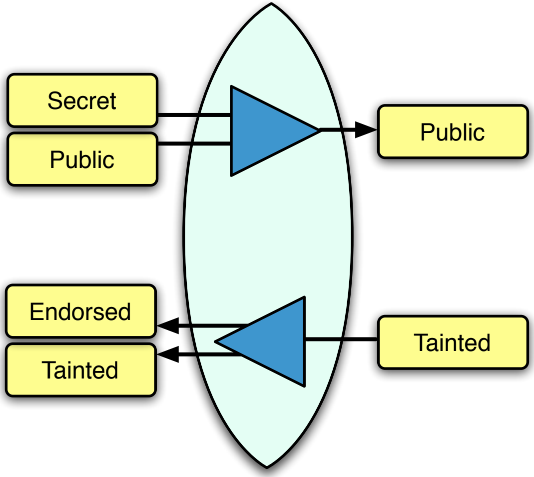


then non-interference says that the secret parts of the input do not affect the public parts of the output.

Secure Lenses



Secure Lenses



Semantics of Secure Lenses

Fix a family of equivalence relations on S and V

- $\sim_k$ — "agree on k-public data"
- $\approx_k$ — "agree on k-endorsed data"

that capture notions of high and low-security data.

Semantics of Secure Lenses

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that capture notions of high and low-security data.

A secure lens obeys refined behavioral laws:

$$\frac{s \sim_k s'}{l.\mathbf{get}\ s \sim_k l.\mathbf{get}\ s'} \qquad (\textsc{GetNoLeak})$$

$$\frac{v \approx_k (l.\mathbf{get}\ s)}{l.\mathbf{put}\ v\ s \approx_k s} \qquad (\textsc{GetPut})$$

(as well as the original PutGet law).

Protocol for Using a Secure Lens

Before the owner of the source allows the user of the view to propagate an update using **put**, they check that the old and new views agree on endorsed data.

The GetPut law

$$\frac{v \approx_k (l.\mathbf{get}\ s)}{l.\mathbf{put}\ v\ s \approx_k s}$$

ensures that endorsed data in the source is preserved.

Enforces high-level integrity policies such as

- "These appointments in the source may be altered"
- "These appointments in the source may not be altered..."

For Experts: the PutPut Law

The following law can be derived.

$$\frac{v' \approx_k v \approx_k (l.\mathbf{get}\ s)}{l.\mathbf{put}\ v'\ (l.\mathbf{put}\ v\ s) \approx_k l.\mathbf{put}\ v'\ s}$$

It says that the **put** function must have no "side-effects" on endorsed source data.

It relaxes the "constant complement" condition, which is the gold standard for correct view update in databases.

Syntax for Secure Lenses

In Boomerang, we describe the $\sim_k$ and $\approx_k$ equivalence relations using annotated regular expressions.

$$\mathcal{R} ::= \emptyset \mid u \mid \mathcal{R}{\cdot}\mathcal{R} \mid \mathcal{R}|\mathcal{R} \mid \mathcal{R}* \mid \mathcal{R}:k$$

The relations are based on an intuitive notion of "erasing" characters inaccessible to a k-observer...

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See paper for:

- A secure lens version of Boomerang's type system that tracks information flow—in two directions!
- An extension to this type system that uses a combination of static and dynamic checks to ensure integrity.

Conclusion

Summary:

- Data processing is a fertile area for exploring language-based approaches to security.
- Secure lenses provide a reliable framework for constructing updatable security views.
- Mechanisms for ensuring the integrity of data are critical.

Ongoing Work:

- Type system implementation
- Applications
- Other semantics for annotated regular types
- Investigate expressiveness vs. precision

Thank You!

Collaborators: Benjamin Pierce and Steve Zdancewic.

Want to play? Boomerang is available for download.

- Source code (LGPL)
- Precompiled binaries
- Research papers
- Tutorial and demos

http://www.seas.upenn.edu/~harmony/

Dynamic Approach

In the paper we show how to extend secure lenses with dynamic tests that check if the **put** function can safelty handle a given source and view:

$$l.\textbf{safe} \in (\mathcal{P} \times \mathcal{Q}) \to V \to S \to \mathbb{B}$$

We replace GetPut with the following law:

$$\frac{l.\textbf{safe}\ (p, q)\ v\ s}{l.\textbf{put}\ v\ s \approx_q s} \quad (\textsc{GetPut})$$

We add a non-interference law stipulating that the **safe** function must not leak secrets:

$$\frac{v \sim_p v' \qquad s \sim_p s'}{l.\textbf{safe}\ (p, q)\ v\ s = l.\textbf{safe}\ (p, q)\ v'\ s'} \ (\textsc{SafeNoLeak})$$