

AI Tutorial

Resolution (3^d Inference Method)

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24 January 2008

Monty Python's Holy Grail World

- 1 Every woman that can be burnt is a witch.
- 2 Everything that is made of wood can be burnt.
- 3 Everything that floats is made of wood.
- 4 Everything that weighs the same as something that floats, does float too.
- 5 This girl is a woman.
- 6 This girl weighs the same as this duck.
- 7 This duck floats.

? Is the girl a witch?

- 1 $(\forall x)(Burns(x) \wedge Woman(x) \Rightarrow Witch(x)).$
 - 2 $(\forall x)(Ismadeofwood(x) \Rightarrow Burns(x)).$
 - 3 $(\forall x)(Floats(x) \Rightarrow Ismadeofwood(x)).$
 - 4 $(\forall x)(\forall y)((Floats(x) \wedge Sameweight(x, y)) \Rightarrow Floats(y)).$
 - 5 $Woman(Girl).$
 - 6 $Sameweight(Duck, Girl).$
 - 7 $Floats(Duck).$
- ? $Witch(Girl)$

Resolution (1/3)

Transform KB into conjunctive normal form (CNF)

- 1 $\neg \text{Burns}(x_1) \vee \neg \text{Woman}(x_1) \vee \text{Witch}(x_1).$
- 2 $\neg \text{Ismadeofwood}(x_2) \vee \text{Burns}(x_2).$
- 3 $\neg \text{Floats}(x_3) \vee \text{Ismadeofwood}(x_3).$
- 4 $\neg \text{Floats}(x_4) \vee \neg \text{Sameweight}(x_4, y_1) \vee \text{Floats}(y_1).$
- 5 $\text{Woman}(\text{Girl}).$
- 6 $\text{Sameweight}(\text{Duck}, \text{Girl}).$
- 7 $\text{Floats}(\text{Duck}).$

We shall insert in KB the complement of the proposition that we want to prove. If the initial proposition is true according to our KB then we will end up in a refutation.

? $\neg \text{Witch}(\text{Girl})$

Resolution (2/3)

Resolution method application (1/2)

$\neg\text{Witch}(\mathbf{Girl})$

$\neg\text{Burns}(x_1) \vee \neg\text{Woman}(x_1) \vee \text{Witch}(x_1)$

Resolution (2/3)

Resolution method application (1/2)

$\neg \text{Witch}(\mathbf{Girl})$

$\neg \text{Burns}(x_1) \vee \neg \text{Woman}(x_1) \vee \text{Witch}(x_1)$

$\neg \text{ismadeofwood}(x_2) \vee \text{Burns}(x_2)$

$\neg \text{Burns}(\mathbf{Girl}) \vee \neg \text{Woman}(\mathbf{Girl})$

Resolution (2/3)

Resolution method application (1/2)

\neg Witch(**G**irl)

\neg Burns(x_1) \vee \neg Woman(x_1) \vee Witch(x_1)

\neg Ismadeofwood(x_2) \vee Burns(x_2)

\neg Burns(**G**irl) \vee \neg Woman(*G*irl)

Woman(**G**irl)

\neg Ismadeofwood(*G*irl) \vee \neg **W**oman(**G**irl)

Resolution (2/3)

Resolution method application (1/2)

\neg Witch(**G**irl)

\neg Burns(x_1) \vee \neg Woman(x_1) \vee Witch(x_1)

\neg Ismadeofwood(x_2) \vee Burns(x_2)

\neg Burns(**G**irl) \vee \neg Woman(*G*irl)

Woman(**G**irl)

\neg Ismadeofwood(*G*irl) \vee \neg **W**oman(**G**irl)

\neg Floats(x_3) \vee Ismadeofwood(x_3)

\neg Ismadeofwood(**G**irl)

Resolution (3/3)

Resolution method application (2/2)

$\neg Floats(x_4) \vee \neg Sameweight(x_4, y_1) \vee Floats(\mathbf{y_1})$

$\neg Floats(\mathbf{Girl})$

Resolution (3/3)

Resolution method application (2/2)

$\neg Floats(x_4) \vee \neg Sameweight(x_4, y_1) \vee Floats(y_1)$

$\neg Floats(\mathbf{Girl})$

$Sameweight(\mathbf{Duck}, \mathbf{Girl})$

$\neg Sameweight(x_4, \mathbf{Girl}) \vee \neg Floats(x_4)$

Resolution (3/3)

Resolution method application (2/2)

$\neg Floats(x_4) \vee \neg Sameweight(x_4, y_1) \vee Floats(y_1)$

$\neg Floats(\mathbf{Girl})$

$Sameweight(\mathbf{Duck}, \mathbf{Girl})$

$\neg Sameweight(x_4, \mathbf{Girl}) \vee \neg Floats(x_4)$

$Floats(\mathbf{Duck})$

$\neg Floats(\mathbf{Duck})$

Resolution (3/3)

Resolution method application (2/2)

$\neg Floats(x_4) \vee \neg Sameweight(x_4, y_1) \vee Floats(y_1)$

$\neg Floats(\mathbf{Girl})$

$Sameweight(\mathbf{Duck}, \mathbf{Girl})$

$\neg Sameweight(x_4, \mathbf{Girl}) \vee \neg Floats(x_4)$

$Floats(\mathbf{Duck})$

$\neg Floats(\mathbf{Duck})$

\emptyset

- 1 We used the resolution method to prove that the **Girl** is a **Witch**. Even if the concluding fact and the rules (of KB) don't reflect our perception in real life, resolution managed to come to a solution.

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- 2 Why?
Because resolution method is an inference rule, that is, it can be applied mechanically. Inference rules do not discriminate between different perceptions of different worlds. Inference rules treat every such world equally.

- 1 We used the resolution method to prove that the **Girl** is a **Witch**. Even if the concluding fact and the rules (of KB) don't reflect our perception in real life, resolution managed to come to a solution.
- 2 Why?
Because resolution method is an inference rule, that is, it can be applied mechanically. Inference rules do not discriminate between different perceptions of different worlds. Inference rules treat every such world equally.
- 3 So, we can surely say that Holy Grail's World thinks Logically!

- ① Marcus was a man.
- ② Marcus was a Pompeian.
- ③ All Pompeian were Romans.
- ④ Ceasar was a ruler.
- ⑤ All Romans were either loyal to Ceasar or hated him.
- ⑥ Everyone is loyal to someone.
- ⑦ Men only try to assassinate rulers that are not loyal to.
- ⑧ Marcus tried to assassinated Ceasar.

? Was Marcus hating Ceasar?

Representing Rome's World using FOL

- 1 $man(Marcus)$.
- 2 $Pompeian(Marcus)$.
- 3 $(\forall x)(Pompeian(x) \Rightarrow Roman(x))$.
- 4 $ruler(Ceasar)$.
- 5 $(\forall x)(Roman(x) \Rightarrow loyalto(x, Ceasar) \vee hate(x, Ceasar))$.
- 6 $(\forall x)(\exists y)loyalto(x, y)$.
- 7 $(\forall x)(\forall y)(man(x) \wedge ruler(y) \wedge tryassassinate(x, y) \Rightarrow \neg loyalto(x, y))$.
- 8 $tryassassinate(Marcus, Ceasar)$.
? $hate(Marcus, Ceasar)$

Resolution (1/2)

Transform KB into conjunctive normal form (CNF)

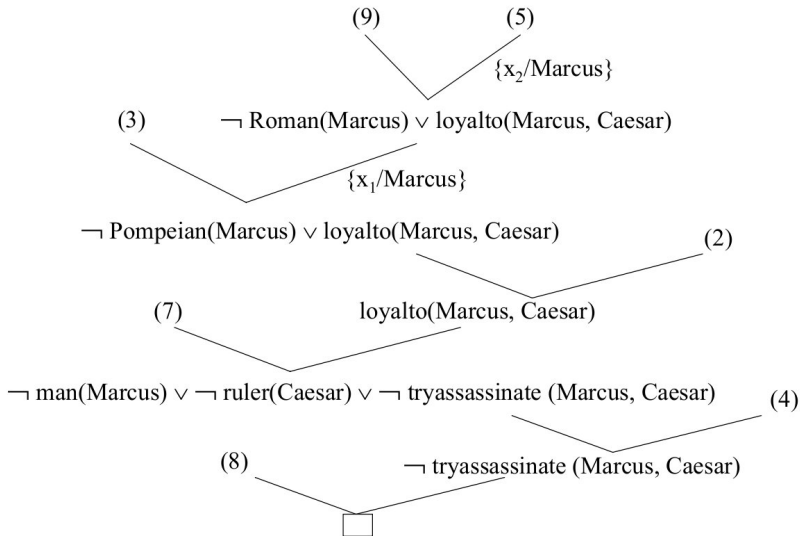
- 1 $man(Marcus)$.
- 2 $Pompeian(Marcus)$.
- 3 $\neg Pompeian(x_1) \vee Roman(x_1)$.
- 4 $ruler(Ceasar)$.
- 5 $\neg Roman(x_2) \vee loyalto(x_2, Ceasar) \vee hate(x_2, Ceasar)$.
- 6 $loyalto(x_3, F(x_3))$.
- 7 $\neg man(x_4) \vee \neg ruler(y_1) \vee \neg tryassassinate(x_4, y_1) \vee \neg loyalto(x_4, y_1)$.
- 8 $tryassassinate(Marcus, Ceasar)$.

We shall insert in KB the complement of the proposition that we want to prove. If the initial proposition is true according to our KB then we will end up in a refutation.

$$(9) \neg hate(Marcus, Ceasar)$$

Resolution (2/2)

Resolution method application





Monty Python and the Holy Grail (1975).

You can find the verbatim dialogue at

http://en.wikiquote.org/wiki/Monty_Python_and_the_Holy_Grail#The_Witch.

You can also find the corresponding movie scene at

http://www.youtube.com/watch?v=zrzMhU_4m-g.



The application of the resolution method in Roman's World has been taken from the

Elaine Rich and Kevin Knight, Artificial Intelligence, 2nd edition, McGrawHill, 1990.



The LaTeX Beamer Class Homepage.

<http://latex-beamer.sourceforge.net/>.

Thank you!