Access Control and Privacy Policies (7)

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Slides: KEATS (also homework is there)

Judgements

$$\Gamma \vdash F$$

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entails sign

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a single formula

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("assumptions")

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Gimel (Phoenician), Gamma (Greek), C and G (Latin), Gim (Arabic), ?? (Indian), Ge (Cyrillic)

Inference Rules

premisses

$$\frac{\Gamma \vdash F_1 \quad \Gamma \vdash F_2}{\Gamma \vdash F_1 \wedge F_2}$$

conclusion

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conclusion

P says $F \vdash Q$ says $F \wedge P$ says G

Inference Rules

premisses

$$\frac{\Gamma \vdash F_1 \quad \Gamma \vdash F_2}{\Gamma \vdash F_1 \wedge F_2}$$

conclusion

$$\underbrace{P\ \mathsf{says}\ F}_{\Gamma} \vdash \underbrace{Q\ \mathsf{says}\ F}_{F_1} \wedge \underbrace{P\ \mathsf{says}\ G}_{F_2}$$

$$\frac{\Gamma \vdash F_1 \Rightarrow F_2 \quad \Gamma \vdash F_1}{\Gamma \vdash F_2}$$

$$\frac{\Gamma \vdash F}{\Gamma \vdash P \text{ says } F}$$

Digression: Proofs in CS

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- in 2008, verification of a small C-compiler
- in 2010, verification of a micro-kernel operating system (approximately 8700 loc)
  - 200k loc of proof
  - 25 - 30 person years
  - found 160 bugs in the C code (144 by the proof)

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(CMU)

Frank Pfenning
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published a proof about a specification in a journal (2005), $\sim$31pages

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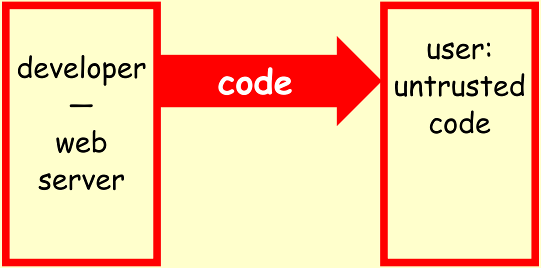
Andrew Appel
(Princeton)

relied on their proof in a **security** critical application

Proof-Carrying Code

Idea:



Proof-Carrying Code

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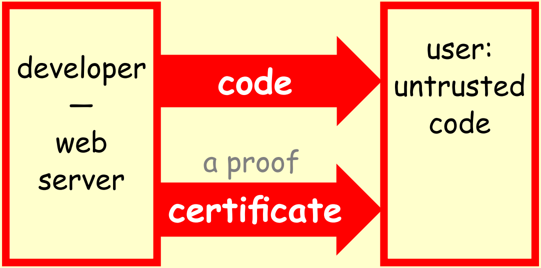
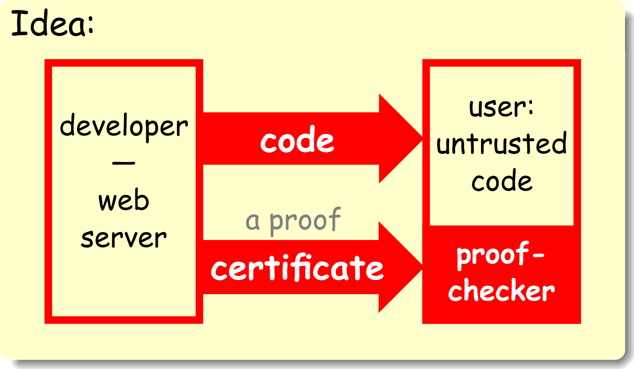
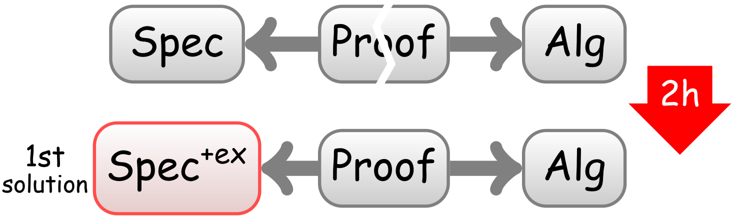


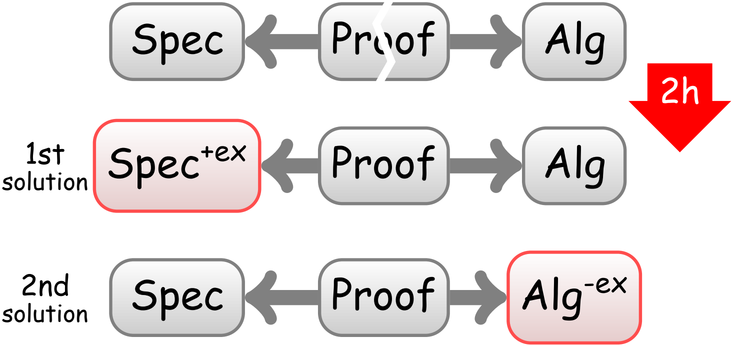
Proof-Carrying Code




Spec
Proof
Alg


Spec
Proof
Alg


Spec
Proof
Alg
2h
1st solution
Spec+ex
Proof
Alg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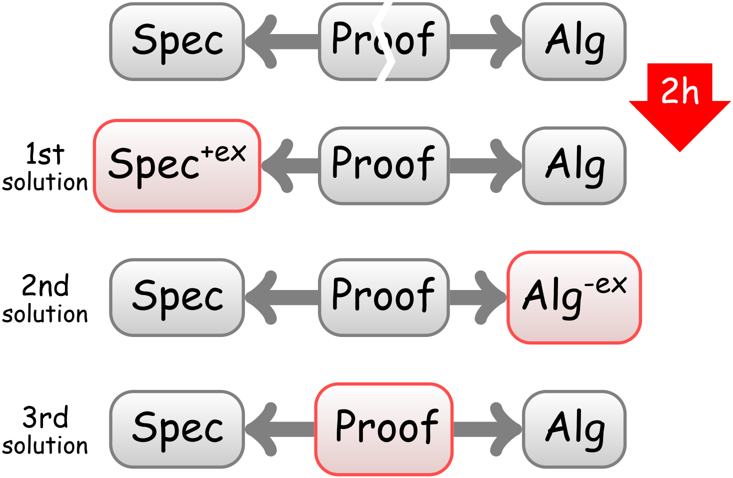
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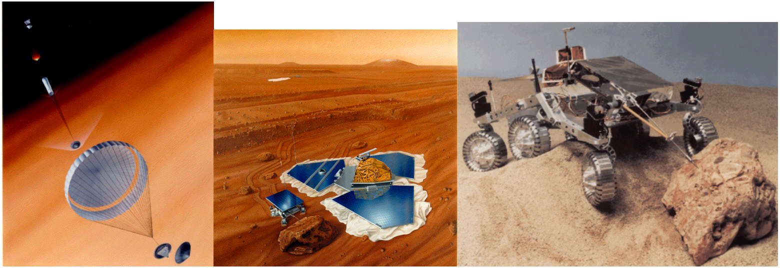
Alg-ex
3rd solution
Spec
Proof
Alg

Mars Pathfinder Mission 1997



- despite NASA's famous testing procedure, the lander crashed frequently on Mars
- problem was an algorithm not used in the OS

Priority Inheritance Protocol

- an algorithm that is widely used in real-time operating systems
- hash been “proved” correct by hand in a paper in 1983
- but the first algorithm turned out to be incorrect, despite the “proof”

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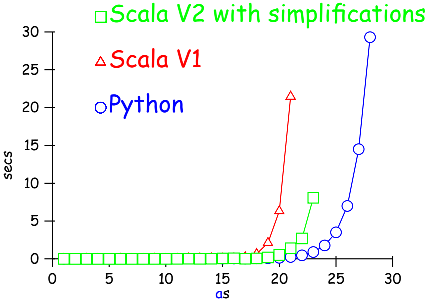
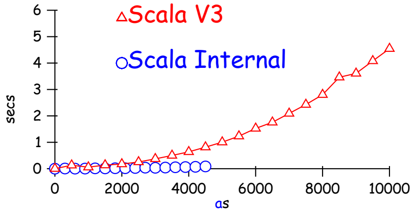
- we specified the algorithm and then proved that the specification makes "sense"
- we implemented our specification in C on top of PINTOS (Stanford)
- our implementation was much more efficient than their reference implementation

Regular Expression Matching





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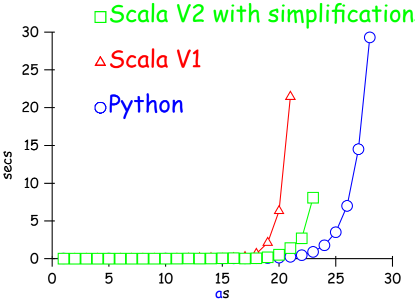
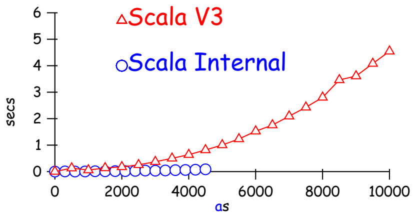
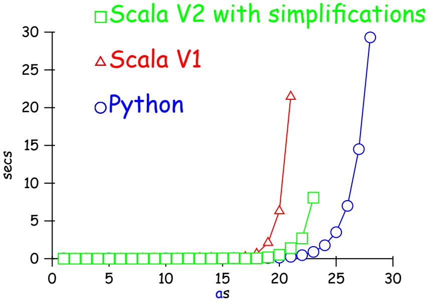
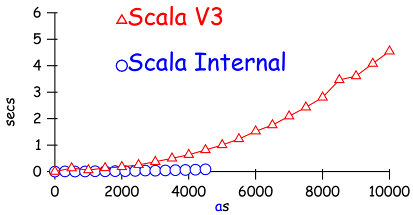




- I needed a proof in order to make sure my program is correct

Regular Expression Matching





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End Digression.
(Our small proof is 0.0005% of the OS-proof.)

One More Thing

- I arrived at King's last year
- Maxime Crochemore told me about a string algorithm (suffix sorting) that appeared at a conference in 2007 (ICALP)
- "horribly incomprehensible", no implementation, but claims to be the best $O(n + k)$ algorithm

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- I arrived at King's last year
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- Jian Jiang found 1 error and 1 superfluous step
- he received 88% for the project and won the prize for the best 7CCSMPRJ project
- no proof ... yet

Trusted Third Party

Simple protocol for establishing a secure connection via a mutually trusted 3rd party (server):

Message 1 $A \rightarrow S : A, B$
Message 2 $S \rightarrow A : \{K_{AB}\}_{K_{AS}}$ and $\{\{K_{AB}\}_{K_{BS}}\}_{K_{AS}}$
Message 3 $A \rightarrow B : \{K_{AB}\}_{K_{BS}}$
Message 4 $A \rightarrow B : \{m\}_{K_{AB}}$

Encrypted Messages

- Alice sends a message m

Alice says m

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- Alice sends an encrypted message m (with key K)

  Alice says $\{m\}_K$

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$$\text{Alice says } m$$

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- Decryption of Alice's message

$$\frac{\Gamma \vdash \text{Alice says } \{m\}_K \quad \Gamma \vdash \text{Alice says } K}{\Gamma \vdash \text{Alice says } m}$$

Encryption

- Encryption of a message

$$\frac{\Gamma \vdash \textit{Alice says } m \quad \Gamma \vdash \textit{Alice says } K}{\Gamma \vdash \textit{Alice says } \{m\}_K}$$

Trusted Third Party

- Alice calls Sam for a key to communicate with Bob
- Sam responds with a key that Alice can read and a key Bob can read (pre-shared)
- Alice sends the message encrypted with the key and the second key it recieved

A sends S	:	Connect(A, B)
S sends A	:	$\{K_{AB}\}_{K_{AS}}$ and $\{\{K_{AB}\}_{K_{BS}}\}_{K_{AS}}$
A sends B	:	$\{K_{AB}\}_{K_{BS}}$
A sends B	:	$\{m\}_{K_{AB}}$

Sending Rule

$$\frac{\Gamma \vdash P \text{ says } F \quad \Gamma \vdash P \text{ sends } Q : F}{\Gamma \vdash Q \text{ says } F}$$

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$$P \text{ sends } Q : F \overset{\text{def}}{=} (P \text{ says } F) \Rightarrow (Q \text{ says } F)$$

Trusted Third Party

$$
\begin{aligned}
&A \text{ sends } S : \mathsf{Connect}(A, B)\\
&S \text{ says } (\mathsf{Connect}(A, B) \Rightarrow\\
&\qquad\qquad \{K_{AB}\}_{K_{AS}} \wedge \{\{K_{AB}\}_{K_{BS}}\}_{K_{AS}})\\
&S \text{ sends } A : \{K_{AB}\}_{K_{AS}} \wedge \{\{K_{AB}\}_{K_{BS}}\}_{K_{AS}}\\
&A \text{ sends } B : \{K_{AB}\}_{K_{BS}}\\
&A \text{ sends } B : \{m\}_{K_{AB}}
\end{aligned}
$$

Trusted Third Party

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$\{K_{AB}\}_{K_{AS}} \wedge \{\{K_{AB}\}_{K_{BS}}\}_{K_{AS}})$
S sends A : $\{K_{AB}\}_{K_{AS}} \wedge \{\{K_{AB}\}_{K_{BS}}\}_{K_{AS}}$
A sends B : $\{K_{AB}\}_{K_{BS}}$
A sends B : $\{m\}_{K_{AB}}$

$\Gamma \vdash B$ says m?

Challenge-Response Protocol

- an engine E and a transponder T share a key K
- E sends out a nonce N (random number) to T
- T responds with $\{N\}_K$
- if E receives $\{N\}_K$ from T, it starts engine

Challenge-Response Protocol

$$
\begin{array}{lr}
E \text{ says } N & \text{(start)}\\
E \text{ sends } T : N & \text{(challenge)}\\
(T \text{ says } N) \Rightarrow (T \text{ sends } E : \{N\}_K \wedge & \\
\qquad T \text{ sends } E : \mathrm{Id}(T)) & \text{(response)}\\
T \text{ says } K & \text{(key)}\\
T \text{ says } \mathrm{Id}(T) & \text{(identity)}\\
(E \text{ says } \{N\}_K \wedge E \text{ says } \mathrm{Id}(T)) \Rightarrow & \\
\qquad \text{start\_engine}(T) & \text{(engine)}
\end{array}
$$

$\Gamma \vdash \text{start\_engine}(T)$?

Exchange of a Fresh Key

A and B share the key K_{AB} and want to share another key

- assumption K_{AB} is only known to A and B

- A sends B : $A, \{N_A\}_{K_{AB}}$
- B sends A : $\{N_A + 1, N_B\}_{K_{AB}}$
- A sends B : $\{N_B + 1\}_{K_{AB}}$
- B sends A : $\{K_{AB}^{new}, N_B^{new}\}_{K_{AB}}$

N_B^{new} is to be used in future messages
Assume K_{AB}^{new} is compromised by I

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- A sends B : $\{msg\}_{K_{AB}^{new}}$

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The Attack

An intruder I convinces A to accept the compromised key K_{AB}^{new}

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- B sends I : $\{K_{AB}^{anew}, N_B^{anew}\}_{K_{AB}}$ intercepted by I
- I sends A : $\{K_{AB}^{new}, N_B^{new}\}_{K_{AB}}$

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