1. [Start of transcript. Skip to the end.](https://courses.edx.org/xblock/block-v1:ColumbiaX+CSMM.101x+3T2020+type@vertical+block@f64cfd21e94549559bdb4bf09129e3ac?show_title=0&show_bookmark_button=0#transcript-end-510bb8a8ed2742f8aeb2a73aa5b6fb2b)
2. Let's get started with model checking, in which we
3. are going to enumerate all possible models using
4. truth tables, OK?
5. So a model is simply an assignment true or false
6. to every propositional symbol in the sentence or the formula.
7. And what we need to do is to check that,
8. actually, the formula, or the sentence,
9. alpha, is true in every model in which the knowledge
10. base is true.
11. OK?
12. So we're going to check by examining this truth table,
13. or that we could find that alpha is actually true
14. whenever KB is true.
15. Let's now consider the set of rules we built in the knowledge
16. base to represent the reduced Wumpus world,
17. in which we used a set of seven propositional symbols,
18. B1,1 through B3,1, and wrote a set of five rules to represent
19. the knowledge base.
20. So in this case, the knowledge base could be written,
21. as actually, the rule one, and the rule two, and rule five,
22. OK?
23. So all these elements has to actually build or make
24. the knowledge base.
25. All right, so we have seven propositional symbols.
26. And we're going to talk about truth table on this knowledge
27. base.
28. So we're going to check the models, or assignments
29. of true or false, for each of these oppositional symbols.
30. So, in total, we have two to the seven
31. equals 128 possible rows in the truth table.
32. We're going to just focus on these three lines
33. here in which the knowledge base is true.
34. Why?
35. You remember we wanted to answer the questions such as does KB
36. entails the proposition P1,1?
37. Does KB entails the proposition P2,2?
38. OK, so far these are questions and we don't know.
39. We want to use model checking, to actually check the truth
40. value of P1,1, whenever KB is actually true.
41. All right, so KB is true in three out of 128 possible rows.
42. So we're going to focus on this three lines
43. here, or three rows here.
44. We're going to check that actually whenever the knowledge
45. base is true we have P1,1 is actually false,
46. in which case we could infer with confidence that KB entails
47. the negation of P1,1, OK?
48. So this is not the question anymore, all right?
49. So we know by model checking that KB entails the negation
50. of P1,1, all right?
51. So it's not the case for P2,2.
52. So if you look at P2,2, we have P2,2 could be either true
53. or false based whenever KB is true.
54. So we can't really say that KB entails P2,2,
55. at least at this stage in which the agent explored the bottom
56. left corner of the environment.
57. In a similar way, we could check whether actually P1,2 is true
58. or P2,1 is true.
59. And just like P1,1, we have KB entailing the negation of P1,2,
60. and KB entailing the negation of P2,1.
61. All right, so this model checking
62. help us actually derive knowledge
63. about the truthfulness, or the validity,
64. of these kinds of formulas, and can help then the agent
65. move in its environment.
66. Now suppose we don't have model checking as a tool,
67. we only can do inference using Modus Ponens and whatever
68. equivalence propositional logic formula we found earlier,
69. all right?
70. So no semantics at all, just syntax.
71. So we're going to focus on the knowledge
72. base of the reduced Wumpus world in which we have the rules
73. R1, R2, through R5.
74. So what you want to prove here, for example, is that--
75. let's say KB entails the proposition P1,2.
76. That's a question.
77. And whether KB entails the proposition P2,1.
78. And that's another question, OK?
79. So can we use inference rules on this knowledge base
80. to actually derive information about whether this
81. is true or false, and whether this is true or false?
82. All right, so first observation, P1,2 and P2,1 appear
83. in the number two, this proposition here.
84. So we can just focus on this one for now.
85. This one does not have P1,2, P, and P2,1,
86. so it is unlikely that this rule would lead to inference these
87. two elements that we are trying to prove.
88. All right, so we're starting with the rule R2, right?
89. So the rule R2 says that breeze in 1,1,
90. if and only if we have a pit in 1,2, or a pit in 2,1, OK?
91. So this is the first rule.
92. This is a rule that we know is true.
93. There is a breeze only if there is a pit is the adjacent rooms.
94. All right, so from this one we're
95. going to make an inference, usually we like to draw lines,
96. so this is a line.
97. And this line will be an inference
98. based on the bi-directional, or the if
99. and only if, splitting into two implications.
100. So I'm going to write this as actually as a B1,1 implies
101. P1,2, or P2,1.
102. And I'm going to put that in another color.
103. And we have P1,2, or P2,1, implies B1,1.
104. It's a good habit to use parenthesis
105. to show that we have these two elements here, proposition
106. P and preposition q, all right?
107. And we want to see what we could do with that next.
108. So let's call this the position rule R6.
109. All right, so from R6 what we can
110. do-- so remember if we have a proposition P and proposition
111. q, then we could infer P. And from P and q
112. we can also infer q.
113. And the reason is that , if this is true,
114. it's guaranteed that both of them are true based
115. on the definition of the connective of conjunction.
116. All right, so we're going to focus on
117. either or of these parts.
118. I would rather say let's pick one of them.
119. I would pick this one first, and I will tell you why later.
120. So we have P1,2, or P2,1, implies B1,1.
121. This is by the definition of the conjunction.
122. In inference rules, if you have the conjunction,
123. you could infer any side of the conjunction.
124. OK, great.
125. So why I'm using this one?
126. Because I simply see that I have B1,1.
127. And I want to be able to infer through Modus Ponens,
128. either P1,2, or P2,1.
129. And remember for Modus Ponens, if we have P and p implies q,
130. I can infer q.
131. But you would tell me that this is actually not
132. on the right side.
133. And I would tell you that actually I don't have B1,1
134. either.
135. I have not B1,1.
136. So I'm going to use the trick of the contrapositive
137. to flip this implication.
138. And in this case this is the contrapositive.
139. Using the contrapositive, it's possible to write this formula
140. as B1,1 implies the negation of P1,2 or P2,1.
141. OK?
142. So I'm trying to put this on the side,
143. but I'm taking also care of having the negation of B1,1
144. on the lefthand side.
145. We could also use actually the Modus Ponens
146. if you want to keep it as.
147. But let's do it this way first, all right?
148. So from this what I can do is I see
149. that I have something that looks very much like Modus Ponens.
150. I have P. I have q.
151. And I also have P here.
152. So I'm going to write this rule, R4.
153. But maybe before I do that, let me try to break this down,
154. because it's the negation of the disjunction of P1,2 and P1,2.
155. So I'm going to use DeMorgan's Law,
156. in which I'm going to distribute the negation,
157. which will give me the negation of B1,1 implies not P1,2
158. and not P2,1.
159. All right, so if you check the properties,
160. we have DeMorgan's law that actually
161. has this property of distributing the negation
162. and changing the disjunction into a conjunction.
163. OK, great.
164. So I start to see things coming up.
165. I have P implies q, and I have P in R4,
166. so I'm going to write R4 here.
167. So I'm going to write R4 here.
168. R4 is what?
169. I have the negation of B1,1, OK?
170. So check this out.
171. We have the negation of B1,1.
172. We have P. P implies q, so I could use Modus Ponens,
173. this rule here, to infer by Modus Ponens that I have
174. the negation of P1,2 and the negation of P2,1, all right?
175. So from this I'm getting close to showing these elements here.
176. So from this one this is the conjunction of these two.
177. So if this is true, again by using the conjunction-- and I
178. meant to use the red here, so that I'm
179. doing the inference here.
180. So I'm going to infer that I have P1,2.
181. And I can also infer that I have P2,1, OK?
182. So what I proved just now is that actually the knowledge
183. base infers, or entails, the negation of P1,2.
184. And it entails the negation of P2,1, all right?
185. So you could think of doing a similar thing,
186. but I would give that does exercise.
187. Right, so try to prove P2,2 and P1,2 using the third rule R3,
188. all right?
189. So hear it's important to observe
190. that I didn't use R3 at all.
191. I ignored it altogether.
192. I just used R2.
193. I used R4 to prove that actually I can entail the negation
194. of P1,2 and the negation of P2,1 without even integrating any
195. model or building any truth table.
196. You might have noticed something from the previous example,
197. which is that inference sounds like search.
198. On I'm searching through what rules to apply,
199. what inference to do to achieve some goal, which
200. is to put entailments between the knowledge base
201. and the proposition, right?
202. So it's possible actually to cast the problem of inference
203. as a search problem and use any of the algorithms we have
204. seen in the previous weeks.
205. So the way to formalize that is to use
206. an initial state, in which we use the knowledge base.
207. This is the set of rules, R1 through R5 that I had before.
208. The actions would be all the inference rules
209. applied to all sentences that match
210. the top of the inference rules.
211. So the top of the inference rule, also as I said
212. called premise-- so we have each interest
213. would be a premise and a conclusion, right?
214. So we're going to apply the set of actions
215. would be all the inference rules that apply to all sentences
216. that's match the premise of the inference rule.
217. So we're going to explore the possible actions
218. on all the inference rules.
219. The result would be to add the sentence that's
220. in the bottom half.
221. So whatever conclusion you get, you're
222. going to add that to as a result of the knowledge base.
223. Now the goal would be a state containing the sentence
224. we're trying to prove.
225. So in the previous example I wanted to find whether KB
226. entails P1,2 or P2,2 or P1,2.
227. Now there are four possibilities.
228. So suppose we have KB.
229. I wanted to know whether KB is P1,2,
230. so I just need to focus on this one as the goal, right?
231. Start this is the initial state and try to apply possible rules
232. until I reach the result P1,2 or the negation of P1,2.
233. So it's possible to just use any search problem
234. algorithm to reach the goal of doing inference just based
235. on the syntax and again without using any model checking.