Advanced Topics in Artificial Intelligence
ANSWERS - don't distribute

T-720-ATAI-2016

EXERCISE 4 (NARS)

In this exercise you will get acquainted with Dr. Pei Wang's Non-Axiomatic Reasoning System (NARS). This assignment reused an assignment made for the 2012 version of this class. Credit goes to Deon Garrett.

Download OpenNARS

OpenNARS is an open source implementation of NARS. Download version 1.7.0 from https://drive.google.com/folderview?id=0B8Z4Yige07tBUk5LSUtxSGY0eVk&usp=sharing . Note that you can also download the source code here, but if you're going to do that, it might be better to get it from GitHub: https://github.com/opennars/opennars. You will not need the source code for this exercise, but you should probably check out the wiki: https://github.com/opennars/opennars/wiki.

When you have unzipped the file, run OpenNARS_GUI.jar to start the program and start the interactive session by clicking the OpenNARS button. Resetting the memory does not appear to work, so if you want that, you'll have to restart the program.

To enter a sentence, press Ctrl + Enter. Documentation about an older but similar interface is here: https://github.com/opennars/opennars/wiki/Graphical-User-Interface. The Narsese grammar is here: https://github.com/opennars/opennars/wiki/Input-Output-Format.

Tip: You can't copy text that you've typed into the OpenNARS GUI. It is probably a good idea to write your commands somewhere else and then paste them into the GUI, so that you don't lose any work.

Non-Axiomatic Reasoning

Answer the following questions. For questions requiring calculations, you must use the low-level method of computing direct evidence via extensional and intentional sets only if the question explicitly asks for that method. Unless so specified, you may use the high-level inference rules (e.g., induction, abduction, similarity, etc.). **Specify which inference rules you used for each step.**

Note that each question may build on the previous answers. Your answers should be consistent with the evidence provided to the system via earlier answers (e.g., if you use “beagle” in one rule, don’t use “beagles” in another, make sure your truth values are calculated based on the truth values generated from earlier steps, etc.)

For any questions where it matters, assume the horizon parameter k=1.

1. Given the following knowledge, encode it into Narsese:
   - dogs are a type of animal.
     i. `<dog --> animal>.`
   - cats are a type of animal.
     i. `<cat --> animal>.`
2. Encode the query “Are dogs equivalent to cats?” into Narsese and show how the truth value of the statement (f and c) is computed in terms of the evidence (i.e., use the definitions of the extensional and intensional sets).
   - `<cat <-> dog>? %1.00;0.45%`
   - To arrive at the conclusion, the system must make the "comparison" inference step (slide 17). w+ = f1&c1&f2&c2, w = (f1|f2)&c1&c2. "&"/"and" is just done by multiplication, and "~"/"not" is done by subtracting a value from 1. Since a|b ("a or b") is the same as ~(~a&~b), we can calculate this by 1-(1-a)(1-b). So w+ = f1*c1*f2*c2 = .9*1*.9*1 = .81, and w = (1-(1-f1)(1-f2))*c1*c2 = (1-(1-1)(1-1))*.9*.9 = .81. Then we can use f=w+/w=1, and c=w/(w+k) = 0.447513812.
3. Encode the following statements into Narsese:
   - Snoopy is a dog.
     i. `<Snoopy {-- dog>.`
     ii. `<{Snoopy} --> dog>.`
   - Garfield is a cat.
     i. `<Garfield {-- cat>.`
     ii. `<{Garfield} --> cat>.`
   - Cujo is a dog.

   i. `<Cujo {-- dog>.`
   ii. `<{Cujo} --> dog>.`

4. Encode the following statements into Narsese:
   - Garfield is aloof.
     i. `<Garfield {-] aloof>.`
     ii. `<{Garfield} --> [aloof]>.`
   - Snoopy is friendly.
     i. `<Snoopy {-] friendly>.`
     ii. `<{Snoopy} --> [friendly]>.`
   - Note that Garfield is a specific cat, and "aloof" is an adjective describing the typical behavior of cats; similarly for Snoopy and dogs.
5. Encode the query "are cats aloof" into Narsese and show the truth value using the standard NARS inference rules from NAL–1 and NAL–2. Do the same for the query "is Cujo friendly?". Note that you may need to perform multiple inferences to answer the query.

- <cat --] aloof>?
  - i. Induction:
    1. <{Garfield} --> cat>. % 1.0;0.9 %
    2. <{Garfield} --] aloof>. % 1.0;0.9 %
    3. <cat --] aloof>. % 1.0; (1.0*0.9*0.9) / (0.9*1.0*0.9 + 1) %
    4. => <cat --] aloof>. % 1.0;0.45 %
-
- <Cujo {-] friendly>?
  - i. Induction:
    1. <{Snoopy} --> dog>. %1.0;0.9%
    2. <{Snoopy} --> [friendly]>. %1.0;0.9%
    3. <dog --> [friendly]>. %1.0;0.45%
  - ii. Deduction:
    1. <{Cujo} --> dog>. %1.0;0.9%
    2. <dog --> [friendly]>. %1.0;0.45%
    3. <Cujo {-] friendly>. %1.0;0.4%
- OR
  - i. Comparison:
    1. <{Snoopy} --> dog>. %1.0;0.9%
    2. <{Snoopy} --> [friendly]>. %1.0;0.9%
    3. <dog <-> [friendly]>. %1.0;0.45%
  - ii. Analogy:
    1. <{Cujo} --> dog>. %1.0;0.9%
    2. <dog <-> [friendly]>. %1.0;0.45%
    3. <Cujo {-] friendly>. %1.0;0.4%
- OR
  - i. Comparison:
    1. <{Snoopy} --> dog>. % 1.0;0.9 %
    2. <{Cujo} --> dog>. % 1.0;0.9 %
    3. <{Snoopy} <-> {Cujo}>. % f;c %
       a. f = (1.0*1.0) / (1.0 + 1.0 - 1.0*1.0) = 1.0

b. c = ((1.0 + 1.0 - 1.0*1.0)*0.9*0.9) / ((1.0 + 1.0 - 1.0*1.0)*0.9*0.9 + 0.99) = 0.45

4. => <{Snoopy} <-> {Cujo}>. % 1.0;0.45 %

ii. Analogy:

1. <{Snoopy} --] friendly>. % 1.0;0.9 %
2. <{Snoopy} <-> {Cujo}>. % 1.0;0.45 %
3. <{Cujo} --] friendly>. % 1.0*1.0; 0.9 * 1.0 * 0.45 %
4. => <{Cujo} --] friendly>. % 1.0;0.4 %

6.

a. Encode the following statements into Narsese.

- retrievers are a type of dog.
  1. <retriever --> dog>.
- beagles are a type of dog.
  1. <beagle --> dog>.
- Snoopy is a beagle.
  1. <Snoopy {-- beagle>.
- OldYeller is yellow.
  1. <OldYeller {-] yellow>.
- OldYeller is a dog.
  1. <OldYeller {-- dog>.
- Snoopy is white.
  1. <Snoopy {-] white>.

b. Show the truth value calculations for the statement “beagles are a type of animal”.

- <beagle --> animal>?
  1. Deduction:
     a. <beagle --> dog>. % 1.0;0.9 %
     b. <dog --> animal>. % 1.0;0.9 %
     c. <beagle --> animal>. % 1.0*1.0 ; 1.0*0.9*1.0*0.9 %
     d. => <beagle --> animal>. % 1.0;0.81 %

c. Show how NARS would combine its estimate for the truth of this statement with its knowledge that Snoopy is a beagle to calculate the truth value of “Snoopy is an animal”

- <{Snoopy} --> animal>?
  1. Deduction:
     a. <{Snoopy} --> beagle>. % 1.0;0.9 %
     b. <beagle --> animal>?
     c. Deduction:
     d. <beagle --> dog>. % 1.0;0.9 %
     e. <dog --> animal>. % 1.0;0.9 %
     f. <beagle --> animal>. % 1.0*1.0 ; 1.0*0.9*1.0*0.9 %
     g. => <beagle --> animal>. % 1.0;0.81 %
     h.
     i. <beagle --> animal>. % 1.0;0.81 %
     j. <{Snoopy} --> animal>. % 1.0*1.0 ; 1.0*0.9*1.0*0.81 %
     k. => <{Snoopy} --> animal>. % 1.0;0.729 %
- Using <Snoopy {-- dog>. and <dog --> animal>. is better and gets a confidence of .81.

7. Using the compound statements from NAL–3 (hint: see page 29 in the NAL PDF document) express the following compound statement in Narsese:
   - Garfield is orange and black.
     i. <{Garfield} --> [orange, black]>.
     ii. <{Garfield} --> (&, [orange], [black])>.
   - Note that you should specify Garfield’s colors separately, not as a single term like “orange_and_black” so that NARS can answer questions like “is Garfield orange?” correctly. Hint: the compound statement operators seem to bind tighter than the set-oriented notations, so “<foo {-] (&, xyz, abc)>” does NOT work.
8. Express the statement “all yellow dogs are retrievers” in Narsese using the variable rules in NAL–6. Show the truth value calculation for the statement “OldYeller is a retriever”. (Note that both the statements about OldYeller as well as the statements about NARS’ belief about dogs are subject to uncertainty. Consider the uncertainty that (a) OldYeller is a dog and (b) OldYeller is yellow, which combine into the uncertainty that OldYeller is a yellow dog.)

- `<(&&, <$x --> dog>, <$x --> [yellow]>) ==> <$x --> retriever>>.`
- `<{OldYeller} --> retriever>? %1.00;0.73%`
-
- `$0.39;0.01;0.13$ (--,<{OldYeller} --> retriever>). :3639: %0.00;0.73%`
  - i. `PARENT $0.19;0.05;0.20$ (--,<{OldYeller} --> retriever>)? :21:`
  - ii. `PARENT $0.18;0.90;1.00$ <{OldYeller} --> retriever>? :1:`
  - iii. `BELIEF $0.38;0.01;0.22$ <{OldYeller} --> retriever>. :939: %1.00;0.73%`
  - iv. `PARENT $0.50;0.09;0.10$ <<{OldYeller} --> dog> ==> <{OldYeller} --> retriever>>. :908: %1.00;0.81%`
  - v. `PARENT $0.50;0.80;0.95$ <(&&, <$1 --> dog>, <$1 --> [yellow]>) ==> <$1 --> retriever>>. :1: %1.00;0.90%`
  - vi. `BELIEF $0.50;0.80;0.95$ <{OldYeller} --> [yellow]>. :2: %1.00;0.90%`
  - vii. `BELIEF $0.50;0.80;0.95$ <{OldYeller} --> dog>. :2: %1.00;0.90%`

9. Express the following statement in Narsese: “if an animal is yellow and is not a bird, then it is a retriever.”
   - `<(&&, <$x --> animal>, <$x --] yellow>, (--, <$x --> bird>)) ==> <$x --> retriever>>.`
10. NAL–4 introduces the ability to model arbitrary relations, such as the one discussed in class:
    - <(*, key, lock) --> open>.
    - which can be interpreted as “there is a relation ”open“ defined between the terms ”key“ and ”lock“, or more informally, ”keys open locks".
    - Use the copula defined in NAL–4 to introduce a new relation “chase”, and specify that OldYeller chases Garfield. Given this new relation, express the query “does Snoopy chase Garfield” into Narsese and calculate its truth value. Similarly, what is the truth value of the statement “dogs chase cats”? Note: for this question, you may use NARS to compute the

truth values and do not have to manually calculate the values or show the inference rules used.

- <(*, {OldYeller}, {Garfield}) --> chase>.
- <(*, {Snoopy}, {Garfield}) --> chase>?
- <(*, dog, cat) --> chase>?
- $0.19;0.02;0.10$ <({Snoopy}, {Garfield}) --> chase>. :718: %1.00;0.36%
    - i. PARENT $0.50;0.80;0.95$ <({OldYeller}, {Garfield}) --> chase>. :3: %1.00;0.90%
    - ii. BELIEF $0.27;0.01;0.06$ <({Snoopy}, {Garfield}) --> ({OldYeller}, {Garfield})>. :90: %1.00;0.40%
    - iii. PARENT $0.37;0.90;1.00$ <({Snoopy}, {Garfield}) --> chase>? :3:
    - iv. BELIEF $0.50;0.16;0.15$ <{Snoopy} --> {OldYeller}>. :88: %1.00;0.45%
    - v. PARENT $0.50;0.80;0.95$ <{Snoopy} --> dog>. :2: %1.00;0.90%
    - vi. BELIEF $0.50;0.80;0.95$ <{OldYeller} --> dog>. :1: %1.00;0.90%
- Inferences:
- <{OldYeller} --> (/, chase, _, {Garfield})>.
- <dog --> (/, chase, _, {Garfield})>.
- <{Snoopy} --> (/, chase, _, {Garfield})>.
-
- $0.40;0.13;0.09$ <{Snoopy} --> (/, chase, _, {Garfield})>. :324: %1.00;0.22%
    - i. PARENT $0.37;0.90;1.00$ <{Snoopy} --> (/, chase, _, {Garfield})>? :1:
    - ii. BELIEF $0.45;0.09;0.09$ <(/, chase, _, {Garfield}) --> {Snoopy}>. :152: %1.00;0.29%
    - iii. PARENT $0.50;0.80;0.95$ <{OldYeller} --> (/, chase, _, {Garfield})>. :1: %1.00;0.90%
    - iv. BELIEF $0.50;0.16;0.15$ <{OldYeller} --> {Snoopy}>. :101: %1.00;0.45%
    - v. PARENT $0.50;0.80;0.95$ <{Snoopy} --> dog>. :1: %1.00;0.90%

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vi.   BELIEF       $0.50;0.80;0.95$ <{OldYeller} --> dog>.
      :1: %1.00;0.90%
```

11. Express the statement "if a dog chases a cat, that dog might capture that cat in the future" in Narsese.
    - `<(&&, <$x --> dog>, <$y --> cat>,  <(*, $x, $y) --> chase>) =/> <(*, $x, $y) --> capture>>.`
    - `<(&&, <$x --> dog>, <$y --> cat>,  <$x --> (/, chase, _, $y)>) =/> <$x --> (/, capture, _, $y)>>.`
12. Express the idea that once and while an animal is captured, it can no longer be chased.
    - `<(&&, <$x --> animal>, <(*, #y, $x) --> capture>) =|> (--, <(*, $z, $x) --> chase>)>.`
    - `<(&&, <$x --> animal>, <$x --> (/, capture, #y, _)>) =|> (--, <$x --> (/, chase, $z, _)>)>.`
13. Express "OldYeller is currently chasing Garfield" in Narsese, and query it about the probability that OldYeller will capture Garfield.
    - `<(*, {OldYeller}, {Garfield}) --> chase>. :|:`
    - `<(*, {OldYeller}, {Garfield}) --> capture>? :/: %1;.34%`
14. Express "Cujo is currently chasing Garfield" in Narsese, and query it about the new probability that OldYeller will capture Garfield.
    - `<(*, {Cujo}, {Garfield}) --> chase>. :|:`
    - `<(*, {OldYeller}, {Garfield}) --> capture>? :/:`
15. Give NARS the goal to make Snoopy capture a cat. Through what sequence of inference steps can NARS derive that Snoopy needs to chase Garfield?

- `<(*, {Snoopy}, cat) --> capture>!`
- `<<#x --> cat> ==> <(*, {Snoopy}, #x) --> capture>>!`
- `<(\, capture, {Snoopy}, _) {-- cat>! // this one, because an individual cat should be caught`
-
- `Inference:`
- `<(\, capture, {Snoopy}, _) {-- cat>!`
- `<Garfield {-- cat>.`
- `<{(\, capture, {Snoopy}, _)} <-> {Garfield}>!`
- `<(\, capture, {Snoopy}, _) <-> {Garfield}>!`
- `<(*, {Snoopy}, {Garfield}) --> capture>!`
- `<(&&, <$x --> dog>, <$y --> cat>,  <(*, $x, $y) --> chase>) =/> <(*, $x, $y) --> capture>>.`
- `<(&&, <{Snoopy} --> dog>, <{Garfield} --> cat>,  <(*, {Snoopy}, {Garfield}) --> chase>) =/> <(*, {Snoopy}, {Garfield}) --> capture>>!`
- `(&&, <{Snoopy} --> dog>, <{Garfield} --> cat>,  <(*, {Snoopy}, {Garfield}) --> chase>)!`
- `<{Snoopy} --> dog>!`
- `<{Garfield} --> cat>!`
- `<(*, {Snoopy}, {Garfield}) --> chase>.`

16. Ask NARS if there is a cat who's being chased by all dogs.
    - `<(&&, <$x --> dog>, <#y --> cat>) ==> <(*, $x, #y) --> chase>>? :|:`

Submit your solutions

Submit your text file with your answers as "ex4_" followed by your name ".txt". Please write your full name and kennitala into the file. Submit it in MySchool.