Access Control and Privacy Policies (7)

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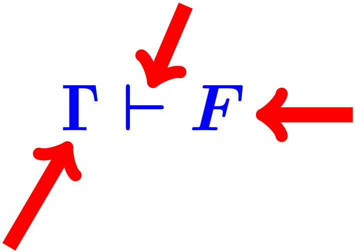
Slides:	KEATS (also homework is there)

Judgements

$$\Gamma \vdash F$$

Judgements



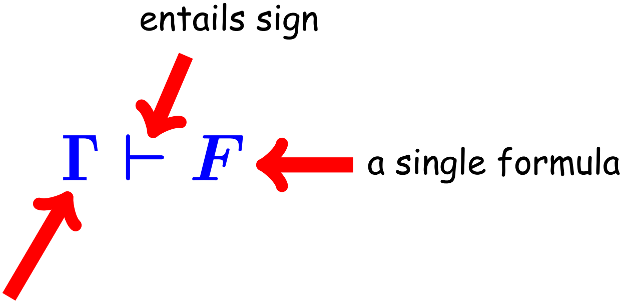
entails sign

$$\Gamma \vdash F$$

a single formula

Gamma
stands for a collection of formulas
("assumptions")

Judgements



entails sign

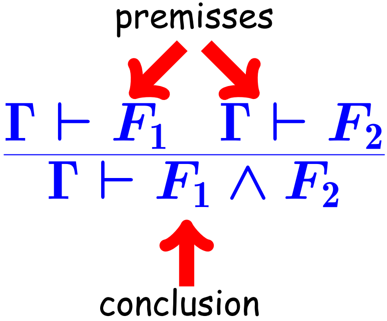
$$\Gamma \vdash F$$

a single formula

Gamma
stands for a collection of formulas
("assumptions")

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

Inference Rules

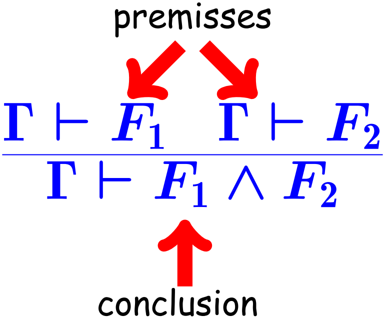


premisses

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

conclusion

Inference Rules



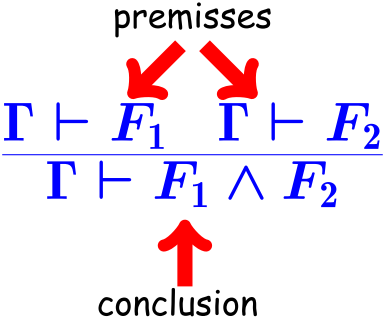
premisses

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

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

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

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

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

Digression: Proofs in CS

Formal proofs in CS sound like science fiction?

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Formal proofs in CS sound like science fiction? Completely irrelevant!

- 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)

Bob Harper
(CMU)

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

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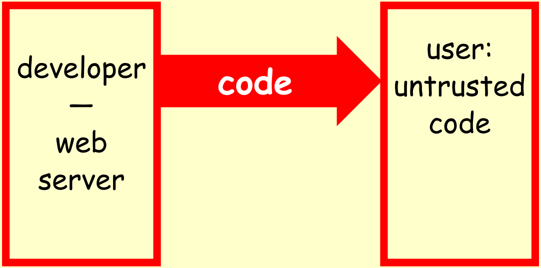
Andrew Appel
(Princeton)

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

Proof-Carrying Code

Idea:



developer

—

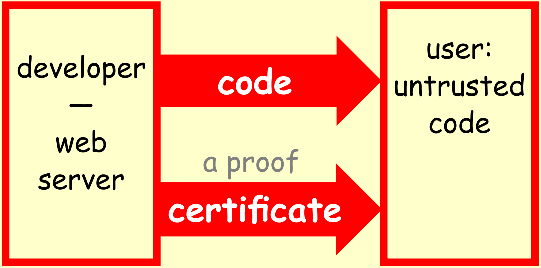
web server

code

user: untrusted code

Proof-Carrying Code

Idea:



developer — web server

code

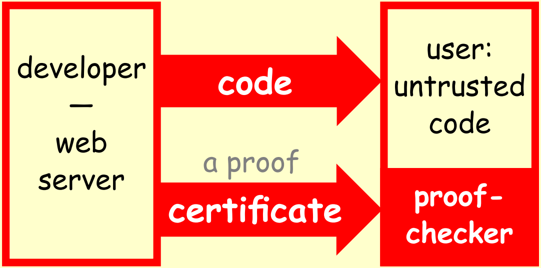
a proof

certificate

user: untrusted code

Proof-Carrying Code

Idea:



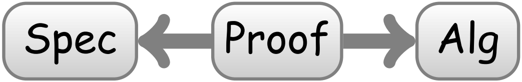
developer — web server

code

a proof certificate

user: untrusted code

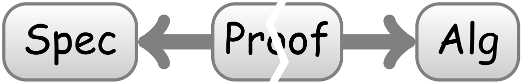
proof-checker



Spec

Proof

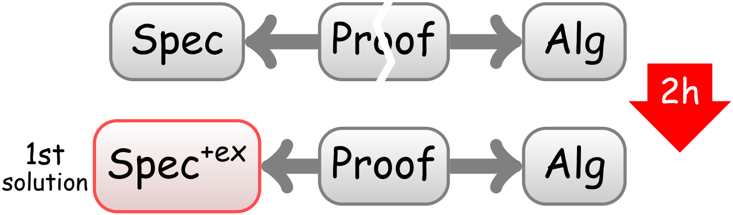
Alg



Spec

Proof

Alg



Spec

Proof

Alg

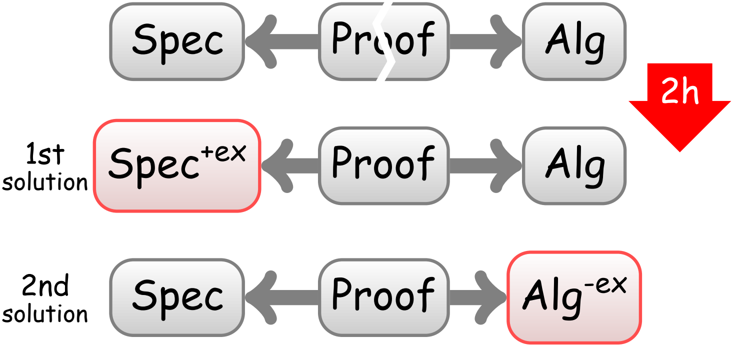
2h

1st solution

Spec^{+ex}

Proof

Alg

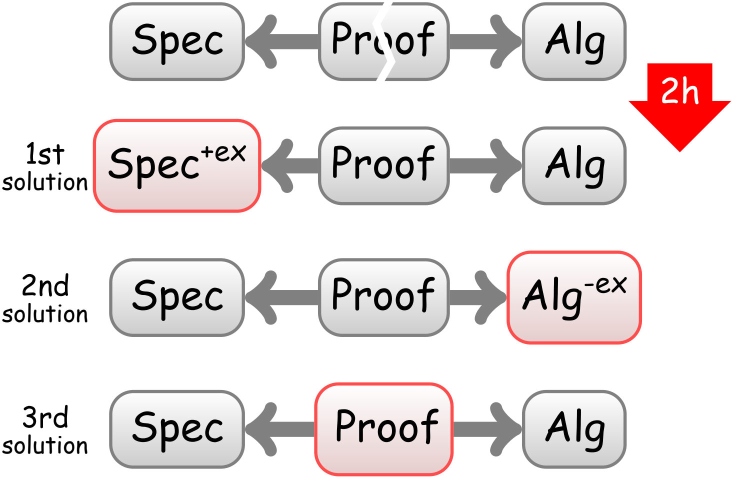


Spec ← Proof → Alg

2h

1st solution: Spec^{+ex} ← Proof → Alg

2nd solution: Spec ← Proof → Alg^{-ex}



Spec ← Proof → Alg

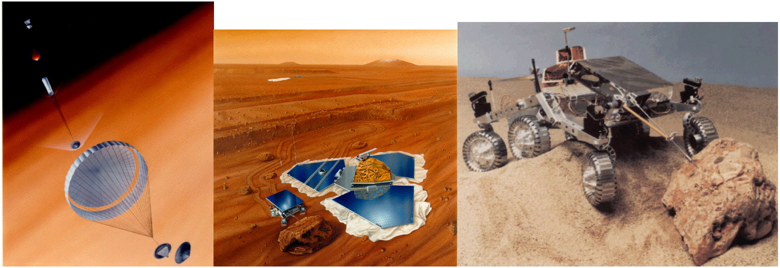
2h

1st solution: Spec^{+ex} ← Proof → Alg

2nd solution: Spec ← 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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- an algorithm that is widely used in real-time operating systems
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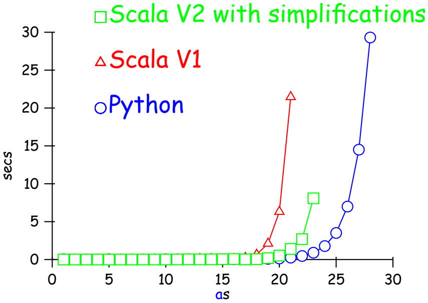
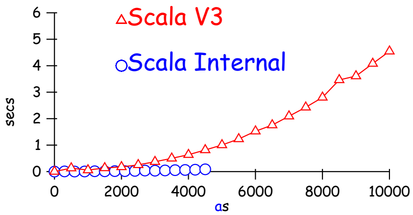
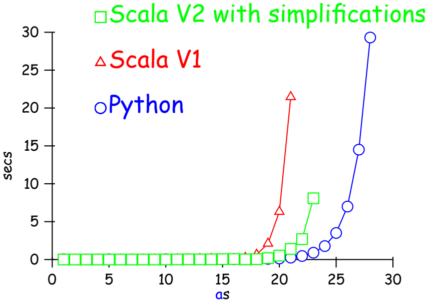
- we specified the algorithm and then proved that the specification makes "sense"
- we implemented our specification in C on top of PINTOS (Stanford)
- our implementation was much more efficient than their reference implementation

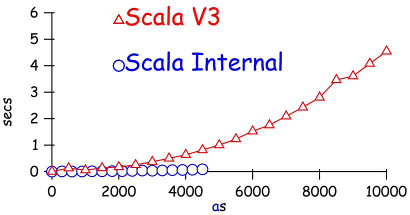
Regular Expression Matching





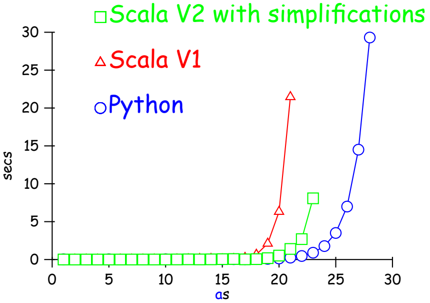
Regular Expression Matching

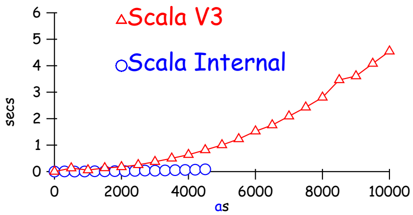




- I needed a proof in order to make sure my program is correct

Regular Expression Matching





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

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

Trusted Third Party

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

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

Encrypted Messages

- Alice sends a message m

Alice says m

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  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

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

Sending Rule

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

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

Trusted Third Party

A sends S : Connect(A, B)

S says (Connect$(A, B) \Rightarrow$

$\{K_{AB}\}_{K_{AS}} \wedge \{\{K_{AB}\}_{K_{BS}}\}_{K_{AS}})$

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

A sends B : $\{K_{AB}\}_{K_{BS}}$

A sends B : $\{m\}_{K_{AB}}$

Trusted Third Party

$$\begin{array}{l}
A \;\textsf{sends}\; S : \textsf{Connect}(A, B) \\
S \;\textsf{says}\; (\textsf{Connect}(A, B) \Rightarrow \\
\qquad\qquad \{K_{AB}\}_{K_{AS}} \wedge \{\{K_{AB}\}_{K_{BS}}\}_{K_{AS}}) \\
S \;\textsf{sends}\; A : \{K_{AB}\}_{K_{AS}} \wedge \{\{K_{AB}\}_{K_{BS}}\}_{K_{AS}} \\
A \;\textsf{sends}\; B : \{K_{AB}\}_{K_{BS}} \\
A \;\textsf{sends}\; B : \{m\}_{K_{AB}}
\end{array}$$

$\Gamma \vdash B \;\textsf{says}\; m$?

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 then starts engine

Challenge-Response Protokol

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

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