Reasoning and Formal Modelling for Forensic Science Lecture 5

Prof. Dr. Benedikt Löwe

2nd Semester 2010/11

Reminder: Controlled Situations.

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Every A is B.
Some C is B.

Some C is A.

Example. A: "Dutch citizen", B "citizen of an EU country", C "Bulgarian citizen". Fix five people in a room: a, b, c, d, e.

a is a Bulgarian citizen, b is a US citizen, c, d, and e are Dutch citizens. All Dutch and Bulgarian citizens are EU citizens (and only those). None of the five people has a dual nationality.

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Then this controlled situation makes "Every A is B" and "Some C is B" true, but not "Some C is A", and this shows the invalidity of the above syllogism.

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	P	Q	R	S
e_0	Yes	No	Yes	No
e_1	Yes	Yes	Yes	No
e_2	Yes	No	No	Yes

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- In order to abbreviate statements like "e has property P", we typically write $P(e)$.

Reminder: Proving that a mood is invalid.

Algorithm. Suppose you have an Aristotelian mood that you want to show invalid. The mood involves the terms A, B and C and has two premisses φ and ψ and a conclusion χ.

Step 1. Draw the Venn diagram for the mood. This gives you an indication how to invalidate the mood.

Step 2. Describe a controlled situation by giving individuals with well-defined properties A, B, and C.

Step 3. Argue that each of the premisses φ and ψ is true in the controlled situation.

Step 4. Argue that the conclusion χ is not true in the controlled situation.

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The knife is the murder weapon, has blood of the victim, and has fingerprints. The gun is not the murder weapon, has no blood, but has fingerprints of the suspect:

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Step 3. k is both A and B; g is B but not C.

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Aristotelean Syllogistics is a very restricted setting: we have exactly three properties A, B and C, and all sentences are of one of the four forms

"All X are Y"	"Some X are Y"
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In other words, we can use our binary and unary connectives to link sentences together: $\wedge$, $\vee$, $\neg$, $\rightarrow$.

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There is exactly one combination of truth values that invalidates a mood, and the algorithm asks us to produce a controlled situation for that combination of truth values.

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$$(H(j) \to M(j)) \wedge (H(s) \to M(s)) \wedge (H(b) \to M(b)).$$

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$$\begin{aligned} \text{BiggerThanTwo} &\rightsquigarrow \{3, 4, 5, 6, 7, ...\}, \\ \text{Odd} &\rightsquigarrow \{1, 3, 5, 7, 9, ...\}, \\ \text{Prime} &\rightsquigarrow \{2, 3, 5, 7, 11, 13, ...\}. \end{aligned}$$

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$$\forall x(\mathrm{BiggerThanTwo}(x) \wedge \mathrm{Prime}(x) \to \mathrm{Odd}(x)).$$

But this cannot be expressed by connectives, as you will never be able to finish the formula describing it (as $\mathbb{N}$ is infinite).

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Note that we do not need symbols for "no" and "some — not", as they can be defined from $\forall$ and $\exists$:

"No individuals have property P"	"Some individuals don't have property P"
$\forall x \neg P(x)$	$\exists x \neg P(x)$

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$\exists x\varphi$ is valid in S	if and only there is some $e \in E$ such that if we replace all occurrances of x in φ by e, then this formula $\varphi\frac{e}{x}$ is valid.

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a	No	Yes	Yes

- Every teacher is a philosopher.
  $\forall x(T(x) \rightarrow P(x))$
  $(T(s) \rightarrow P(s)) \wedge (T(p) \rightarrow P(p)) \wedge (T(a) \rightarrow P(a))$
  $\rightsquigarrow$ **YES!**
- Every teacher is a student.
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MQL: Example 1

We have three individuals, s (Socrates), p (Plato), and a (Aristotle), and three properties T (teacher), S student, and P (philosopher).

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s	Yes	No	Yes
p	Yes	Yes	Yes
a	No	Yes	Yes

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  $\forall x(T(x) \rightarrow P(x))$
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  $\rightsquigarrow$ **No!**

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Individuals: m (male), o (officers). Properties: D (took drugs), S (has unusual strength), A (is arrested).

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  $\rightsquigarrow$ **No!**

MQL: Example 3

Prof. Dr. Benedikt Löwe

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Police report, Colorado Springs, 16 Feb 2011, 7:54 am:
Officers responded in regards to an unresponsive female found inside of the home. When officers arrived they contacted members of the Colorado Springs Fire Department who indicated that the female was deceased. A short time later, the 20 year old female was pronounced dead by medical personnel. At this time, there are no identifiable suspicious circumstances surrounding the death. However, the exact cause of death has not been determined. The El Paso County Coroners Office responded and took possession of the female. They will be performing an autopsy in an attempt to determine a cause of death.

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  $\forall x(U(x) \to D(x))$
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- There is someone who is neither dead nor pronounced someone dead.

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Formally: a controlled situation with individuals f (female), d (dog), m (medical personnel) and properties D (dead) and P (made a pronouncement of death).

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How do we express that the medical personnel only pronounced the female dead, but not the dog?

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Leibniz's Monadology: attempt to reduce everything to properties

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> *The question whether all propositions are reducible to subject-predicate form is one of fundamental importance to all philosophy. ... I cannot here, however, do more than indicate the grounds for rejecting the traditional view. ... We must admit, ... relations between subjects [cannot be regarded as a mere sum of subject-predicate propositions]—e.g. relations of position, of greater and less, of whole and part. (pp. 13–14)*

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Examples.

- The medical personnel pronounces the female dead.
- Jeff kills Sue.

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Examples.

- The medical personnel pronounces the female dead.
- Jeff kills Sue.
- Plato is the teacher of Socrates.

Semantics of (dyadic) quantifier logic

A controlled situation with relations is a controlled situation together with some relations $R_0, ..., R_m$.

We fix a controlled situation with relations S: collection E of individuals, some properties $P_0, ..., P_n$ and some relations $R_0, ..., R_m$. We say

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$R_j(e, f)$ is valid in S	if and only if e and f are in relation R_j

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We fix a controlled situation with relations S: collection E of individuals, some properties $P_0, ..., P_n$ and some relations $R_0, ..., R_m$. We say

$P_i(e)$ is valid in S	if and only if e has property P_i
$R_j(e, f)$ is valid in S	if and only if e and f are in relation R_j
$\varphi \wedge \psi$ is valid in S	if and only if φ is valid in S and ψ is valid in S
$\varphi \vee \psi$ is valid in S	if and only if φ is valid in S or ψ is valid in S
$\neg\varphi$ is valid in S	if and only if φ is not valid in S
$\forall x \varphi$ is valid in S	if and only if no matter which $e \in E$ we choose, if we replace all occurrances of x in φ by e, then this formula $\varphi\frac{e}{x}$ is valid.
$\exists x \varphi$ is valid in S	if and only there is some $e \in E$ such that if we replace all occurrances of x in φ by e, then this formula $\varphi\frac{e}{x}$ is valid.

DQL: Example 1.

Prof. Dr. Benedikt Löwe

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Police report, Colorado Springs, 15 Feb 2011, 2:55 pm:
A female victim called 911 to report that she had been stabbed near the Stargazers Theater ... The victim reported a Hispanic male in his late 20's to early 30's attempted to rob her, and he stabbed her in the stomach area. Officers and medical personnel contacted the victim in the south parking lot of the Stargazers Theatre and she was transported to the hospital to have the knife removed from her lower stomach area. The victim described the suspect as a Hispanic male in his late 20's to early 30's, approximately 5-10 in height with a heavier build and a ponytail. The suspect was reported to be wearing a plain black long sleeve shirt, jeans, and black gloves. Officers searched the area but were unable to locate the suspect.

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Individuals: f (female), m (male), o (officers).

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f	Yes
m	No
o	No

S	f	m	o
f	No	No	No
m	Yes	No	No
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- Someone who stabbed someone else is still not located.

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  $\exists x(\exists y S(x,y) \wedge \forall z \neg L(z,x))$

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  $\leadsto$ **YES!**

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  $S(m,f) \wedge (\neg L(f,m) \wedge \neg L(m,m) \wedge \neg L(o,m))$
  $\rightsquigarrow$ **YES!**
- There is someone who got stabbed but was not hospitalized.

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  $S(m,f) \wedge (\neg L(f,m) \wedge \neg L(m,m) \wedge \neg L(o,m))$
  $\rightsquigarrow$ **YES!**
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  $\exists x(\exists y S(y,x) \wedge \neg H(x))$

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  $\exists x(\exists y S(x,y) \wedge \forall z \neg L(z,x))$
  $S(m,f) \wedge (\neg L(f,m) \wedge \neg L(m,m) \wedge \neg L(o,m))$
  $\rightsquigarrow$ **YES!**
- There is someone who got stabbed but was not hospitalized.
  $\exists x(\exists y S(y,x) \wedge \neg H(x))$
  $S(m,f) \wedge H(f)$, $\neg\exists y S(y,m)$, $\neg\exists y S(y,o)$

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  $S(m,f) \wedge (\neg L(f,m) \wedge \neg L(m,m) \wedge \neg L(o,m))$
  $\rightsquigarrow$ **YES!**
- There is someone who got stabbed but was not hospitalized.
  $\exists x(\exists y S(y,x) \wedge \neg H(x))$
  $S(m,f) \wedge H(f)$, $\neg \exists y S(y,m)$, $\neg \exists y S(y,o)$
  $\rightsquigarrow$ **No!**