Finding and Resolving Contradictions in a Battle Scenario[1]

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Abstract

This report presents an initial attempt to run a battle scenario with built in inconsistencies on the SNePS knowledge representation and reasoning system. This system alerts the user to the inconsistencies as soon as they are detected and offers an opportunity to correct the base hypotheses as well and, consequently, the beliefs that were derived from them. In this scenario, automatic belief revision is able to narrow down its culprit choices to one proposition each time it is called, so it removes those propositions. The system automatically stops believing any derived beliefs whose justifications rely on the removed beliefs.

1 Introduction

This report presents an initial attempt to run a battle scenario with built in inconsistencies on the SNePS (Shapiro and the SNePS Implementation Group, 1999; Shapiro and Rapaport, 1987; Shapiro and Rapaport, 1992) knowledge representation and reasoning system, which alerts the user to the inconsistencies and offers an opportunity to correct the base hypotheses as well as the beliefs that were derived from them. Even humans have trouble correcting their inferences after revising an underlying hypothesis, and errors like this in battle situations can be extremely costly. By catching inconsistencies early, there is a hope that the number of incorrect inferences can be reduced and errors from those inferences caught as early as possible.

Section 2 provides background information on SNePS. The initial scenario, given in Appendix 1, is summarized in section 3 including alterations, which were made for ease of demonstration. The frame problem and our treatment of it are discussed briefly in section 4. Section 5 contains a discussion of the system-scenario interaction (an edited version of which is given in Appendix 3), and is followed by a final analysis of the system, offered in section 6.

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2 SNePS

2.1 SNePS

SNePS is a "semantic-network language with facilities for building semantic networks to represent virtually any kind of information, retrieving information from them, and performing inference with them." (Shapiro and Rapaport,1987) The underlying logic of SNePS is a monotonic, relevance-style, paraconsistent logic. One way that users can interact with SNePS is through the SNePSLOG interface – an interface which allows the user to input propositions in a style that uses "predicate calculus augmented with SNePS logical connectives"(McKay and Martins, 1981; Shapiro and the SNePS Implementation Group, 1999) – where propositions are expressed as well-formed formulas, or *wffs*.

Propositions added to the knowledge base by the user are called hypotheses. The system records the justification for each proposition (whether it is a hypothesis or derived) by associating it with an origin set consisting of the hypotheses used in its derivation (ATMS style). A hypothesis has a singleton origin set, containing only itself, but might also be derivable from other hypotheses. Multiple derivations of a single proposition can result in its having multiple origin sets. If the hypotheses in a proposition's origin set are asserted, or believed, then the proposition is also believed and is part of the belief space.

In addition to dealing with knowledge in the form of propositions, SNePS can also represent and reason about the *sources* of that knowledge (Johnson and Shapiro 2000). This information and the relative credibility of the sources is also stored as propositions, allowing the system to order propositions based on the relative order of their sources' credibility. Propositions can also be ordered by credibility directly. The resulting credibility ordering of the propositions in the knowledge base is also referred to as their epistemic entrenchment, where those with higher credibility are considered more entrenched than those that are less believed. This ordering is used during belief revision to aid in culprit selection.

2.2 SNeBR

The SNePS belief revision sub-system, SNeBR (Martins and Shapiro, 1988), is activated when a derived proposition or a hypothesis is added to the context that contradicts a pre-existing belief. It is at this point that the system 'realizes' that it is inconsistent. It is possible, therefore, for the system to be inconsistent but not know that it is inconsistent – in the case where the inconsistency has not, yet, been derived. This is a natural limitation of every implemented system, because they always have some implicit beliefs remaining to be derived. Because of this, the knowledge base of an implemented system can never truly be considered *consistent*… only *not known to be inconsistent*. In this paper, therefore, whenever we refer to a set of propositions as "consistent", it should be assumed that we mean "not known to be inconsistent."

Once the inconsistency is detected, SNeBR analyzes the sets underlying the inconsistency. Each of these sets is a minimally-inconsistent set of hypotheses – a set that is known to be inconsistent, but will be made consistent upon the removal of any one of its members. A minimally-inconsistent set is formed by the union of the origin sets for the contradicting beliefs – multiple origin sets for a belief result in multiple inconsistent sets to be revised. For example: If the contradictory propositions *P(a)* and *~P(a)* had one (α) and two (β and γ) origin sets respectively, then there would be two minimally-inconsistent sets formed for belief revision: ($\alpha \cup \beta$) and ($\alpha \cup \gamma$).

SNeBR analyzes these sets and forms a recommended culprit list based on belief revision guidelines (Gärdenfors and Rott 1995) which favor (a) removing lesser-believed hypotheses and (b) minimizing the information lost from the knowledge base. If the culprit list contains only a single hypothesis, the automatic belief revision system, AutoBR (Johnson and Shapiro 2000), will remove it and inform the user of that removal. The system automatically no longer believes any propositions whose origin sets all included the removed proposition.

3 Scenario Summary and Alterations

3.1 Summary

The scenario and accompanying map were provided by James Llinas, The Center for Multisource Information Fusion, and can be found in Appendix 1. French and German forces are battling in France circa 1940 WWII. The battles take place first in Petite Dot Sur La Mappe (PDot) and later at Dot Sur La Mappe (Dot) [fictional names, we suspect]. The French forces lose this battle largely due to some errors made by their General:

- It is assumed that the German force in PDot, which has no tanks, is the major German unit in the area, and, therefore, it is assumed that the Germans have no tanks in the area.
- The French force battling in Petite Dot is assumed to be strong.
- There is no accounting for the German air superiority in the battle area.

It turns out that the German force in PDot is backed up by a Panzer Division with tanks. The first two errors are detected as contradictions invoking belief revision. The last error is treated more as an update, assuming that the allied air defense was ineffective against the German planes (rather than as an error – e.g., allied planes were expected but should not have been).

3.2 Simplifications

The information on locations of forces and battles required the accompanying map for clarity. Although directional location, movement, etc. *can* be included in the information that we feed into our system, we decided to leave it out since it was largely unrelated to the contradictions we are concerned with.

The inconsistencies that arise as the scenario unfolds are due to inaccurate estimates of the strength of a small French force in PDot and the German force size, their tank supply, and their air superiority. The only error catching that requires some sense of location and movement is the fact that the force in PDot was not strong at the start of this scenario (or at least is not strong by the second day). This error is caught when the French General's forces are attacked by a German Panzer Division at a location much further west than anticipated. This location-dependency is bundled into the concept of a "surprise advanced attack", which indicates that a force has proceeded further than expected. They, therefore, have overrun anyone they were battling earlier, and that defending force is (and probably was) weak (i.e., not strong).

We also included a proposition that indicates whether any nation has an advantage at a particular time. This advantage is based on the weapons and equipment (in this case, tanks and planes) that the forces have, but could be adjusted to include force strength, number of soldiers, etc. At the start of the scenario, the French seem to have an advantage; but, with the discovery that the Germans do indeed have tanks, that advantage is lost. When the German air superiority becomes evident, the advantage swings to the Germans, who end up destroying the French forces the following day.

The simplifications described above can be seen in Appendix 2.

3.3 General Knowledge or Battle Knowledge

To fill in the holes and gaps in the scenario, we established a series of rules that encompass the general knowledge and battle knowledge needed to understand the scenario. These are also very simplistic, but could be altered to be more realistic and detailed. Some examples of these rules are:

- Time is linear, so the relation "before" is transitive.
- Everyone is limited to one nationality.
- A surprise advanced attack is an attack.
- If a group doesn't have something (e.g., tanks), neither do any of its subgroups.

These rules can be seen at the beginning of the system interaction in Appendix 3 under the section called Domain Rules.

3.4 Sources

Because the scenario information varied in its accuracy or believability, we chose to represent epistemic entrenchment by identifying each piece of information with one of five sources, ranked by credibility. They are listed below in decreasing order of believability:

- Fact — not disputable
- Experience — as seen or experienced by the French general
- Rule — information *not* stated expressly in the scenario, but considered some form of general (or battle) knowledge (see sections 3.3 & 4)
- Information — knowledge from some outside, reliable, and experiencing source
- Assumption — information that is third-hand, lacking experience, or derived by rules we are unaware of

The relative ordering of these sources enables the beliefs to be ordered as described in the last paragraph of section 2.1 . This information is used during AutoBR to aid in culprit selection – choosing to remove a less-believed proposition if possible.

4 The Frame Problem

The frame problem refers to how a knowledge representation and reasoning system deals with changes over time – or, more specifically, how it deals with things that do not change over time. We would like to assume that from one time slice to another, there are minimal changes in the world with most things staying the same. Unfortunately, since we are using a SNePSLOG form of situation calculus to represent our propositions, most of our beliefs are time-stamped – i.e., identified with the specific time they are stated. This means that each unchanged proposition is not identified with the next time slice, and must be restated in order to be believed at *that* time. Situations that have changed are explicitly mentioned, but it would be better if the unchanged beliefs continued within the new time slice without needing explicit mention.

In general, we would like to assume that, unless mentioned otherwise, everything stays the same from one time slice to the next. This would include whether a force was weak or strong, whether they have tanks or planes, etc. One way to handle this could be to use default reasoning about things that tend to remain unchanged as time passes, but our system is not set up to use default reasoning at this time. This is something we hope to add in the future. For the purposes of this scenario demonstration, we adjusted by making a general statement *at the beginning of each time slice* that says that everything stays the same (excluding exceptions; e.g., no more allied planes after the first German air attack). These rules can be found, when they apply, in each new time slice. One example of this kind of rule is:

```
 ;;; Everyone has whatever they started out with.
: all(x) (equipment(x) => (all(y)(has(y,x,t0) => has(y,x,t1))))
```

5 Discussion of System Output

It is important to note that the system is taking the role of assistant to the French general, so the information it is given is limited to what the general knows (or believes) at a given time. All input and output has been edited for clarity (mostly deletions of cluttered information).

5.1 At the End of Time 0

The relation "some-advantage" is used to show whether one nation has **any** advantage over another at a given time. `Some-Advantage(x,y,t)` means that nation `x` has "some" advantage over nation `y` at time `t`. This might mean `x` has planes when `y` does not. If `y` has tanks at time `t` and `x` does not, then `Some-Advantage(y,x,t)` would *also* be true – they are not mutually exclusive. If, however, only one is true, it lends hope to the advantaged nation that they will be victorious.

The system is asked to list all who have "some advantage" at the end of time 0 (comments are in *italics*, system printout in **bold**):

```
;;; Who has any advantage at time T0?
: some-advantage(?x,?y,T0)?                    Query

  WFF77:  SOME-ADVANTAGE(French,German,T0)         Reply
```

Since the system derives that the French have an advantage, it is likely that the French general feels the same.

5.2 German Panzers attack

Panzers are tanks, but the French (and our system) had reasoned that there were no tanks in the vicinity, so a contradiction is detected:

```
A contradiction was detected within [the] context.
  The contradiction involves the newly derived proposition:
      WFF108:  HAS(German,tanks,T1)
  and the previously existing proposition:
      WFF109:  ~HAS(German,tanks,T1)

Automatic Belief Revision (AutoBR):
       The least believed hypothesis:
        (WFF48)
       The most common hypothesis:
        (NIL)
       The hypothesis supporting the fewest nodes:
       (WFF121)
```

```
   I will remove the following node:
      WFF48:  MAJORUNIT(German,SSTot,T0)
    because it is the best choice given the previous
 information.
```

WFF48 was the best choice because it was the least believed of the base propositions that supported the conflicting beliefs.

5.3 The German attack in 5.2 was a Surprise

The French also did not expect the Germans to have advanced so far west. This means that the French forces that were supposedly holding them in PDot were not actually doing that, and a contradiction is found:

```
A contradiction was detected within [the] context.
  The contradiction involves the newly derived proposition:
      WFF169:  ~STRONG(60th,T0)
  and the previously existing proposition:
      WFF50:    STRONG(60th,T0)

  The least believed hypotheses:
   (WFF33 WFF35 WFF50)
  The most common hypothesis:
   (NIL)
  The hypothesis supporting the fewest nodes:
  (WFF50)

I will remove the following node:
     WFF50:  STRONG(60th,T0)
because it is the best choice given the previous
information.
```

…and among the other propositions derived…

```
  WFF160:  OVERRUN(60th,T0)
```

WFF50 is singled out as the best culprit choice, because it is one of the least believed propositions and it supports the fewest nodes in the knowledge base (as far as the system knew at this time[2]). This means that this contraction will resolve the inconsistency with minimal damage to the knowledge base (i.e., the smallest number and least believed propositions are lost). Note, also, that a belief that was derived during this process is that the French forces at PDot must have been overrun (WFF160).

In this demonstration, automatic belief revision was actually able to narrow the culprit list to a single hypothesis both times that it was activated. In the event that it cannot find a singleton

[2] SNePS is guaranteed to be sound, but not complete. There might be derivable beliefs that depend on a proposition but have not yet been derived.

culprit, the user is asked to make a selection from a list of recommended culprits. In either case, belief revision is activated as soon as an inconsistency is detected, and (whether by the user or autoBR) the system is returned to a consistent state.

Note that the system can no longer find anyone who has an advantage (French and German forces seem to be equal in both tanks and planes):

```
;;; Does anyone have an advantage, now???
: some-advantage(?x,?y,T1)?          query

[no answer from the system]
```

No answer means that the system was unable to derive any advantages at time T1.

5.4 No more Allied Planes

Although the French general believed the Germans had no air superiority, the lack of Allied planes is treated here by a simple update of information. We decided not to implement any rules that equal forces should not have an unequal outcome. Here, the French general simply realizes that the Germans have beaten the Allies in the air. The system is asked again whether it can find anyone with some advantage, and it finds the Germans (air advantage, tanks equal):

```
: some-advantage(?x,?y,t4)?          query

  WFF267:  SOME-ADVANTAGE(German,French,T4)  reply
```

At this point, the system "realizes" that the Germans have the advantage. The French general probably came to this conclusion as well.

6 Analysis of the scenario

The demonstration[3] shows that our system detects inconsistencies as soon as possible and eliminates the culprit propositions. This results in all erroneously derived beliefs also being removed from the knowledge base. A nice improvement might be to add a message that notifies the user of the hypothesis removed *and* all beliefs dependent on that hypothesis that are no longer believed. This would be helpful, since humans sometimes forget this step[4] or may have forgotten the connection between the justification and the belief (Galliers 1992 citing Gärdenfors 1989 and Harman 1986).

Perhaps additional information would have enabled the French general to form a better plan of attack and avoid defeat. There was no information in the scenario to set that up, but it would be possible to add in reliability of sources and battle tactics. The analysis in the original text scenario criticizes the general for not considering factors he seems to feel he couldn't have known.

If there was information that the Germans had "control of the skies over the battlefield", perhaps the general missed including that information in battle-plan formulation. In this case, an

[3] An edited version of the scenario run is given in Appendix 3.
[4] Fran cites personal experience.

expert system with the information and rules for formulating battle-plans might catch the general's error immediately and suggest an alternate plan.

Appendix 1

The Scenario as first seen:

World War II: France 1940 The Battle of Dot Sur La Mappe

The scenario deals with an attack by a French armored formation – 1st DCR – on an advancing German mobile column that was trying to capture the French town of Dot Sur La Mappe. Map of area, modified for this exercise to include Draws and Spurs, is attached.

The battle took place in late May 1940. The reasons why this town was so important for both the French and the Germans were:

- The area's status as a minor communications hub, being bisected by major North-South and East-West roads as well as having a railway terminus on the South West side of the town (useful for bringing up reinforcements from the Capital);

- The French belief (mistaken in the event) that the German forces in the area contained no tanks, the major unit having been identified as the SS-Totenkopf-Regiment, a motorized unit.

The area was defended by the French 60th Infantry Division, advanced elements of which (in Petite Dot Sur La Mappe) had already been engaged in light skirmishing with the leading (and thoroughly exhausted) elements of Totenkopf.

The French counter-attack force was the 1st DCR, a regular unit that was well equipped with modem tanks, and was under the command of the egregious General de Brigade Coeur du Roi. 1st DCR had to undertake an overnight road march of some 50km to reach the arena in question.

Unknown to the French, SS-Totenkopf-Regiment was only the advance guard of a German column, the main strength of which – the veteran 2nd Panzer-Division – was due to arrive in the area at around the same time as 1st DCR. It will be recalled that 2nd Panzer-Division was at this time commanded by the dynamic General der Panzertruppen 'Willy' Wilhelm, who was later to achieve fame both for his role as adviser to the Finnish Army and his Wehrmacht publication 'A Wine Looter's Guide To Occupied Europe'.

A French account of the battle

"When I was ordered to counter-attack the German Panzer attack being made in the area of Dot Sur La Mappe, I was informed that the 60th Infantry Division was in extensive defenses in and around that town and its smaller sister hamlet Petite Dot Sur La Mappe. I therefore ordered my division – 1st DCR – into a column of march and moved as rapidly as the situation allowed towards the town. My intention was then to use Dot Sure La Mappe as a base from which to launch my counter-attack.

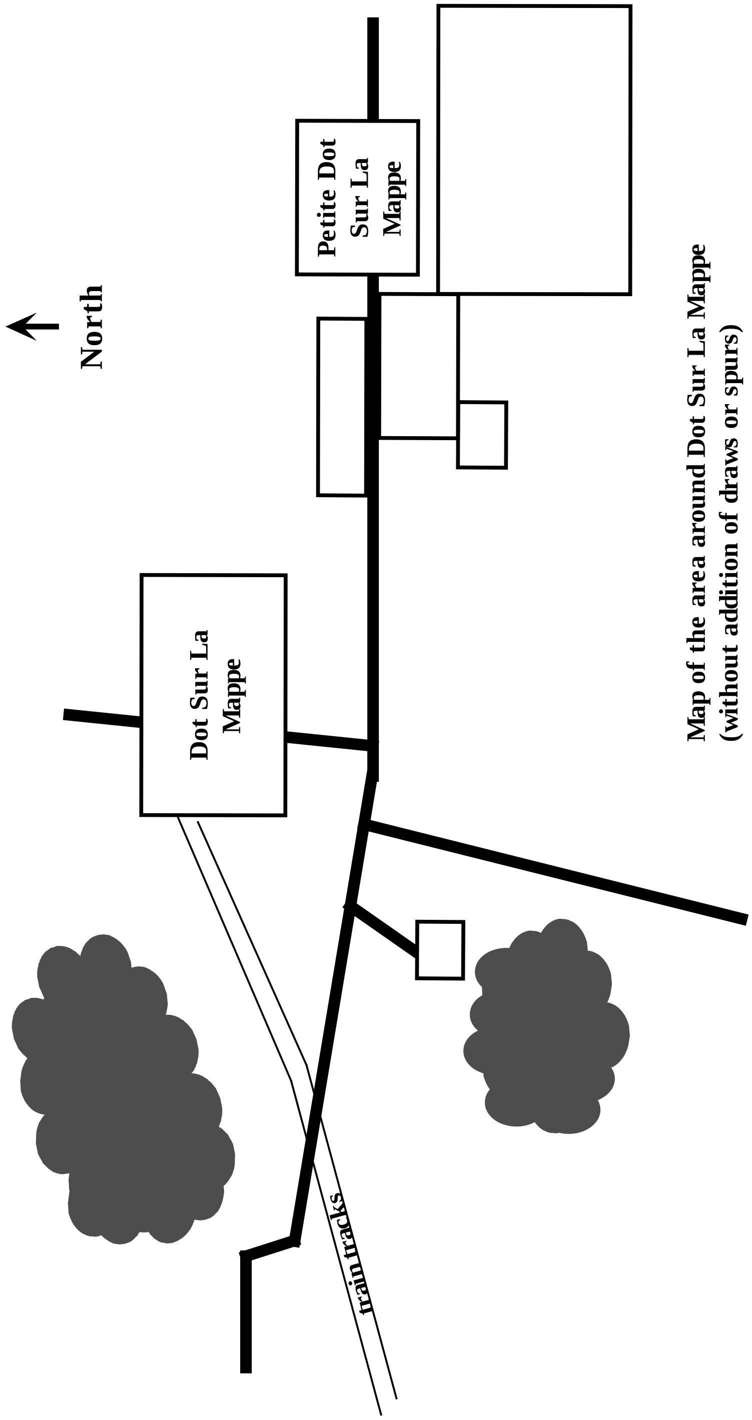
During the march to Dot Sur La Mappe my forces became somewhat disorganized, and I ordered the leading units to set up camp outside the town when they arrived there so that my troops could reorganize before being committed to battle. What I was unaware of was that fact that the "extensive defenses" at Dot Sur La Mappe were ill-manned and even worse prepared, and that as a result the leading elements of the German Panzer forces were already on the main road towards the town. The 2nd Demi-Brigade, the Dragoons Portée, and the Divisional Staff were able to reach the area set aside for reorganization without hindrance, but the artillery were caught in an attack by German tanks, and had to deploy to fight them off. As a result the column was cut into two parts, and the 1st Demi-Brigade and my own command cell were isolated from the rest of the DCR.

In the circumstances I felt that the best course of action was to attack the Germans as soon as possible, and at first light on the next day both "wings" of my division mounted an all-out attack on the main German force. By a fortunate chance both "wings" were able to attack in unison, and the resulting fighting destroyed many vehicles and killed many Germans. The attack was only broken off at the end of the day because Stuka attacks – which were called down by the Germans to save them from annihilation – were beginning to inflict some casualties on my force.

I felt at the time – and have felt since – that this battle had a most significant effect in that it slowed the Germans advance into France, and that it has not had the recognition it deserved. Those so-called "experts" who decry my efforts because my division was never able to be re-built have forgotten the dire circumstances the country was in at the time, and I can hardly be blamed for the failure of the French and Royal Air Forces in protecting my two demi-brigades from the Stuka attacks that destroyed them on the day after the battle.

(From Unpublished manuscript entitled "Armoured General" by General de Brigade Coeur de Roi)

As can be seen from this extract, General Coeur de Roi's initial plan seemed to take little account of the fact that the Germans were advancing so rapidly and had control of the skies over the battlefield. His attack did halt one part of the German advance for at least two days, but he fails to mention the fact that he left the 60th Infantry Division – one of whose regiments had fought very hard to retain control of Dot Sur La Mappe during the battle – to its fate (it was effectively destroyed and not subsequently reformed), and he left the Germans in control of the battlefield. They were thus able to recover and repair much of the equipment they had lost during the battle, and within three days they were, again, in the forefront of the German advance.



Map of the area around Dot Sur La Mappe (without addition of draws or spurs)

Appendix 2

The following is a simplified version of the scenario given in Appendix 1. This is the scenario implemented in SNePS. Section 3 of the report describes most of these simplifications.

%%%%%%%% French Battle Scenario %%%%%%%%%

At the start of this scenario (Time T0)…

Fact:
This battle will involve French and German forces. The French forces consist of 1stDCR & 60th. The key resources/equipment involved consists of tanks and planes.

Information:
The 60th is battling the German SSTot.

Experience:
The 1st DCR has tanks.

Information:
The SSTot has no tanks. Both forces have planes (assumed equal in force, an error).

Assumption:
The French believe that the German force is primarily made up of the SSTot, believed to be the major unit. (We learn later, that this is an error)

Information:
The 60th is strong.

The French general reasons that the Germans have no tanks…

%%%%%%%%%%%%%%%%%%%%%%%%%%%

Once 1stDCR nears the battle area (Time T1)…

Experience:
Part of the 1stDCR is attacked by a German Panzer Division (tanks) which has advanced much further than expected (a surprise-advanced-attack). (Exactly when the French general learned of the German tanks is unclear, so we chose to say it happened here.)

German Panzers have Tanks – this results in an inconsistency: the Germans DO/DO-NOT have tanks…

The Panzers launch a surprise attack on the 1stDCR. (At this point the General should realize that the 60th has weakened.)

%%%%%%%%%%%%%%%%%%%%%%%%%%%

The next morning (Time T2)...

Fact:
1stDCR attacks the Germans combined forces (SSTot & Panzers)

%%%%%%%%%%%%%%%%%%%%%%%%%%%

Later that day (Time T3)...

Experience:
German Stuka's attack 1st DCR.

%%%%%%%%%%%%%%%%%%%%%%%%%%%

The next day (Time T4)...

Experience:
Germans still have planes.

BUT...
Experience:
There is insufficient aid from the Allied air forces.

It is now apparent that the Germans have the advantage.

%%%%%%%%%%%%%%%%%%%%%%%%%%%

Epilogue:
As expected, the 1stDCR and the 60th were destroyed and the Germans (after a few days to repair their vehicles) continued their advance. The key errors were the assumptions about lack of German tanks and the equality of the air forces. Correction of this information at an earlier time might have allowed the French general to alter his attack plans or call in more air support. The realization (after the Panzer attack) that the 60th was no longer strong, might also have affected battle decisions.

It would be interesting to explore the identical scenario with added battle tactic recommendations (thus moving the system from assistant to advisor) and compare outcomes depending on when the French learn of the German air superiority.

Appendix 3

The following run shows the Dot-Sur-La-Mappe Demonstration in SNePSLOG using sources and Automatic Belief Revision. Some editing has been done to reduce redundancy and remove extraneous system reports or details. Comments external to the input file are in Times New Roman. All file text (input and output) is in `Courier New font`, with the internal comments preceded by semicolons. Any additional comments inserted into the demonstration will be in *italicized Times New Roman*. Comments that are excerpted from the scenario summary are emphasized in **bold**. Input to the system is preceded by the SNePSLOG prompt, a colon (**:**).

Because the scenario information varied in its accuracy or believability, we chose to represent this epistemic entrenchment by assigning each piece of information to one of five sources, ranked by credibility. From most credible to least, they are:

- **Fact** **not disputable**
- **Experience** **as seen or experienced by the French general**
- **Rule** **Information *NOT* stated expressly in the scenario, but considered some form of General (or Battle) Knowledge**
- **Information** **knowledge from some outside reliable and experiencing source**
- **Assumption** **information that is third-hand or lacking experience or derived by rules we are unaware of**

```
;;; The system is taking the role of assistant to the French general, so the information
;;;   it is given is limited to what the general believes/knows at a given time.

;;; %%%%%%%%%%%%%%%%%%%%%%%%%%% Source Information %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

;;; Sources:  Fact > Experience > Rule > Information > Assumption
;;; the relation Sgreater is transitive
;;; the relation Greater is transitive, and
;;;   the believability of sources is passed on to the information they supply
;;;   i.e. Source(x,y) & Source(v,w) & Sgreater(x,v) => Greater(y,w)

: SGreater(Fact,Experience)
```

input

```
  WFF1:  SGREATER(FACT,EXPERIENCE) {<HYP,{WFF1},{}>}
```

output (wff1 is a hypothesis based on itself)

Since most system output lines look like echoes of the input lines with the proposition's WFF# added, only the output lines in these cases will be shown from now on.

```
  WFF2:  SGREATER(EXPERIENCE,RULE)
  WFF3:  SGREATER(RULE,INFORMATION)
  WFF4:  SGREATER(INFORMATION,ASSUMPTION)

;;; %%%%%%%%%%%%%%%%%%%%%%%%%%% Domain Rules %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

The Domain Rules do not come directly from the scenario, but fill in gaps by adding "General Knowledge" or "Battle Knowledge" to the knowledge base. These are (simplified) rules that allow inferences to be made about the scenario's ground propositions.

```
;;; Parts of groups have the same nationality as their groups.
  WFF5:  all(Z,Y,X)({NATIONALITY(Y,Z),PART OF(X,Y),NATION(Z)} &=> {NATIONALITY(X,Z)})

;;; Anyone with a nationality is a force.
  WFF6:  all(N,X)(NATION(N) => (NATIONALITY(X,N) => FORCE(X)))

;;; Nations cannot have their own or other Nationalities.
  WFF7:  all(X)({NATION(X)} v=> {~NATIONALITY(X,X),all(Y)(~NATIONALITY(X,Y))})

;;; Strong forces/nations are not weak & vice-versa.
  WFF8:  all(T,X)((~WEAK(X,T)) ⇔ STRONG(X,T))
  WFF9:  all(T,X)((~STRONG(X,T)) ⇔ WEAK(X,Y))

;;; Everyone is limited to one Nationality.
  WFF10:  all(Z,Y,X)({NATION(Z),NATION(Y)} &=> {{NATIONALITY(X,Y)} &=> {~NATIONALITY(X,Z)}})

;;; If one nation has equipment that another nation does not,
```

```
;;;    then the first nation has an advantage.
  WFF11:  all(T,X,N2,N1)({TIME(T),EQUIPMENT(X),NATION(N2),NATION(N1)} &=>
{{~HAS(N2,X,T),HAS(N1,X,T)} &=> {SOME-ADVANTAGE(N1,N2,T)}})

;;; If a group doesn't have something, neither do any of its subgroups.
  WFF12:  all(T,Z,Y,X)({PART OF(Z,X),~HAS(X,Y,T)} &=> {~HAS(Z,Y,T)})

;;; If a group has something, so does its nation & its super-groups.
  WFF13:  all(T,Z,Y,X)({HAS(X,Y,T)} v=> {all(N)(NATION(N) => (NATIONALITY(X,N) =>
                                            HAS(N,Y,T))),PART OF(X,Z) => HAS(Z,Y,T)})

;;; If one group attacks another, they are battling.
  WFF14:  all(T,Y,X)(ATTACK(X,Y,T) => BATTLING({Y,X},T))
;;; A surprise advanced attack by a Nation implies that anyone it was battling earlier
;;;   is no longer strong   … (and wasn't strong in the battle – simplistic)
;;; I.E.  Any force (not nation) that lets attackers through has been overrun.
  WFF15:  all(T2,T1,Z,Y,X)({FORCE(Y),BATTLING({Y,X},T1),BEFORE(T1,T2),SADV-ATTACK(X,Z,T2)} &=>
                                            {OVERRUN(Y,T1)})

;;; Overrun forces are weak (aka not strong) at the time they were overrun and after.
  WFF16:  all(T2,T1,Y)({BEFORE(T1,T2),OVERRUN(Y,T1)} &=>
                      {WEAK(Y,T2),WEAK(Y,T1),~STRONG(Y,T2),~STRONG(Y,T1)})

;;; Surprise advanced attacks are attacks.
  WFF17:  all(T,Y,X)(SADV-ATTACK(X,Y,T) => ATTACK(X,Y,T))

;;; If a force does a surprise advanced attack, so does its nation.
  WFF18:  all(T,N,Y,X)({NATIONALITY(X,N),SADV-ATTACK(X,Y,T)} &=> {SADV-ATTACK(N,Y,T)})

;;; Battling groups are battling the Nations, as well.
  WFF19:  all(T,N,Y,X)({NATIONALITY(X,N),BATTLING({Y,X},T)} &=> {BATTLING({N,Y},T)})

;;; One can't acquire resources/equipment (within the time scope of the scenario).
  WFF20:  all(T2,T1)(BEFORE(T1,T2) => (all(Y,X)((~HAS(X,Y,T1)) => (~HAS(X,Y,T2)))))

;;; The major unit is one such that every unit of the same nationality is part of it.
  WFF21:  all(T,X,N)(MAJORUNIT(N,X,T) => (all(Y)({NATIONALITY(Y,N),NATION(N)} &=> {PART OF(Y,X)})))

;;; If a major unit has no tanks, the "Nation" has no tanks
;;;    (within the locative scope of the scenario).
  WFF22:  all(T,X,N)({~HAS(X,tanks,T),MAJORUNIT(N,X,T),NATION(N)} &=> {~HAS(N,tanks,T)})

;;; "Before" is transitive
  WFF23:  all(Z,Y,X)({BEFORE(T,Z),BEFORE(X,Y)} &=> {BEFORE(X,Z)})


;;;%%%%%%%%%%%%%%%%%%%%%%%%%%% Source ALL rules %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

All the Domain rules above are considered to be from some "Rule" source.

```
: Source(Rule,{WFF5,WFF6,WFF7,WFF8,WFF9,WFF10,WFF11,WFF12,WFF13,WFF14,WFF15,WFF16,WFF17,
                                    WFF18,WFF19,WFF20,WFF21,WFF22,WFF23})
```

This becomes `WFF24`*, a **very** long Proposition, because all the other wffs are **fully** printed out.*
And, finally, we come to the scenario…

```
;;; %%%%%%%%%%%%%%%%%%%%%%%%%%% French Battle Scenario %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%


;;; At the start of this scenario (Time T0)…
  WFF25:  TIME(T0)                                        Fact
  WFF26:  SOURCE(FACT,TIME(T0))

;;; Fact:
;;; This battle will involve French and German forces.
  WFF27:  NATION({French,German})
  WFF28:  SOURCE(FACT,NATION({French,German}))

;;; The French forces consist of 1stDCR & 60th.
  WFF29:  NATIONALITY(1stDCR,French)
  WFF30:  SOURCE(FACT,NATIONALITY(1stDCR,French))
  WFF31:  NATIONALITY(60th,French)
```

```
  WFF323  SOURCE(FACT,NATIONALITY(60th,French))
```

;;; Information:
;;; The 60th is battling the German SSTot.

```
  WFF38:  NATIONALITY(SSTot,German)
  WFF34:  SOURCE(INFORMATION,NATIONALITY(SSTot,German))
  WFF35:  BATTLING({SSTot,60th},T0)
  WFF36:  SOURCE(INFORMATION,BATTLING({SSTot,60th},T0))
```

;;; Fact:
;;; The key resources/equipment involved consists of tanks and planes.

```
  WFF37 EQUIPMENT({planes,tanks})
  WFF38:  SOURCE(FACT,EQUIPMENT({planes,tanks}))
```

;;; Experience:
;;;The 1st DCR has tanks.

```
  WFF39:  HAS(1stDCR,tanks,T0)
  WFF40:  SOURCE(EXPERIENCE,HAS(1stDCR,tanks,T0))
```

;;; Information: The SSTot has no tanks.

```
  WFF42:  ~HAS(SSTot,tanks,T0)
  WFF43:  SOURCE(INFORMATION,~HAS(SSTot,tanks,T0))
```

;;; Information: Both forces have planes (assumed equal in force, an error).

```
  WFF44:  HAS(French,planes,T0)
  WFF45:  SOURCE(INFORMATION,HAS(French,planes,T0))
  WFF46:  HAS(German,planes,T0)
  WFF47:  SOURCE(INFORMATION,HAS(German,planes,T0))
```

;;; Assumption:
;;; The French believe that the German force is primarily made up of the SSTot,
;;; believed to be the major unit. (We learn later, that this is an error)

```
  WFF48:  MAJORUNIT(German,SSTot,T0)
  WFF49:  SOURCE(ASSUMPTION,MAJORUNIT(German,SSTot,T0))
```

;;; Information: The 60th is strong.

```
  WFF50:  STRONG(60th,T0)
  WFF51:  SOURCE(INFORMATION,STRONG(60th,T0))
```

;;; The French general reasons that the Germans have no tanks… *so does the system…*

`: Has("German","tanks", T0)?` *Query: Do the Germans have tanks at time T0?*

`  WFF60:  ~HAS(German,tanks,T0)  {<DER,{WFF22,WFF27,WFF42,WFF48},{}>}` *Reply*

*The reply indicates that the system derives that it is **not** the case that the Germans have tanks at time T0. The hypotheses underlying this belief are:*

- *WFF22: all(T,X,N)({~HAS(X,tanks,T),MAJORUNIT(N,X,T),NATION(N)} &=> {~HAS(N,tanks,T)})*
- *WFF27: NATION({French,German})*
- *WFF42: ~HAS(SSTot,tanks,T0)*
- *WFF48: MAJORUNIT(German,SSTot,T0)*

*The relation "some-advantage" is used to show whether one Nation has **any** advantage over another at a given time. Some-Advantage(x,y,t) means that Nation x has "some" advantage over nation y at time t. This might mean x has planes when y does not. If y has tanks at time t & x does not, then Some-Advantage(y,x,t) would also be true – they are not mutually exclusive. If, however, only one is true, it lends hope to the advantaged Nation that they will be victorious.*

`;;; Who has any advantage at time T0?`
`: some-advantage(?x,?y,T0)?` *Query*

`  WFF77:  SOME-ADVANTAGE(French,German,T0)` *Reply*
Derived from: `{WFF11,WFF13,WFF22,WFF25,WFF27,WFF29,WFF37,WFF39,WFF42,WFF48}`

Since the system derives that the French have an advantage, it is likely that the French General feels the same.

;;;%%

;;; Once 1stDCR nears the battle area (Time T1)… *Fact*

```
  WFF104:  TIME(T1)
```

```
  WFF105:  SOURCE(FACT,TIME(T1))
```

Time T0 precedes Time T1… and what does that tell us? The exclamation point tells the system to do forward inferencing.

```
: Before(T0, T1)!                                         input
```

A long list was generated. Below are some of the interesting replies:

```
  WFF114:  BATTLING({60th,German},T0)
  WFF113:  BATTLING({German,French},T0)
  WFF112:  BATTLING({SSTot,French},T0)
  WFF111:  ~HAS(SSTot,tanks,T1)
  WFF109:  ~HAS(German,tanks,T1)
  WFF106:  BEFORE(T0,T1)
```

And of course we add that this time order is a fact…

```
  WFF117:  SOURCE(FACT,BEFORE(T0,T1))

;;; Frame problem rules for updates
;;; Rules at T1 (to deal with the frame problem):
;;; Major German Unit has not changed.
: all(x)({MajorUnit("German",x,T0)}
              v=> {MajorUnit("German",x,T1)})  ;; WFF118

  WFF118:  all(X)(MAJORUNIT(German,X,T0) => MAJORUNIT(German,X,T1))

;;; Everyone has whatever they started out with.
: all(x) (equipment(x) => (all(y)(has(y,x,t0) => has(y,x,t1))))  ;; WFF119

  WFF119:  all(X)(EQUIPMENT(X) => (all(Y)(HAS(Y,X,T0) => HAS(Y,X,T1))))

: Source(Rule,{WFF118,WFF119})  ;;  WFF120
```

```
;;; Experience:
;;; Part of the 1stDCR is attacked by a German Panzer Division (tanks) which has
;;;  advanced much further than expected (a surprise-advanced-attack).
;;;   (Exactly when the French general learned of the German tanks is unclear,
;;;     so we chose to say it happened here.)

;;; German Panzers have Tanks -> inconsistency that the Germans DO/DO-NOT have tanks…
  WFF121:  NATIONALITY(Panzers,German)
  WFF122:  SOURCE(EXPERIENCE,NATIONALITY(Panzers,German))
  WFF124:  SOURCE(EXPERIENCE,HAS(Panzers,tanks,T1))  ;; giving source before asserting what it says
: Has("Panzers", "tanks", T1)!                        ;; WFF123  -  and what do we know from that?
```

This is the system output (with some details edited out)which includes automatic belief revision using the source information:

```
         A contradiction was detected within context DEFAULT-DEFAULTCT.
         The contradiction involves the newly derived proposition:
             WFF108:  HAS(German,tanks,T1)
         and the previously existing proposition:
             WFF109:  ~HAS(German,tanks,T1)
```

Automatic Belief Revision (AutoBR):

```
         The least believed hypothesis:
          (WFF48)
         The most common hypothesis:
          (NIL)
         The hypothesis supporting the fewest nodes:
         (WFF121)

         I will remove the following node:
            WFF48:  MAJORUNIT(German,SSTot,T0)
          because it is the best choice given the previous information.
```

```
;;; The Panzers launched a surprise attack in the 1stDCR
  WFF136:  SOURCE(EXPERIENCE,SADV-ATTACK(Panzers,1stDCR,T1))

: Sadv-attack("Panzers","1stDCR",T1)!                    input -> WFF135
```

Output with AutoBR:

```
         A contradiction was detected within context DEFAULT-DEFAULTCT.
         The contradiction involves the newly derived proposition:
```

```
            WFF169:  ~STRONG(60th,T0)
        and the previously existing proposition:
            WFF50:    STRONG(60th,T0)

  The least believed hypotheses:
   (WFF33 WFF35 WFF50)
  The most common hypothesis:
   (NIL)
  The hypothesis supporting the fewest nodes:
  (WFF50)

  I will remove the following node:
           WFF50:  STRONG(60th,T0)
       because it is the best choice given the previous information.
```

…and among the other propositions derived…

```
  WFF160:  OVERRUN(60th,T0)
  WFF146:  SADV-ATTACK(German,1stDCR,T1)
  WFF135:  SADV-ATTACK(Panzers,1stDCR,T1)

;;; Does anyone have an advantage, now???  NO.
: some-advantage(?x,?y,T1)?
```

query

No answer means that the system was unable to derive any advantages at time T1.

```
;;;%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

;;; The next morning (Time T2)...
  WFF224:  TIME(T2)
  WFF225:  SOURCE(FACT,TIME(T2))
  WFF226:  BEFORE(T1,T2)
  WFF227:  SOURCE(FACT,BEFORE(T1,T2))

;;; Frame problem rule for updates
;;; Rule at T2
;;; Everyone still has most of their equipment.
WFF228:  all(X)(EQUIPMENT(X) => (all(Y)(HAS(Y,X,T1) => HAS(Y,X,T2))))
WFF229:  SOURCE(RULE,all(X)(EQUIPMENT(X) => (all(Y)(HAS(Y,X,T1) => HAS(Y,X,T2)))))

;;; Fact:
;;; 1stDCR attacks the Germans combined forces (SSTot & Panzers)
  WFF230:  MAJORUNIT(German,CombinedForce,T2)
  WFF231:  SOURCE(INFORMATION,MAJORUNIT(German,CombinedForce,T2))
  WFF232:  PARTOF({Panzers,SSTot},CombinedForce)
  WFF233:  SOURCE(INFORMATION,PARTOF({Panzers,SSTot},CombinedForce))
  WFF234:  ATTACK(1STDCR,CombinedForce,T2)
  WFF235:  SOURCE(EXPERIENCE,ATTACK(1STDCR,CombinedForce,T2))

;;;%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

;;; Later that day (Time T3)...
  WFF236:  TIME(T3)
  WFF237:  SOURCE(FACT,TIME(T3))
  WFF238:  BEFORE(T2,T3)
  WFF239:  SOURCE(FACT,BEFORE(T2,T3))

;;; Frame problem rule for updates
;;; Rule at T3
;;; Everyone still has their equipment (though maybe less of it)
WFF240:  all(X)(EQUIPMENT(X) => (all(Y)(HAS(Y,X,T2) => HAS(Y,X,T3))))
WFF241:  SOURCE(RULE,all(X)(EQUIPMENT(X) => (all(Y)(HAS(Y,X,T2) => HAS(Y,X,T3)))))

;;; Experience:
;;; German Stuka’s attack 1st DCR.
  WFF242:  NATIONALITY(Stukas,German)
  WFF243:  SOURCE(EXPERIENCE,NATIONALITY(Stukas,German))
  WFF244:  ATTACK(Stukas,1stDCR,T3)
  WFF245:  SOURCE(EXPERIENCE,ATTACK(Stukas,1stDCR,T3))
```

Stukas are planes… represented as the Stuka's "have" planes:

```
  WFF246:  HAS(Stukas,planes,T3)
  WFF247:  SOURCE(EXPERIENCE,HAS(Stukas,planes,T3))


;;;%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

;;; The next day (Time T4)...
  WFF248:  TIME(T4)
  WFF249:  SOURCE(FACT,TIME(T4))
  WFF250:  BEFORE(T3,T4)
  WFF251:  SOURCE(FACT,BEFORE(T3,T4))

;;; Frame problem rule for updates
;;; Rule at T4
;;; Everyone still has their tanks.
WFF252:  all(Y)(HAS(Y,tanks,T3) => HAS(Y,tanks,T4))
WFF253:  SOURCE(RULE,all(Y)(HAS(Y,tanks,T3) => HAS(Y,tanks,T4)))

;;; Germans still have planes.
  WFF254:  HAS(Stukas,planes,T4)
  WFF255:  SOURCE(EXPERIENCE,HAS(Stukas,planes,T4))

;;; BUT...
;;; Experience:
;;; There is insufficient aid from the Allied air forces.  Whether they didn't show or
;;;   were defeated, the representation we chose was an absence of planes to aid the French.
  WFF257:  ~HAS(French,planes,T4)
  WFF258:  SOURCE(EXPERIENCE,~HAS(French,planes,T4))

;;; System should deduce (or we could add, due to experience):
;;; It is now apparent that the Germans have the advantage.
 some-advantage(?x,?y,t4)?                                 query

  WFF267:  SOME-ADVANTAGE(German,French,T4)                reply

;;;%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

Epilogue:
As expected, the 1stDCR and the 60th were destroyed and the Germans (after a few days to repair their vehicles) continued their advance. The key errors were the assumptions about lack of German tanks and the equality of the air forces. Correction of this information at an earlier time might have allowed the French general to alter his attack plans or call in more air support. The realization (after the Panzer attack) that the 60th was no longer strong, might also have affected battle decisions.

It would be interesting to explore the identical scenario with added battle tactic recommendations (thus moving the system from assistant to advisor) and compare outcomes depending on when the French learn of the German air superiority.

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