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

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

conclusion

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

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

$$\frac{\Gamma \vdash F}{\Gamma \vdash P \; \textsf{says} \; F}$$

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)

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published a proof about a specification in a journal (2005), ∼31pages

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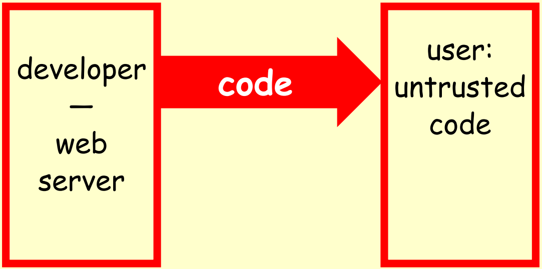
Andrew Appel
(Princeton)

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

Proof-Carrying Code

Idea:



Proof-Carrying Code

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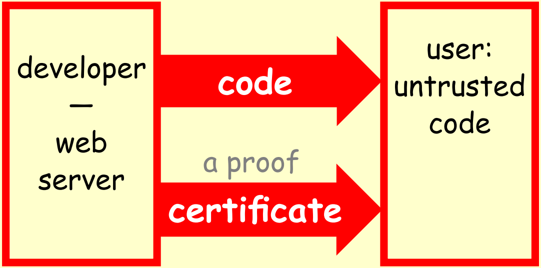
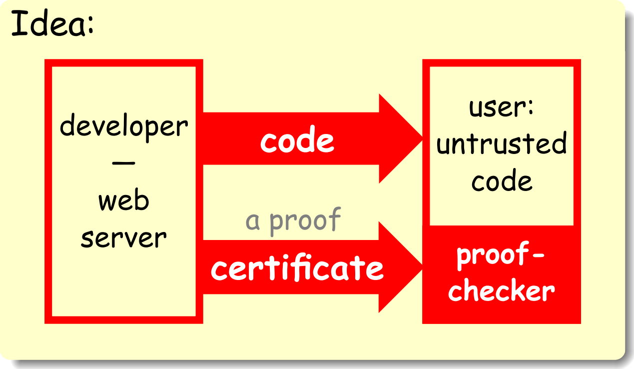
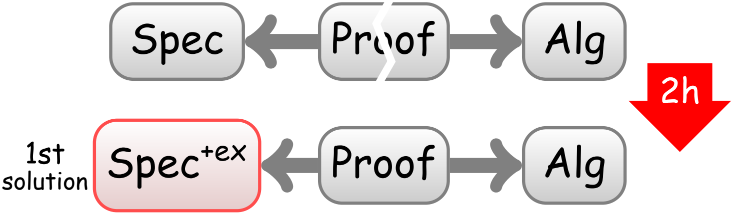


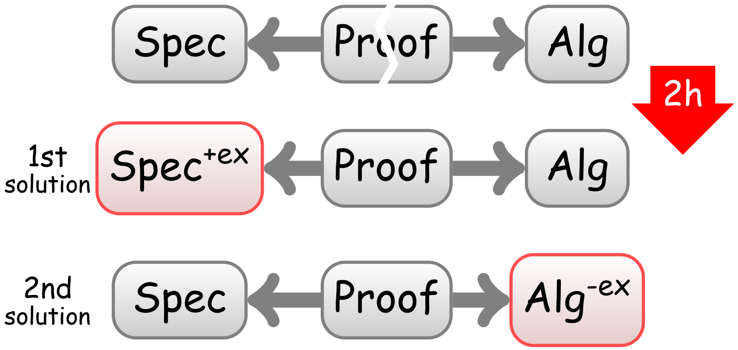
Proof-Carrying Code




Spec
Proof
Alg


Spec
Proof
Alg


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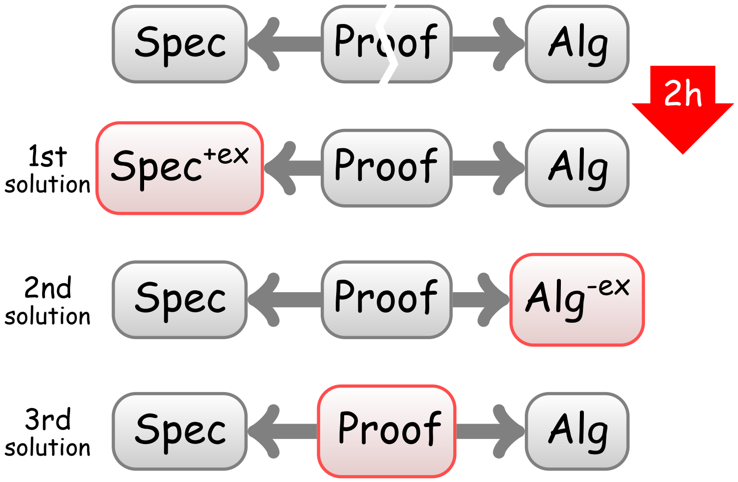
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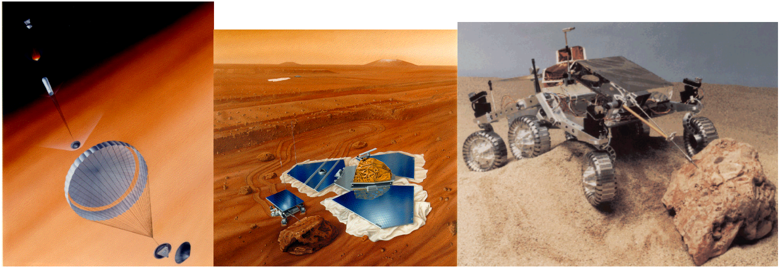
Proof
Alg-ex
3rd solution
Spec
Proof
Alg

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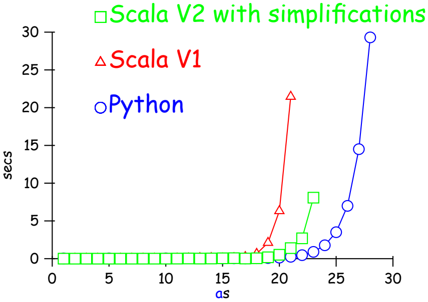
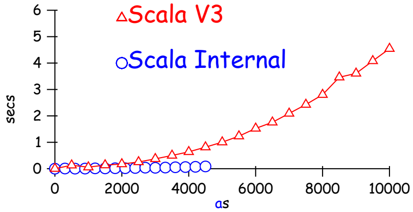
- we specified the algorithm and then proved that the specification makes "sense"
- we implemented our specification in C on top of PINTOS (Stanford)
- our implementation was much more efficient than their reference implementation

Regular Expression Matching





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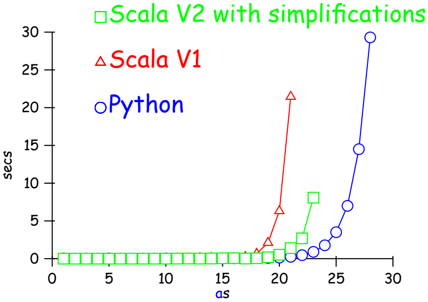

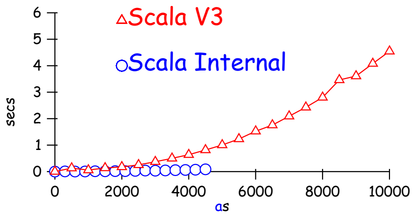

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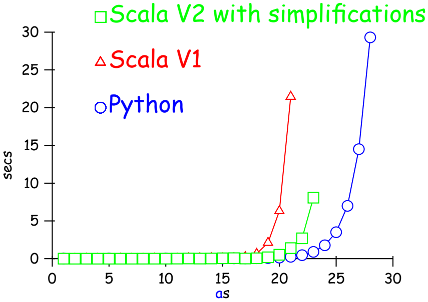
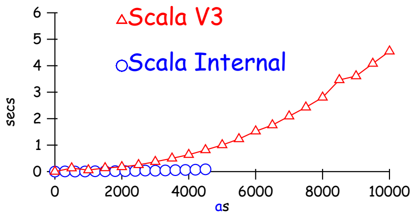
Regular Expression Matching





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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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$$\text{Alice says } m$$

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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

$$
\begin{array}{lcl}
A \text{ sends } S & : & \text{Connect}(A, B) \\
S \text{ sends } A & : & \{K_{AB}\}_{K_{AS}} \text{ and } \{\{K_{AB}\}_{K_{BS}}\}_{K_{AS}} \\
A \text{ sends } B & : & \{K_{AB}\}_{K_{BS}} \\
A \text{ sends } B & : & \{m\}_{K_{AB}}
\end{array}
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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{array}{l}
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}} \\
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$\Gamma \vdash B$ 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

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

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

Exchange of a Fresh 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 : $\{K_{AB}^{new}, N_B^{new}\}_{K_{AB}}$

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We hope K_{AB}^{new} is only known to A and B.
N_B^{new} is to be used in future messages

The Attack

An intruder I convinces B to accept an old compromised key

- A sends B : $A, \{N_A\}_{K_{AB}}$
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