Capturing and Reusing Experience

2016-07-19
OOB

• Capstone
  – Wed 7/6: Team formed
  – Thurs 7/14: Plan and pitch done, implementing
  – Yesterday 7/18: Game runs (bugs & naïve AI ok – stubs 😞)
  – Thurs 7/21: Rough, runnable demo ready
  – Mon 7/25: Impl’n finished. Polishing & small debugging
  – Delivery Thursday night 7/28
  – Capstone demos 7/29 (Fri) 2:50pm-5:40pm, here

• Trajectory
  – CBR & Action prediction
  – Game demos. AI Based games
  – Recap & Evals
Questions

1. How can we describe decision making?
2. What do the algorithms we’ve seen share?
3. What are the dimensions we tend to assess?
4. FSMs/Btrees: _____ :: Planning : ______
5. For the 2\textsuperscript{nd} blank, we need m_______s.
6. When is reactive appropriate? Deliberative?
7. What is the ‘hot-potato’ passed around (KE)?
8. H_______ have helped in most approaches.
9. Which approach should you use?
Questions

1. What are the 2 most “complex” decision making techniques we’ve seen?
2. What are their strengths? Weaknesses?
3. What is the key (insight) to their success?
4. What is typically necessary to support this insight (hint: used in Planning + RBS)?
5. What does Planning have that (forward chaining) RBS do not?
6. When do we need a communication mechanism?
PCG Questions

1. What is PCG?
2. PCG can be used to p_____ or a_____ game aspects
3. Why does industry care about PCG?
4. What are some risks of PCG?
5. Major concerns involving PCG include...
6. What is a player model? What does it allow?
7. What are ways to get a player model?
8. Bartle’s 4-part feature vector: <k,a,e,s>
PCG Desiderata

• Speed (real-time/design time)
• Reliability (catastrophic failures/crashes)
• Controllability (wrt constraints and goals)
• Diversity (variations on a theme)
• Creativity (looks “computer-generated”)

See IGDA Webinar, 10 December 2014: PCG in games
PCG as Local Search Questions

- What “search” is happening? Do we seek a path to goal?
- What is the state space? How many states do we save?
- How memory efficient is this search?
- Hill climbing:
  - L____ search
  - What is the “landscape”?
  - Need a function that maps p____ to f_____
- GAs:
  - Good in ______ domains, where _D.K.__ is scarce or hard to encode
  - Can also be used for _____ search
  - Also needs a f____ function (maps c____ to f_____
- Other local search techniques
  - Gradient Descent
  - Simulated annealing
  - Local beam
  - Tabu
  - Ant Colony Optimization
GA Steps

1. Create a random set of $n$ chromosomes (**population**)
2. Assign a fitness score to each chromosome (**fitness function**)
3. Remove the $m\%$ ($m < 100$) worst chromosomes
4. Cycle through remaining pairs of chromosomes and **cross-over** (with some probability)
5. Randomly mutate (during?) cross-over (with some probability)
6. Reduce new population to size $n$
7. Repeat steps 2-6 until [stepwise improvement diminishes || one individual is fit enough || # generations reached]
GA Tuning Parameters

- Population size
- Number of generations
- Fitness function
- Representation
- Mutation rate
- Crossover operations
- Selection procedure
- Number of solutions to keep
PCG See also

- Papers linked above & T-square
- **IGDA Webinar, 10 December 2014: PCG in games: perspectives from the ivory tower**
  - https://www.youtube.com/watch?v=UVRqCK6m7m4
- **PCG Book** [http://pcgbook.com/](http://pcgbook.com/)
- **9.1: Genetic Algorithms and Evolutionary Computing - The Nature of Code**
  - [https://www.youtube.com/watch?v=6l6b78Y4V7Y](https://www.youtube.com/watch?v=6l6b78Y4V7Y)
CAPTURING AND REUSING EXP: ACTION PREDICTION
Action Prediction

• Guess what player will do next
  – E.g. waypoint, weapon, cover point, melee
  – Make more realistic, challenging (helpful) NPC
  – Can do with little observation
  – Can transfer from other players

• Humans bad at random (Psychology)
Naïve Algorithm

- **Predict using raw probability**
  - Keep a tally, use to predict
  - **Pro**
    - Easy, fast
    - Gives a lot of feedback to player
    - Can learn from many different players
  - **Con**
    - Player can “game” the system
    - Eventually can reduce to equal probabilities

- **Incremental update of average**
  - Keep mean, and count
  - \( m_n = m_{n-1} + \frac{1}{n}(v_n - m_{n-1}) \)
String Matching

• “Left or Right” coin game
• Choice made several times
  – Encode as string “LRRLRLRLLRRLRLRR”
  – Predict ➔ find substring, return subsequent choice
  – Example: “RR”
  – Window size
Prediction: \(N\)-Grams

• String matching + probabilities
  – \(N\) is window size + 1 (e.g. 3-gram from before)
  – Record Prob of each move for all windows
  – Must sum to 1
  – E.g. “LRRLRLLLRRLRLRRLRR”

<table>
<thead>
<tr>
<th></th>
<th>..R</th>
<th>..L</th>
</tr>
</thead>
<tbody>
<tr>
<td>LL</td>
<td>1/2</td>
<td>1/2</td>
</tr>
<tr>
<td>LR</td>
<td>3/5</td>
<td>2/5</td>
</tr>
<tr>
<td>RL</td>
<td>3/4</td>
<td>1/4</td>
</tr>
<tr>
<td>RR</td>
<td>0/2</td>
<td>2/2</td>
</tr>
</tbody>
</table>
Prediction: $N$-Grams

- String matching + frequencies
  - $N$ is window size + 1 (e.g. 3-gram from before)
  - Record count of each move for all windows
  - Must sum to count
  - E.g. “LRRLRLLLLRLRLRR”

<table>
<thead>
<tr>
<th></th>
<th>..R</th>
<th>..L</th>
</tr>
</thead>
<tbody>
<tr>
<td>LL (2)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>LR (5)</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>RL (4)</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>RR (2)</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>
Window Size

ACCURACY

N-Gram

Random

2 3 4 5 6 7 8 9 10 11 12 13 14
Window Size

• Increase size helps initially, hurts later. Why?
  – Future actions predicted by short causal process
  – Similar to Markov assumption?
  – Psychology?
  – Degree of randomness in actions
    • (↑ random ↓ window)

• How to tune?
Hierarchical $N$-Grams

• Online learning approach
• Balances max predictive power and alg. perf.
  – Large window, better potential, slower coverage
• Essentially several parallel $N$-grams
  – E.g. Hierarchical 3-gram: 1, 2, and 3 gram
  – When prediction requested, look up window with
    • sufficient examples
    • highest predictive accuracy
  – What is sufficient number of examples?
N-gram summary

• Simple, effective prediction mechanism
• Synon. with combo-based melee games
  – Can make unbeatable (no fun) AI
  – Often is “gimped”
• Many other uses
  – statistical analysis techniques (e.g. language)
  – [Weapon, location, unit] selection...
CAPTURING AND REUSING EXP: CASE-BASED REASONING
Sources

• Many(!) slides from Dr. Hector Munoz-Avila
• cbrwiki.fdi.ucm.es/
• www.iiia.csic.es/People/enric/AICom.html
• www.cse.lehigh.edu/~munoz/CSE335/
• www.aic.nrl.navy.mil/~aha/slides/
• www.csi.ucd.ie/users/barry-smyth
• www.csi.ucd.ie/users/lorraine-mcginty
Overview of Case-Based Reasoning

CBR is [...] reasoning by remembering. (Leake 1996)

A case-based reasoner solves new problems by adapting solutions that were used to solve old problems. (Riesbeck & Schank 1989)

CBR is both [...] the ways people uses cases to solve problems, and the ways we can make machines use them. (Kolodner 1993)

Bergmann, Survey of CBR, 2000
CBR in one slide

- CBR is a methodology
  - to model human reasoning and thinking
  - for building intelligent computer systems

- Basic idea
  - Store known past experiences (cases) in memory (case-base)
  - Given a new problem…
    - Retrieve most similar experience (similarity assessment)
    - Reuse it for the new problem (adaptation)
    - Revise it based on efficacy (feedback)
    - Retain for future use (learning)
Videos: CBR in games

• Many Games (Tetris, Soccer, RTS, Poker, ...)

• Xdomain (AAAI 2010 best video)
  – [http://www.youtube.com/watch?v=fwYfkCu4mFl](http://www.youtube.com/watch?v=fwYfkCu4mFl)

• Imitation in soccer (AAAI 2008 winner)
  – [http://www.youtube.com/watch?v=zNjyXLWVSWI](http://www.youtube.com/watch?v=zNjyXLWVSWI)

• Football (Casey’s Quest)
  – [http://www.youtube.com/watch?v=sITkmOefamc](http://www.youtube.com/watch?v=sITkmOefamc)
CBR: Definition

A problem-solving methodology where solutions to similar, previous problems are reused to solve new problems.

Notes:
- Intuitive
- AI focus (e.g., search, knowledge representation, inference)
- Case = <problem, solution>
- Lazy, incremental, sustained approach to learning

Courtesy of David W. Aha
Problem-Solving with CBR

CBR(problem) = solution

Problem Space

Solution Space

p_2 \leftarrow p_? \quad p_3

p_? \rightarrow p_1

s_? \leftarrow s_1

s_4 \rightarrow s_3

s_? \rightarrow s_2

Courtesy of David W. Aha
Example: Slide Creation

1. Retrieve

2. Reuse

3. Revise

4. Review

5. Retain

Repository of Presentations:
- 05/2005: Master’s Defense
- 03/2007: DARPA prep
- 07/2008: AAAI-08
- 10/2012: Talk@ GT AGAI
- 07/2015: GAi Lecture

Specification

First draft

Revised talk

New Case

New Slides

07/2016 GAi Lecture

Courtesy of David W. Aha
Problem Solving Cycle of CBR

Aamodt & Plaza 1994
Key ideas

• “Similar problems have similar solutions”

• Observations define a new problem
  – Not all feature values must be known
  – A new problem is a case without solution part

• Similarity computation is essential (retrieval)
• Adaptation can be essential (reuse)
CBR: History

1982-1993: Roger Schank’s group, initially at Yale
  • Modeling cognitive problem solving (Janet Kolodner, 1993)
  • New topics: Case adaptation, argument analysis, …

1990: First substantive deployed application (Lockheed)

1991-: Help-desk market niche (Inference/eGain)

1992: Derivational analogy (Veloso, Carbonell); CBP

1993: European emergence (EWCBR’93)

1993-1998: INRECA ESPRIT projects

1995: First international conference (ICCBR’95)
  • Knowledge containers (M. Richter)
  • First IJCAI Best Paper Award (Smyth & Keane: Competence models)

1997-: Knowledge management / CB maintenance

1999-: e-Commerce

2001-: Recommender Systems

2003-: Readings in CBR

2016: International Conference on CBR to be held at GT late October
You Have Seen this Before!
(A consumer’s Customer Service Experience)

Have you called a customer service support line lately?

It goes something like this (automatic machine):
1. If you want to speak to a sales representative, please press one
2. ....
...
9. If you are experiencing technical difficulties with our wonderful product **Neutronious-L** please press nine
Welcome to our customer support menu (automatic machine):

1. If you want to listen to the FAQ please press one
2. ....
3. ....
9. If none of the above help you please press nine.

After 40 minutes of hearing music meant to drive you insane...
Yes this is Felix may I have the serial number of Neutronious-L, please? (a person reading from an automatic machine):

1. Is Neutronious-L ringing? You: no
2. Is a red light Neutronious-L blinking? You: no
   ...
9. How many green lights are on on Neutronious-L? You: 3
10. Are you sure? You: yes

Well, in that case you should call the company that constructed your building. If you ask me that must be excessive moisture... Now let me ask you a few questions about our service... sir? Hello? Are you still there?
What is Going on the Other Side

Space of known problems for Neutronious-L

Case:
- Red light on? Yes
- Beeping? Yes
- ...
- Transistor burned!

This is an example of a **Conversational Case-Based Reasoning Process**
Representing Cases

• Cases contain knowledge about a previous problem solving experiences

• Typically a case contains the following information:
  ➢ Problem/Situation
  ➢ Solution
  ➢ Adequacy (utility)

• Scope of the information:
  ➢ Complete/partial solution
  ➢ Detailed/abstracted solution

• Representation formalism (depends upon domain/task):
  ➢ Attribute-value vector: Case = (V₁, ..., Vₖ, Vₖ₊₁, ..., Vₙ)
  ➢ Structured representation: Objects, graphs
  ➢ High-order: predicate logic formula, plans
Similarity and Utility in CBR

• The goal of the similarity is to select cases that can be easily adapted to solve a new problem

![Similarity = Prediction of the utility of the case](image)

• Utility: measure of the improvement in efficiency as a result of a body of knowledge

• However:
  - The similarity is an a priori criterion
  - The utility is an a posteriori criterion

• Sample similarity metric: aggregating local similarity metrics, SIM():
  - \( \text{SIM}(V_{1..n}, Y_{1..n}) = \alpha_1 \text{sim}_1(V_1, Y_1) + \ldots + \alpha_n \text{sim}_n(V_n, Y_n) \)
  - \( \text{sim}_i() \) is a local similarity metric, values in \([0,1]\)
Case Retrieval

Problem description:

• **Input**: a collection of cases $CB = \{C_1, \ldots, C_n\}$ and a new problem $P$

• **Output**:

  ➢ The most similar case: A case $C_i$ in $CB$ such that $\text{sim}(C_i, P)$ is minimal, *or*

  ➢ A collection of $m$ most similar cases in $CB$ $\{C_1, \ldots, C_m\}$, *or*

  ➢ A *sufficiently* similar case: case $C_i$ in $CB$ such that $\text{sim}(C_i, P) > th$

Solutions:

• Sequential retrieval: $O(|CB| \times \log_2(k))$
• Two-step retrieval: (1) select subset $S$ of cases. (2) Sequential retrieval on $S$.
• Retrieval with indexed cases
Case Adaptation

Problem description:

• **Input:** A retrieved case C and a new problem P

• **Output:** A solution for P obtained from C

Considered an open problem
Trade-off between Retrieval and Adaptation Effort

- If little time is spent on retrieval, then the adaptation effort is high.
- If too much time is spent on retrieval, then the adaptation effort is low.
- There is an optimal intermediate point between these two extremes.
Taxonomy of Problem Solving and CBR

For which of these CBR have been shown to be effective?

- **Synthesis:**
  - constructing a solution
  - Methods: planning, configuration

- **Analysis:**
  - interpreting a solution
  - Methods: classification, diagnosis
Main Topics of CBR Research ~ 10yr

- Study by Derek Greene, Jill Freyne, Barry Smyth, Pádraig Cunningham
- Social network analysis based on co-citations links
- Sources:
  - Bibliographic data from Springer about ICCBR, ECCBR
  - Citation data from Google scholar
- An Analysis of Research Themes in the CBR Conference Literature. ECCBR'08
- Next two slides from http://mlg.ucd.ie/cbr
Major Themes in CBR

- Recommender systems and diversity
- Case-Based Maintenance
- Case Retrieval
- Learning similarity measures
- Adaptation
- Image analysis
- Textual & Conversational CBR
- Feature weighting and similarity

Some Interrelations between Topics

• Retrieval
  – Information gain
  – Similarity metrics
  – Indexing
• Reuse
  – Rule-based systems
  – Plan Adaptation
• Revise & Review
  – Constraint-satisfaction systems
• Retain
  – Induction of decision trees
Focus Point: Diversity in CBR
Traditional Retrieval Approach

- **Similarity-Based Retrieval**
  - Select the $k$ most similar items to the current query.
    - Query
    - Available case
    - Similar case

- **Problem**
  - Vague queries.
  - Limited coverage of search space in every cycle of the dialogue.
Diversity Enhancement

- Diversity-Enhanced Retrieval
  - Select $k$ items such that they are both similar to the current query but different from each other.
    - Query
    - Available case
    - Retrieved case
  - Providing a wider choice allows for broader coverage of the product space.
  - Allows many less relevant items to be eliminated.
Dangers of Diversity Enhancement

- **Leap-Frogging the Target**
  - Problems occur when the target product is rejected as a retrieval candidate on diversity grounds.
  - $\Rightarrow$ Protracted dialogs.

- **Diversity is problematic in the region of the target product.**
  - Use similarity for fine-grained search.

- **Similarity is problematic when far from the target product.**
  - Use diversity to speed-up the search.
Focus Point: Augmenting General Knowledge with Cases
Why Augment General Knowledge With Cases?

• In many practical applications, encoding complete domain knowledge is unpractical/infeasible and episodic knowledge is available

   **Example:** Some kinds of military operations where two kinds of knowledge are available:

   - General guidelines and standard operational procedures which can be encoded as a (partial) general domain knowledge
   - Whole compendium of actual operations and exercises which can be captured as cases
Hierarchical Problem Solving

Hierarchical case-based planning techniques combine domain knowledge and episodic knowledge (cases)

Knowledge source

- Travel(Lehigh, GT)
- Travel(Lehigh, Philly)
- Walk(Lehigh, LV Bus)
- Bus(LV Bus, PHL)
- Fly(PHL, ATL)
- Travel(ATL, GT)
- Marta(ATL, GT)
Knowledge Sources

General

Methods denote generic task decompositions and conditions for selecting those decompositions:

Task: travel(?A, ?B)

Decomposition:
  - travelC(?A, ?Airp1)
  - travelIC(?Airp1, ?Airp2)
  - travelC(?Airp2, ?B)

Conditions:
  - in(?A, ?City1)
  - in(?B, ?City2)
  - airport(?Airp1, ?City1)
  - airport(?Airp2, ?City2)

Episodic

Cases denote concrete task decompositions:

Task: travelC(Lehigh, PHL)

Decomposition:
  - take(bus, Lehigh, PHL)

Conditions:
  - enoughMoney()
CBR: Final Remarks
Advantages of CBR

• Reduces knowledge acquisition effort
• Requires less maintenance effort
• Reuse of solutions improves problem solving performance
• Can make use of existing data
• Improves over time, adapts to changes
• Has enjoyed high user acceptance

Bergmann, Survey of CBR, 2000
Why not cbr?

In fact, this is the crux of the argument: if you have a good scripting language, or even a visual tree editor to capture sequences, you’ll be orders of magnitude more productive (and more reliable) than an expert trying indirectly to get the system to induce specific sequences from examples. As such, it’s fair to claim that CBR isn’t particularly well suited to these kinds of problems in game AI.

Recent uses at GT

Games


## CBR: Takeaway

1. Sometimes natural (e.g., law, diagnosis)

2. Cases simplify knowledge acquisition
   - Easier to obtain than rules
   - Captures/shares people’s experiences

3. Good for some types of tasks
   - When perfect models are not available
     - Faulty equipment diagnosis
     - Online sales
     - Legal reasoning
     - Games

4. Commercial applications
   - Help-desk systems (e.g., Inference corp.: +700 clients)

5. Similar problems have similar solutions.
   - Retrieve, Reuse, Revise, Retain
Questions?

- http://cbrwiki.fdi.ucm.es/
- http://aitopics.net/CaseBasedReasoning
- http://www.cse.lehigh.edu/~munoz/CSE335/
- http://mlg.ucd.ie/cbr

- http://gaia.fdi.ucm.es/research/colibri/jcolibri
1) What are the 4 processes, each beginning with an "R", commonly used to describe the CBR methodology?

2) The ______ metric is used to find the problem/solution pair in the casebase most related to the new problem, by comparing the relatedness of the features of the new problem to the features of known problems in the casebase.

3) In case-based reasoning, problem solving cannot commence without the ability to compute this, which is a number indicating how related an existing case is to the new problem.

4) A foundational assumption in CBR is that "Similar problems have __________  __________".