

Introduction

In this essay, we will describe an information processing account of two individuals working to make sense of data that corresponds to events and actions. There were 100 data points that we worked to make sense of including information about actions, agents, objects, locations, co-agents, and time. We will first describe high level strategies, plans, and heuristics that we worked out how to approach the problem. The problem space was rather large, so we figured out methods that would shrink the problem space into a manageable size. Next, we will describe different cognitive mechanisms that we employed to reason about and infer causal structures from related events.

Planning

Upon beginning the task, we were presented with a wealth of information, and were tasked with trying to make sense of the data. There were a potentially infinite number of ways to combine and link the events, and therefore a heuristic had to be adopted for grouping related items. The approach we decided on was organizing features into groups based on surface similarities to generate categories and concepts. We decided to move onto a higher level analysis only after this initial sorting and organization was complete. This plan served multiple purposes. First, it structured our activities into two phases. The first phase consisted of a quick sorting method based on surface level similarities, and the second phase consisted of a detailed analysis of those groupings. This cognitive process is very similar to MAC/FAC, which is a two-stage model of similarity based reminding (Forbus, Gentner, & Law, 1995). In the first phase of MAC/FAC a comparison item is used to probe memory for many items that have a surface level similarity. These items are then analyzed in detail in a slower and more computationally expensive manner with using the Structure Mapping Engine.

The Structure Mapping Engine (SME) was a breakthrough in theories of analogy because it went beyond feature-based analogical retrieval and mapping (D Gentner, 1983). The SME examines the structural relationships between concepts independent of the content and features that fill roles in propositional statements using predicate calculus. Instead of projecting features from one domain to another, the SME projects entire structures and syntactic relationship to more accurately describe the inferential productivity of analogy as a cognitive mechanism.

The cognitive processing we employed in our two stage process mirrors that described by Forbus et al. in MAC/FAC. We initially conducted a coarse yet easy classification, and then analyzed each of those groups based on more fine grained rules. We settled on the notion of 'agency' as the metric by which to compare similarity among different events, and used common agents to group events. The reason we selected agency could be described by the notion of categorical organization of concepts presented by Thagard (Thagard, 2005). The concept of agent seemed to be at the highest level of a categorical hierarchy in the sense that almost every event included an agent. Therefore, the concept of agent was selected as the best concept to use to conduct the initial organization step.

Categorization

We soon realized that using the notion of agency to define categories led to some situations where the boundary of the category was not as well defined as we initially anticipated. Some events had an agent with the same name as a co-agent in another event, or the object of yet another event. Therefore, we had to extend our categorization heuristic to include events with overlapping features in a manner akin to the prototype theory of categorization where membership is determined through family resemblance (Lakoff, 1987). Family resemblance describes a relationship where many items might have overlapping similarities between their features, but no feature has to be common to all of them (Lakoff, 1987).

Chunking

Organizing the data into discrete units exemplifies a cognitive technique called chunking. Chunking is a procedure whereby many data points are reduced into a smaller number to facilitate cognitive processing (Thagard, 2005). It is usually used to help remember strings of information, such as telephone numbers, but in this case, we used chunking to help reduce the size of our search space. Instead of looking through 100 points of data, we had approximately 10 groups that we could actively hold in short term memory at once in order to reason about them and try to develop causal connections between them. If we didn't chunk this data into manageable groups, it would not have been possible to think about all the data at once.

Heuristics

Chunking also enabled us to adopt another heuristic that could be summarized as solving the easy problems first. We adopted this strategy to further limit our problem space to a smaller number. Using this heuristic, we analyzed categories that had fewer members with no known links to other categories.

Mental Modeling

Now that we have described some initial methods that we used to organize the data, we will describe the second phase of our process, namely in-depth analysis. We began our in-depth analysis by reading through the categories and building mental models about how we interpreted the data. A mental model is a cognitive construct that organizes information and enables reasoning. Mental models are contrasted against the logical positivists view that posits cognition is a system of rules and logical inferences based on manipulating patterns of symbolic representations (Nersessian, 2002). Mental models are similar to real life models in that they can be descriptive, predictive, and contain diagrammatic components that have a structural correspondence to the situation they reference.

The mental models we constructed included trying to develop a coherent situation that accounted for all the data in a category. This included associations that we were reminded of and possible causal links between events. Sometimes our mental models were inaccurate and provided us with

false assumptions that lead to logical errors. For example, we assumed that Rex Luthor was involved in a voting scam because he was advocating for changing the voting machines, and the vote was tampered with. We thought there was voting fraud going on because there was a scandal. Once we realized there was a political scandal, we applied the ‘crooked politician’ mental model. Using this model, we ordered the events in the following manner:

1. Rex lobbied for a change in the machines
2. It was changed
3. The voters have trouble with the machines (i.e. voter fraud)

This explanation and temporal ordering aligned with our ‘crooked politician’ mental model. However, after we investigated further, we discovered that our mental model was inaccurate. Fixing our mental model to include trustworthy politicians changed the ordering of the voting situation to resemble a more commonplace situation where a politician lobbies for change based on requests from his constituency.

Behavioral Modeling

One can describe our process in assuming voter fraud based on the concept of a problem space in the SOAR architecture. From the phrases given, we saw certain features such as (runs-for(john-torch , alderwood-mayor , , ,)) and (57 (wants(rex-luthor , upgrade-voting-machines , , ,))) which describe the features of John Torch running for mayor and Rex Luthor wanting to upgrade voting machines. However, this does not indicate any malevolent connection between the two men. Going further, the statements: (64 (were-taken(, steamy-photos(john-torch brunette-woman) , starbucks , ,)) and (65 (said(rex-luthor , were-unfortunate(steamy-photos(john torch))) , , ,)) gave rise to the features of a John Torch scandal as well as a link to Rex Luthor. Through analogical reasoning, the presence of one scandal seemed to imply that others might exist in the narrative. Another statement (47 (has-a(john-torch , personal-frustrating-history , , tom-lanctot ,))) and the Boynton investigation allowed for us to make a pre-emptive assumption of a further scandal goal state between Rex Luthor and John Torch involving the voting machines.

On assessing our hypothesis of voting fraud, we discovered a faulty mental model. We were able to navigate through the given states to make appropriate connections in a behavior model as described by SOAR, yet there seems to be no statement indicating the goal state of any kind of fraud occurring related to the voting machines. Since there was no goal state indicating foul play we decided to abandon our hypothesis.

Due to Rex Luthor’s announcement about Boynton labs and the statement (94 (started(two-key-scientists , boynton-labs , , ,))), we drew another goal state of Rex Luthor being one of these scientists. The path link was derived from the fact that Rex Luthor worked with Phillip Boynton, the lab’s namesake and founder. Later, we discovered that Rex Luthor had been put in charge of investigating and upgrading the voting system. This seems to imply a vocation of political nature. The principle of rationality states that “if an agent has knowledge that an operator application will lead to one of its goals then the agent will select that operator” (Lehman, Laird, & Rosenbloom, 1996). Through an inverse of the principle of rationality, and since the concept

of a scientist does not typically link to politician, we were able to abandon our imagined goal state of Rex Luthor being neither a founder of Boynton labs, nor being a scientist at all. From the newfound information, a path was derived in which Rex Luthor is instead perhaps a politician or a state official, which rationally follows his concern with the voting machines.

Creative Discovery

We at first believed Von Ryker was separate from Boynton Labs. We can describe the linking of these two concepts in terms of a connectionist network. The investigation activated common meanings enough between the two systems until a threshold was reached. This threshold pointed to an undeniable link between the two events, but the link and causality between the events was not clear. There was also an internal logic discrepancy in the Von Ryker case because Ryker's investigation of a breach on bioethics laws did not connect to the Swiss Research Board investigation of misuse of state funds. We then were able put together that the misuse of state funds may have actually come from Boynton's lab, and that by inventing prion disease they were committing a bioethics violation, which Ryker tried to cover up by faking papers. The motivation for Ryker to cover up the situation was still unclear, but the connection between the two events was established.

Conclusions and Reflections

Our initial assessment through division into a categorical hierarchy based on agency was sufficient in dividing to problem into workable parts. A key advantage was to offload the burdens of short term memory by writing smaller stories, or chunks, from the mass of data. A heuristic based on categorization, chunking, and solving the easiest problems first was effectively employed to define and break down the task. A higher mental function was required to do further analysis to determine the actual causal relations between the items. Using mental models, we made coherent links between the data statements. Behavioral models, such as SOAR, can accurately describe how we made links between the actions of the agents in the story to go from initial to a goal state. The mistakes we made involved connectionist networks, faulty goal state definitions, and flawed mental models. Through these cognitive mechanisms we employed, we were able to successfully reason about and infer causal structures from related events.

References

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Appendix: Analyzed Stories

Stories

Voters

(71 (had-problems(voters , voting-machines , , ,)))
(58 (vulnerable(voting-machines , tampering , , ,)))
(72 (asked-to-investigate(rex-luthor , voting-machines , , ,)))
(57 (wants(rex-luthor , upgrade-voting-machines , , ,)))
(73 (pledged-answer(rex-luthor , voting-machines , , ,)))
(59 (signed-contract(rex-luthor , voting-machines , , ,)))
(67 (received(rex-luthor , 50000-contribution , , republican-boosters ,)))
(60 (installed(, voting-machines , , ,)))

John Torch

(55 (interested-in(john-torch , arts , , ,)))
(56 (interested-in(john-torch , culture , , ,)))
(52 (active-in(john-torch , politics , , ,)))
(62 (support-among(john-torch , citizens , , ,)))
(63 (confident(john-torch , advisors , , ,)))
(51 (runs-for(john-torch , alderwood-mayor , , ,)))
(68 (raised(john-torch , 30000 , , ,)))
(61 (contender(john-torch , alderwood-mayor , , ,)))
(70 (opposed(john-torch , gambling , , ,)))
(44 (voted-against(john-torch , liquor-license , , ,)))
(48 (made(john-torch , negative-comments , , martin-luther-king-jr ,)))
(49 (requested(pete-sartin , resignation , , john-torch ,)))
(50 (refused(john-torch , resignation , , ,)))
(40 (had-under(, hand , shirt , , ,)))
(64 (were-taken(, steamy-photos(john-torch brunette-woman) , starbucks , , ,)))
(5 (print(, steamy-photos(john-torch female-companion) , starbucks , , ,)))
(4 (same-as(female-companion , laurel-sulfate , , ,)))
(65 (said(rex-luthor , were-unfortunate(steamy-photos(john torch))) , , ,)))
(66 (said(rex-luthor , are(moral-values important) , , ,)))
(69 (decreased(john-torch , effort , , , after-starbucks-scandal)))
(2 (drops-out(john-torch , mayoral-race , , ,)))

City Council/ Bob Leeds

(53 (asked-for(bob-leeds , ammendment , , city-council ,)))

(54 (disagrees(city-council , bob-leeds , , ,)))

Robbers

(38 (parked(robbers , car , , ,)))
(39 (walked-toward(robbers , market , , ,)))
(42 (grabbed(dog , robber pants , , ,)))
(41 (got-scared(robbers , , , ,)))
(43 (run-away(robbers , , , ,)))

Robert E. Ford

(19 (go-to(robert-e-ford , store , , ,)))
(20 (give(robert-e-ford , fake-check , , clerk ,)))
(21 (give(robert-e-ford , fake-id , , clerk ,)))
(23 (suspect(clerk , fraud , , ,)))
(24 (call(clerk , police , , ,)))
(25 (run-away(robert-e-ford , , , ,)))
(27 (get-away(robert-e-ford , , , accomplice ,)))
(26 (chase-down(police-officers , robert-e-ford , , ,)))
(22 (get-caught(robert-e-ford , , , ,)))

Purse Robbery

(34 (attempted-snatch(man , purse , , ,)))
(37 (ran-away-without(man , purse , , ,)))
(28 (entered-car(employee , , , ,)))
(30 (came-from(man , , behind-bushes , , ,)))
(31 (opened(man , car-door , , ,)))
(32 (yelled(employee , , , ,)))
(33 (pulled-from(man , employee , car , , ,)))
(35 (hit(man , head , , employee ,)))
(36 (knocked-down(man , employee , , ,)))
(29 (snatch(man , purse , , ,)))

Mad Cow Disease

(102 (outbreak(mad-cow-disease , , argentina , , ,)))
(103 (imposed-ban(philippines , argentine-beef , , , ,)))
(99 (not-enforced(fda , , feed-ban , , ,)))
(98 (needed(stronger-measures , protect-from-mad-cow-disease , , , ,)))
(92 (said(philip-boynton , focus-on(boynton-labs mad-cow-disease) , , , ,)))
(104 (chose(us-government , boynton-labs test-for-mad-cow-disease , , , ,)))
(100 (approved(agriculture-department , rapid-testing-boynton-labs , , , ,)))
(101 (has-goal(agriculture-department , test 220000-animals , , , december-2005)))

Boynton Labs or Laurel-Sulfate

(86 (has-been(alderwood , financial-hardship , , , ,)))
(85 (believes(rex-luthor , increase(new-lab economic-development) , , , ,)))
(45 (worked-with(philip-boynton , rex-luthor , , , ,)))

(84 (announced(rex-luthor , new-lab , alderwood , ,)))
(94 (started(two-key-scientists , boynton-labs , , ,)))
(95 (background-in(scientists , medicine-science protein-science , , ,)))
(8 (founded(, boynton-labs , , ,)))
(7 (named-after(lab , philip-boynton , , ,)))
(87 (required(boynton-labs , start-up-funds 1000000 , , ,)))
(88 (has-a(washington-state , biotechnology-initiative , , ,)))
(89 (invested(washington-state , 250000 , , boynton-labs ,)))
(90 (working-on(washington-state-legislature , additional-funding 300000 , , boynton-labs ,)))
(91 (invested(philip-boynton , 25000 , , boynton-labs ,)))
(93 (broke-ground(governor-gary-locke , boynton-labs , , philip-boynton ,)))
(9 (have-developed(boynton-labs , prion-disease , , ,)))
(12 (injected-mouse(boynton-labs , prion-disease , , ,)))
(13 (injected-cow(boynton-labs , prion-disease , , ,)))
(77 (investigating(von-ryker , breach-bioethics-laws , , ,)))
(75 (faked(von-ryker , prion-diseases-papers , , ,)))
(74 (reported(von-ryker , papers , , swiss-research-board ,)))
(79 (was-alerted(swiss-research-board , anonymous-tip , , von-ryker-institute ,)))
(78 (investigating(swiss-research-board , misuse-state-funds , , von-ryker ,)))
(76 (remains(von-ryker , director-von-ryker-institute , , ,)))
(83 (continuing(swiss-research-board , investigation , , von-ryker-institute ,)))
(82 (announced(chief-investigator , closed(von-ryker-institute) , , ,)))
(81 (not-expected(shut-down(von-ryker-institute) , , , ,)))
(10 (announced-investigation(usfda , boynton-labs , , ,)))
(14 (treatment-mouse(boynton-labs , prion-disease , , ,)))
(15 (treatment-cow(boynton-labs , prion-disease , , ,)))
(6 (cured-disease(boynton-labs , prion-disease , , ,)))
(11 (discontinued-investigation(usfda , boynton-labs , , ,)))

Outliers:

(80 (researches(swiss-research-board , transmissible-spongiform-encephalopathies , , ,)))

(47 (has-a(john-torch , personal-frustating-history , , tom-lanctot ,)))

(46 (has-a(john-torch , personal-frustating-history , , bob-story ,)))

US

(96 (received(us , 650000-pounds-foreign-pork , , embargoed-country ,)))

(3 (works-for(laurel-sulfate , boynton-labs , , ,)))

Washington State

(18 (cash(, washington-state-unemployment-check , , ,)))

No Agent

(97 (exists-because(foot-and-mouth-disease , threat , , ,)))

(1 (stolen(, money \$40 , highway-tire-store , , ,)))

(16 (kicked-in(, door , daves-recycling-center , , ,)))

(17 (not-stolen(, money equipment , , ,)))