Logic I: Fast Lecture 07

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Readings refer to sections of the course textbook, *Language, Proof and Logic*.

1. Every Time I Go to the Dentist Someone Dies

Reading: §11.2

∀t (

(Time(t) ∧ ToDentist(a,t))

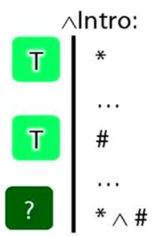
→

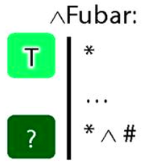
∃x (Person(x) ∧ TimeOfDeath(x,t))

)

2. The Soundness Property and the Fubar Rules (fast)

Reading: §8.3

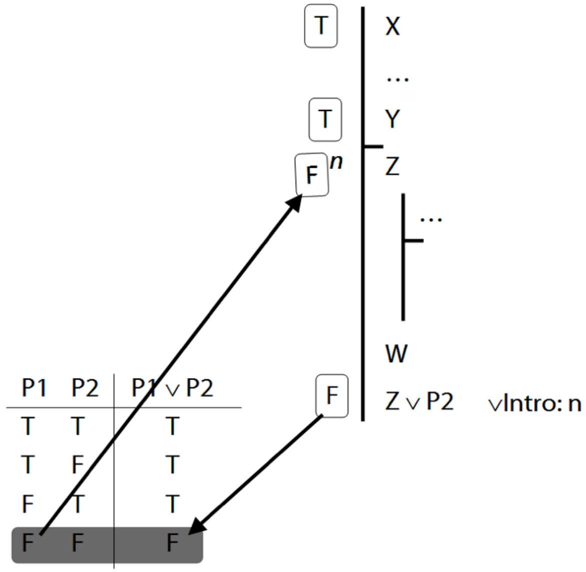




3. Proof of the Soundness Theorem

Reading: §8.3

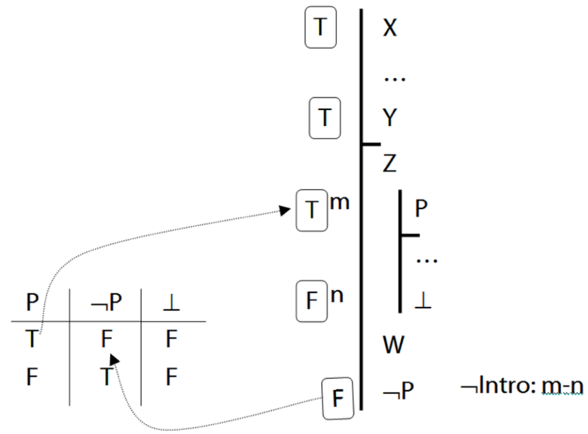
Illustration of soundness proof: ∨Intro



Useful Observation about any argument that ends with ∨Intro. Suppose this argument is not valid, i.e. the premises are true and the conclusion false. Then Z must be false. So the argument from the premises to Z (line n) is not a valid argument. So there is a shorter proof which is not valid.

Stipulation: when I say that *a proof is not valid*, I mean that the last step of the proof is not a logical consequence of the premises (including premises of any open subproofs).

Illustration of soundness proof: ¬Intro



How to prove soundness? Outline

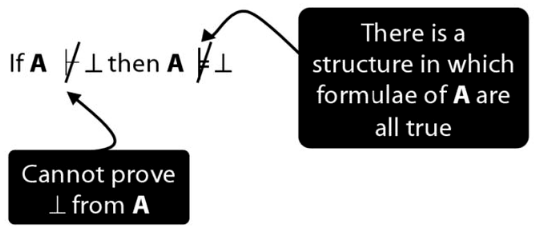
Step 1: show that each rule has this property:

Where the last step in a proof involves that rule, if proof is not valid then there is a shorter proof which is not valid.

Step 2: Suppose (for a contradiction) that some Fitch proofs are not valid. Select one of the shortest invalid proofs. The last step must involve one of the Fitch rules. Whichever rule it involves, we know that there must be a shorter proof which is not valid. This contradicts the fact that the selected proof is a shortest invalid proof.

4. The Essence of the Completeness Theorem

Reading: §8.3



Arrange the sentence letters in a series: P1, P2, P3, …

Define a structure, *h*, as follows.

Take each sentence letter, Pi, in turn.

- If **A** ⊢ Pi then *h*(Pi) = True

- If **A** ⊢ ¬Pi then *h*(Pi) = False

- Otherwise *h*(Pi) = True

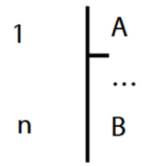
Every sentence of **A** is true in the structure *h*

Therefore **A** ⊭ ⊥

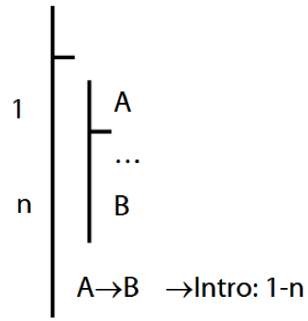
5. Proofs about Proofs

If A ⊢ B then ⊢ A⟶B

Proof Given a proof for A ⊢ B …



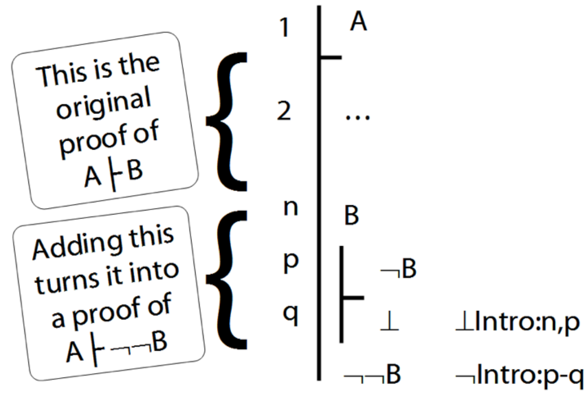
… we can turn it into a proof for ⊢ A⟶B:



If ⊢ A⟶B then A ⊢ B

If A ⊢ B then A ⊢ ¬¬B

Proof:



If A ⊢ C then A ⊢ B⟶C

If A ⊢ B and A ⊢ ¬C then A ⊢ ¬(B⟶C)

6. Lemma for the Completeness Theorem

Reading: §8.3

If for every sentence letter, P, either A ⊢ P or A ⊢ ¬P, then for every formula, X, either A ⊢ X or A ⊢ ¬X.

Proof

Step a. Suppose (for a contradiction) that there are formulae, X, such that A ⊬ X and A ⊬ ¬X. Take a shortest such formula, call it Y.

Step b. This formula, Y, must have one of the following forms: ¬P, P∨Q, P∧Q, P⟶Q, P↔Q, ⊥

Step c. We can show that whichever form X has, either $A \vdash Y$ and $A \vdash \neg Y$.

Case 1: X is $P \rightarrow Q$. Then since P and Q are shorter than X, either:

(i) $A \vdash P$ and $A \vdash \neg Q$

or

(ii) $A \vdash \neg P$

or

(iii) $A \vdash Q$

If (i), $A \vdash \neg(P \rightarrow Q)$, that is, $A \vdash \neg X$.

If (ii), $A \vdash P \rightarrow Q$, that is, $A \vdash \neg X$.

If (iii), $A \vdash P \rightarrow Q$, that is, $A \vdash \neg X$.

(Here we use the last two Proofs about Proofs, see earlier)

Case 2: X is $\neg P$.

Then since P is shorter, $A \vdash P$ or $A \vdash \neg P$.

If $A \vdash P$ then $A \vdash \neg\neg P$ so $A \vdash \neg X$ which would contradict our assumption. This is shown in the proofs about proofs above.

If $A \vdash \neg P$ then $A \vdash X$ (because X is $\neg P$), which would contradict our assumption.

Case 3: ...

Step d. The demonstration in Step c contradicts our assumption, so we can conclude that it is false. That is, either $A \vdash X$ and $A \vdash \neg X$ for every formula X.

7. Proof of the Completeness Theorem

Reading: §8.3, §17.2

Suppose **A** $\nvdash \bot$. Define **A*** as every formula in **A** plus the following:

For every sentence letter, P,

if **A** $\vdash$ P, add P to **A***

if **A** $\vdash \neg$P, add $\neg$P to **A***

otherwise add P to **A***

Now **A*** $\nvdash \bot$ and **A*** contains every sentence letter or its negation

Claim: for any formula X, **A*** $\vdash$ X or **A*** $\vdash \neg$X

Define a structure, *h*, so that:

h(P)=T when P is in **A***

h(P)=F when $\neg$P is in **A***

Claim: *h*(X)=T for every X that is a logical consequence of **A*** (see Prop. 4, p. 475).

Thus **A** $\nvdash \bot$

8. More Records Than the KGB

Reading: §14.1, §14.3

9. The End Is Near

Reading: §14.3

10. Exercises

These exercises will be discussed in seminars the week after this lecture. The numbers below refer to the numbered exercises in the course textbook, e.g. '1.1' refers to exercise 1.1. on page 39 of the second edition of *Language, Proof and Logic.* Exercises marked '*' are optional.

14.2

14.4, 14.5

14.10, 14.11

14.26, 14.28

13.51–2, 14.13

For each of the following sentences of FOL, give a logically equivalent sentence of idiomatic English using the specified interpretation. Your English sentences should be as concise as possible.

Domain : people and actions

D(x) : x is desirable

V(x) : x is virtuous

A(x) : x is an action

H(x) : x is a person

P(x,y) : x performed y

i. $\forall x\ ((\ D(x) \longrightarrow V(x)\ )$

ii. $\forall x\ (\ (A(x) \wedge D(x)\ ) \longrightarrow V(x)\ )\ )$

iii. $\exists x\ (\ A(x) \wedge \neg(\ D(x) \longrightarrow V(x)\ )\ )$

*iv. $\exists x(H(x) \wedge \forall y((A(y) \wedge P(x,y)) \longrightarrow V(y)))$

**v. $\neg\exists x\ (\exists y\ (H(x) \wedge P(x,y) \wedge A(y) \wedge \neg V(y)) \wedge \neg\exists z[P(x,z) \wedge A(z) \wedge V(z)))$