Facilitating Self-Education by Questioning Assumptive Reasoning

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Abstract

Making assumptions limits the depth of inference chains and reduces the potential for complex interactions, but assumptions that are made implicitly can blind the reasoner to important inferences and interactions. A self-education aid makes students aware of their assumptions by demonstrating how these assumptions might be violated. DECIDER is a self-education aid for history that tracks student assumptions using political models and illustrates possible violations using dramatic stories and video sequences from real historical cases.

1 What is a Self-Education Aid?

A self-education aid (SEA) is a program that makes a student aware of their assumptions by demonstrating how these assumptions can be violated. It focuses the student on where they need to do more reasoning, but without doing that reasoning for them.

Creating a self-education aid for a task domain involves:

- Creating an environment where the student can confront problems in that domain

- Tracking their reasoning in that environment and uncovering key assumptions

- Inferring plausible violations of these assumptions

- Finding lessons that explain why these violations are likely to be repeated in other situations

- Deciding which of these lessons is most important to teach

- Refocusing the student's reasoning by communicating their implicit assumptions, possible violations of these assumptions, and the lessons

An SEA should not be viewed as a simulator [Stevens, 81] because it gives feedback about assumptions, not about the execution of plans. It should not be viewed as a solution debugger [Anderson et al., 87; Soloway et al., 82] because student solutions are often not buggy; they are quite reasonable given the assumptions the student has made. To facilitate learning, one must find those assumptions and make them explicit.

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What do you want to do about the situation in
Nicaragua?

--> send in the marines

[Audio and Video illustrating protests
 during the Vietnam War]
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Figure 1: The DECIDER program

1.1 DECIDER: A Self-education Aid for History

DECIDER is a self-education aid for history that confronts students with a present foreign policy problem [Bloch and Farrell, 88] and tracks students' assumptions as they develop a plan. The program makes students aware of these assumptions by illustrating how they were violated in a past historical case. These cases, as communicated by DECIDER, point out the possible invalidity of one or more student assumptions and communicate one explanation for why the events turned out the way they did.

DECIDER communicates historical cases to the student using a customized videodisc with photographs and footage from actual historical events (e.g. the US war in Vietnam). These images and the textual overlay describing the events give the student a situated, attached, and dramatic view of history [Etheridge, 85; Papert, 80] rather than the typical detached analytic view offered by books and lectures.

1.2 Comparison with Tutoring System Approach

Intelligent Tutoring Systems [Sleeman and Brown, 82] typically represent problems as a set of goals for the student to achieve, then interpret student answers as achieving or failing to achieve these goals [Farrell et al., 84; Johnson and Soloway, 83]. These systems tacitly assume that students adopt the goals specified in the problem description. However, as any human tutor knows, students often produce solutions for entirely different goals. Rather than giving students feedback on their own goals, "intelligent" tutoring systems misinterpret students as giving buggy answers to the system's own goal descriptions! It is not surprising that many students feel frustrated by the feedback given by these systems. Students spend most of their time learning what the computer "wants" instead of learning the problem domain.

A self-education aid avoids giving this kind of inappro-

priate feedback because it allows the student to formulate and pursue their own goals. SEAs have no notion of correct and buggy solutions [Brown and Burton, 78; Johnson et al., 83] because they assume that student solutions are a reasonable attempt at some set of goals. An SEA must identify those goals - or give no feedback at all. If the student is unable to formulate goals, an SEA can provide information to help them decide on a some goals (e.g. "Nicaragua received a large shipment of attack helicopters from the USSR"), but it will never set goals for the student explicitly (e.g. "Get the Contras into power").

This paper will focus on the representations and processes needed to:

- Infer student assumptions about the causal relationships between plans (e.g. "invasion using ground forces") and policy-level goals (e.g. "maintain influence over governments in security zones")

- Demonstrate that these causal relationships do not always hold by finding a case where they failed for a reason that could plausible apply to the current case

2 Representation of Mental Models

We believe that people approach complex problems by quickly retrieving a set of overlapping mental models (frames [Minsky, 75], scripts [Schank and Abelson, 77], or stereotypes [Seifert, 87]), forcing these models to fit the problem, and drawing inferences from them [Burstein, 85]. These models focus the reasoner on certain parts of the problem to the exclusion of others, thus making reasoning efficient by ignoring interactions not described by the model. Blindness [Winograd and Flores, 87] results from failing to question the assumptions underlying the applicability of these models, the inferences within these models, or the possible interactions between models [Neustadt and May, 86]. This paper will address how to question assumptions arising from inferences within models.

POLICYs are an important class of political models because they encode inferences about how plans work collectively to achieve certain conditions that are desirable to political groups. Typically, these conditions exist over long periods of time (e.g. control Jerusalem) and political groups use plans repeatedly in attempting to achieve and maintain them (e.g. terrorist attacks). POLICYs reduce the search involved in explaining how specific plans, proposed by students, can be used to achieve these long-term conditions.

Policies have 3 parts:

Conditions - What qualitative states exist and when

Inferences - A causal chain that explains how plans can work collectively to achieve the Conditions.

Prototypes - Prototypical examples of the objects, states, and actions that make up the plans and Conditions.

The Reagan administration's policy in Nicaragua between 1981 and 1984 partially matches a POLICY we call IIP (for INCREASE INSURGENCY POWER) (see Figure 2). The essence of this POLICY, stated as an outline for a plan on the part of a SUPPORTER, is that increasing

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POLICY: IIP(SUPPORTER, INSRGNCY, LOC)

          ** Conditions: **
C1: exists(INSRGNCY)      C2: increase(S2)
C3: increase(S12)         C4: increase(S9)
C5: decrease(S11)

          ** Inferences: **
PA1: RESULTS(P1,C1)       TC1: ENABLES(C1,P2)
PA2: RESULTS(P2,C2)       TC2: ENABLES(C2,P3)
PA3: RESULTS(P3,C3)       TC3: ~MNTAIN(C3,S7)
TC4: NCSSRY-SUBGL(S7,S8)  PA4: GL-SCRFCE(P4,S8)
TC5: RESULTS(P4, (C4 C5))

          ** Prototype Objects: **
INSRGNCY: Revolutionary INCMBNT: Corrupt-elite
LOC:      Third-world    RESOURCE: Guns
    SUPPORTER: Rich-superpower-govt

          ** Prototype Plans: **
P1: Propaganda(SUPPORTER, LOC)
P2: Aid(SUPPORTER, INSRGNCY, RESOURCE)
P3: Guerilla-warfare(INSRGNCY, INCMBNT, S4)
P4: Surrender(INCMBNT, INSRGNCY, S6)

          ** Prototype States: **
S1:  POSSESS(RESOURCE)     S2: NUMBER(RESOURCE)
S3:  MILTRY-CNTRL(S4)      S4: LOC(S5)
S5:  OPRATE-ORGN(INCMBNT)  S6: GOVT-POWER(LOC)
S7   MAINTAIN(S10)         S8: MAINTAIN(S11)
S9:  IN(INSRGNCY, S6)      S10: IN(INCMBNT, S3)
S11: IN(INCMBNT, S6)       S12: IN(INSRGNCY, S3)
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Figure 2: The IIP (Increase Insurgency Power) POLICY

the ability of an insurgency to inflict costs on an incumbent can facilitate the insurgency's ascent to power.

The Conditions of a POLICY can be satisfied in many different ways, leading to a broad coverage of historical cases. For example, the incumbent can maintain power through military force, public support, or foreign support. These methods can be challenged by guerilla warfare, the media, or diplomacy.

It is important that models are represented so that they are neutral with respect to their possible use in reasoning. In this way they can be used for planning, prediction, understanding, and a range of other tasks. For example, when used as an outline for a global plan of action, a POLICY helps explain how plans can achieve policy-level goals (e.g. how U.S. aid to the Contras could increase the Contras' power in Nicaragua). When used predictively, a POLICY helps explain how plans can alleviate or avoid undesirable side effects of a foreign policy (e.g. how humanitarian aid could alleviate civilian casualties during a war of attrition).

3 Recovering Mental Models

Let's trace how DECIDER uses POLICYs to understand a specific student plan. First, DECIDER picks a region of the world where there are interesting trends that might

affect the student's goals (e.g. Nicaragua) and asks the student for a plan. DECIDER avoids biasing the student to any particular interpretation of "the problem" by referring to a region of the world instead of a particular threatening action or trend:

What do you think the US should do about the situation in Nicaragua?

--> have the US marines invade Managua

DECIDER is initialized with a decision maker (e.g. USA), a set of prototypical policy-level goals (e.g. "maintain influence in security zones"), and a set of qualitative state changes (e.g. "increase in Nicaraguan military resources"). The program initially assumes the student is adopting the prototypical goals, but these can be retracted if the student later explicitly rejects them ("I don't want to increase US influence in Nicaragua") or if DECIDER cannot find a plausible interpretation of the student plan using them.

3.1 Computing Qualitative States and Trends

DECIDER uses its model of the student's goals, POLICYs, and knowledge of states and trends in the region of interest to create plausible interpretations of why the student chose the plans they did. We will trace DECIDER explaining how the student's plan of US marines invading Managua could possibly increase U.S. influence in Nicaragua. DECIDER will conjecture that the invasion would result in US control of the seat of Nicaragua government, which would enable the US to force the Sandinistas to surrender their governmental power to a local insurgency (e.g. the Contras), thus increasing US influence in Nicaragua.

DECIDER first retrieves and applies POLICY models to the input qualitative state changes to predict "dangerous trends". It assess whether each new state or trend could possibly threaten any of the assumed goals. The result is a causal graph linking the qualitative states ("stopped elections", "increasing influence of USSR") and changes with possible threats to the student's goals.

The program creates expectations for student subgoals to resolve or alleviate these threats ("achieve elections", "increase US influence"), then matches the new desired states against the Conditions that various POLICYs are designed to achieve.

3.2 Matching POLICYs Using Prototypes

Once DECIDER has predicted that a student will carry out a given POLICY, it can predict that they will plan to achieve and maintain the various Conditions that the POLICY describes. For example, once the goal to achieve the trend "decrease power of Sandinista government" matches the GOVT-POWER prototype of the IIP POLICY, DECIDER will try to interpret the student plan ("have the marines invade Managua") as a way of carrying out the IPP policy.

However, the student plan does not directly match any prototype plans stored under the IIP POLICY (e.g. Propaganda, Aid) and does not directly bring about any of

the prototypical Conditions (e.g. increasing resources of the insurgency). Therefore, the program searches for another POLICY that will connect the INVADE plan to one of the prototypical POLICY Conditions.

Using the results of INVADE and the conditions of IIP, DECIDER finds a POLICY called ACHIEVE-AND-TRANSFER-CONTROL that explains how the INVADE plan could result in military power for the insurgency by transfer of military control (see Figure 3).

```
C3:  increase(IN(INSRGNCY,
            MILTRY-CNTRL(Managua)))
            ^
         |  Results
   TRANS(US, INSRGNCY, MILTRY-CNTRL(Managua))
            ^
         |  Enables
    IN(US, MILTRY-CNTRL(Managua))
            ^
         |  Results
   INVADE(US, Sandinistas, Managua)
```

Figure 3: The student's plan (INVADE) achieves the POLICY Condition (C3)

Next, DECIDER uses the Inferences section of the POLICY (IIP) to connect the desired trend (C5: Decreasing power of the Sandinistas) with those POLICY Conditions achieved by the student's plan (C3: Increasing military control of the insurgency in Managua) (see Figure 4)

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C5:  decrease(IN(Sandinistas,
GOVT-POWER(Nicaragua.loc)))
            ^
         |  TC5: RESULTS
         |
PA4:  Surrender(Sandinistas, INSRGNCY,
            GOVT-POWER(Nicaragua.loc))
            ^
         |  PA4: GL-SCRFCE
         |
S8:  maintain(IN(INCUMBENT,
GOVT-POWER(Nicaragua.loc)))
            ^
         |  TC4: NCSSRY-SUBGL
         |
S7:  maintain(IN(INCUMBENT,
MILTRY-CNTRL(Managua)))
            ^
         |  TC3: ~MNTAIN
         |
C3:  increase(IN(INSRGNCY,
MILTRY-CNTRL(Managua)))
```

Figure 4: Inferences connect the POLICY Condition C3 with the student's A-GOAL

The output of the model recovery phase is a causal chain (CC) connecting the student's plans ("have the US marines invade Managua") to their policy-level goals ("achieve and maintain influence in security zones").

4 Questioning Model-based Assumptions

Once an SEA has identified a set of idealized models, it tries to derestrict the student's learning by making them aware of the assumptions implicit in these models. It must question these assumptions, finding an plausible explanation for why the current case does not meet the idealized model and a past case exemplifying this explanation.

4.1 Locating Plausible Assumption Violations

DECIDER finds possible states to invalidate the student model-based inferences by examining a causal network stored with the model that produced the inference. For example, when questioning the inference that INVADE will result in the U.S. gaining mlitary control, DECIDER finds a causal network in the INVADE model that supports the state S7: IN(US, MILTRY-CNTRL(Managua)). Under each of the states in this network are failures and explanations for those failures from past cases (see Figure 5). Explanations for failures are models that encode important interactions that were overlooked when the plan was chosen. In the INVADE causal network, DIVERT-RESOURCE-FOR-CONFLICT provides an explanation for why a government might not be able to maintain attacking troops at the location of an invasion: more pressing needs for those resources elsewhere.

```
                    INVADE

        achieve military control    -- GOALS
             of location
           /              \
maintain forces  maintain forces    -- SUBGOALS
   at-loc            attacking
   /    \            /       \
retreat diversion casualties  no    -- FAILURES
           |              weapons
           |
   DIVERT-RESOURCE-FOR-CONFLICT -- EXPLANATORY
                                       MODELS
```
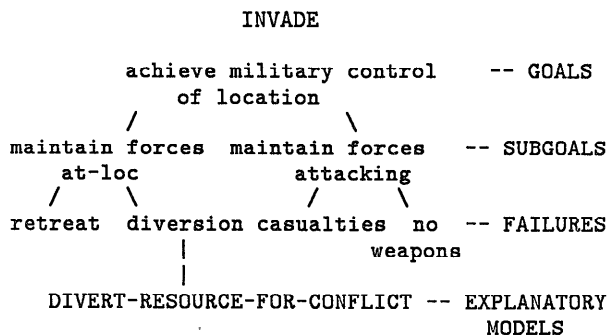
Figure 5: Failures and Explanatory Models for INVADE

A paradigmatic example of DIVERT-RESOURCES-FOR-CONFLICT causing problems with INVADE was when Spanish troops invaded the Netherlands. Although Spanish Habsburg king Phillip II desperately wanted to put down the revolution in the Netherlands, and probably had enough troops to accomplish that goal, he eventually surrendered. This was partially because he was constantly diverting troops to the war with France, a war of much greater threat to Spain's national security.

Once DECIDER has found a paradigm case to display, it communicates the plan, the reasons for choosing the plan, and the failed assumption, using text and video. Then, if the student wants to hear the explanation for the failure, DECIDER collects those parts of the paradigm case that exemplify the explanatory model and displays them using dramatic video sequences and story-like text.

4.2 Student Reactions to Explanatory Models

After DECIDER displays the paradigm case it allows the student to respond. The student can change their plan, change their goals, or disagree with the explanatory model [Bloch and Farrell, 88], supporting a continuous cycle of plan and goal refinement.

We believe that computers have played a relatively minor role in education largely because the communication between student and machine has been a one-way street, either directed toward the student (most CAI and ITS programs) or directed toward the computer (most microworld programs). Student responses are not answers to be recorded and scored or programs to be run; they are important communicative artifacts to be used as a way of inferring the student's deeper understanding. An SEA and a student should become a "coupled" learning system. Through mutual communication of arguments about the applicability of existing models, they should settle on a way of extending these models to new cases.

5 Extensibility of the Model

DECIDER's ability to aid the student's learning process depends on:

- A database about the input situation that includes many facts unknown to the target group of students
- A detailed model of causality for evaluating inference chains in student models
- A large database of past cases and the models they exemplify

Our input situation database includes facts about geography, national resources, internal politics, and diplomatic and economic status that we feel are unknown to our target group. We are aiming for several hundred such facts per case.

Indexing a large number of cases of foreign policy success and failures forces us to make important distinctions in the inferences section of our POLICY models, leading to greater coverage. To get our current database of cases, we gave historians a set of current crises (e.g. Gaza Strip, Nicaragua, Panama, South Africa) and asked them for alternative policies. We then asked them to argue against these policies by giving a paradigmatic example from history. Our experts were easily reminded of several cases, many of which they used in classes or scholarly works. Based on a sampling of places, times, and types of crises, we approximate that expert historians have at least a passing familiarity with approximately 1 million such cases. Although purely speculative, this clarifies the large amount of scaling up to be done before a case-based program could hope to approach human performance.

6 Conclusion

Guided by the intuition that student solutions are often plausible given student-like assumptions and these same assumptions are implicit in a large number of student solutions, we have proposed a new paradigm for computers in education: facilitated self-education. A self-education aid tracks student reasoning and acts on opportunities to

communicate possible assumption violations in that reasoning. We have built a system called DECIDER that tracks student reasoning using political models and communicates possible assumption violations in a dramatic, story-like fashion using text plus actual footage and photographs of paradigmatic cases of foreign policy problems.

Acknowledgments

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