

Simulating the Senate with Intelligent Agents

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ABSTRACT

(To be filled in)

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1. INTRODUCTION

(To be filled in)

2. THE DOMAIN

The intention of this system is to model the United States Senate, the upper house of the legislative branch of the United States government. As established in Article One of the US Constitution [15], the Senate will be made up of one-hundred voting members. Unlike the House of Representatives, which determines membership percentages by state population, each state may only select two senators. Although it is not technically within the scope of this model, it should be noted that the Senate has several powers not allotted to the House of Representatives including the ability to negotiate treaties, to impeach high officials, and to vote on the appointment of certain positions.

In Federalist No. 62, James Madison stated that the "senatorial trust" calls for a "greater extent of information and stability of character." [13] Thus, the qualifications for becoming a senator are stricter than those of other legislative bodies. All senators must meet the following three requirements:

- Each senator must be at least 30 years old;
- Must have been a citizen of the United States for at least the past nine years;
- Must be (at the time of the election) an inhabitant of the state that they seek to represent.

Although they were originally selected by state legislatures and not the common population, the ratification of the 17th amendment in 1913 standardized popular election of senators. Senators serve terms of six years each, and may be reelected an unlimited number of times. The seats are staggered such that one third of the senators are up for election every two years. This practice is done to ensure that both seats for a state are not up for contest at the same time.

Senators may come from any political party, but are likely to belong to either the Republican or Democratic parties. The party with the majority of seats is given certain special positions such as the president pro tempore and the committee chairmen. If neither party has a majority, the party that the Vice President of the United States belongs to becomes the majority party. This simulation decides what party senators belong to stochastically. The real senate is currently made up of fifty-eight Democrats, forty Republicans, one Independent (who sits with the Democrats), and one empty seat (vacated by the death of Senator Ted Kennedy of Massachusetts).

Because very little would be accomplished if every matter required the consent of the entire floor, the United States Senate conducts much of its business through committees and subcommittees. All bills must be reviewed by the appropriate committee before they may be proposed to the Senate as a whole. Membership is determined by the Senate, with senators being given their choice of committees by seniority. Each party is allocated seats on committees in proportion to their overall percentage of floor seats. There are sixteen standing committees:

- Agriculture, Nutrition, and Forestry
- Appropriations
- Armed Services
- Banking, Housing, and Urban Affairs
- Budget
- Commerce, Science, and Transportation
- Energy and Natural Resources
- Environment and Public Works
- Finance
- Foreign Relations
- Health, Education, Labor, and Pensions
- Homeland Security and Governmental Affairs
- Judiciary
- Rules and Administration
- Small Business and Entrepreneurship
- Veterans' Affairs

The Senate also utilizes multiple subcommittees and non-

standing committees, but they are not modeled within this simulation.

Why model the Senate? The Senate provides us with a discrete group of fascinating agents, all working towards both common and competing goals. Each senator wants to discuss certain issues and pass their own bills, and each political party is working towards what they see as a *greater good*. Although each party's goals may run counter to those of the other party, neither has enough of a majority to do any business without help from the other. Therefore, modeling the Senate gives us a collection of competing agents that must be convinced to put aside their own selfish goals temporarily in exchange for help later. While some agent architectures model communities of agents working together, the point of this system is to model a community of agents that must work together despite not necessarily liking each other.

2.1 Domain Compromises

Because of the limited time allowed to model this domain, and in order to develop a working system, several simplifications have been made. This list is not complete, but these are the major compromises and changes made:

- Senators are assigned a party randomly, and the available parties are limited to Democrat and Republican.
- Senators are assigned a committee randomly.
- Committee membership is not controlled by the simulation. Committees are not checked for party composition or number of members.
- Senate procedure is simplified, and in some cases, ignored.
- Every senator is trying to pass a bill. Therefore, this model is likely to pass many more bills than the real Senate could pass in a single day.
- The rules and procedure controlling filibusters have been simplified.
- While a senator may propose a bill to the floor only twice per day (like in the real Senate), they may propose a bill to their committee any number of times until it passes.
- Committees are implemented, but subcommittees and the special committees do not exist within the simulation.
- No special positions have been implemented.
- There is no tie-breaking mechanism.
- All polls require a three/fifths majority to pass.

3. AGENT THEORY

Carl Hewitt remarked in a keynote that the question of what, exactly, an agent is can be as embarrassing a question for the agent-oriented software development community as the question of what intelligence can be for the artificial intelligence community. There are roughly as many definitions as there are researchers. For the purposes of this work, however, we will default to the definitions provided by Michael Wooldridge [16]. Specifically, *agents* can be defined in terms of *weak agency* and *strong agency*.

Weak Agents are a general type of agent that satisfies the following minimal properties:

- **Autonomy:** The agents operate without direct human intervention and have some control over their actions;

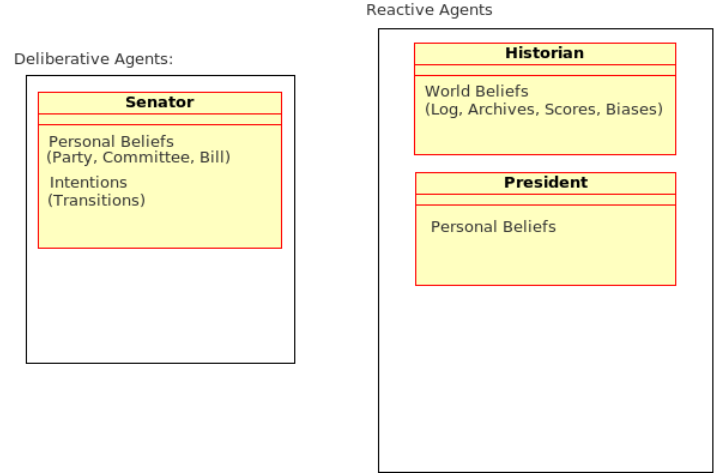


Figure 1: Actors as representations of agent theory

- **Social Ability:** Agents can interact with other agents and objects within their domain;
- **Reactivity:** Agents have knowledge of their environments and can respond to changes or stimuli from it;
- **Pro-activeness:** Agents are able to take actions towards some goal.

This weak notion of agency has found wide-use, likely because it is a natural extension of the object-oriented software development paradigm [1, 2]. Many self-contained processes can satisfy the requirements for weak agency. It can be argued that such concepts as a Unix software process are weak agents.

When explaining human behavior, it can be useful to evaluate events through the attribution of attitudes - things like believing, wanting, hoping, fearing, and expecting. These attitudes are called *intentional notions*. A philosopher, Daniel Dennett [8] described intentional systems as those "whose behaviour can be predicted by the method of attributing beliefs, desires, and rational acumen." Thus, the difference between weak agents and *strong agents* is that these "strong" agents have explicit notions of beliefs, desires, and intentions. Strong agents have, and act upon, these intentional notions:

- **Beliefs:** Beliefs represents an agent's view of their domain. They are a series of facts or variables, and their known values. They can change over time, certain beliefs can be forgotten, and new beliefs can be learned.
- **Desires:** These are the goals of an agent. An agent needs to be pro-actively working towards some sort of goal, even if it is a vague one like "run until the system shuts down."
- **Intentions:** The intentions are the actions that an agent can take towards completing a goal.

When describing agents, the specific software implementation is often either *deliberative*, *reactive*, or some hybrid of the two. Deliberative agents [10] are those that contain an explicitly represented model of the world where decisions are guided by some logical reasoning process. These agents often have explicit notions of beliefs, desires, and intentions and some sort of theorem proving algorithm to decide which

intentions to follow. Two core problems exist with purely deliberative agents - how to translate the world into an adequate model and how to reason with that model in time for the results to be useful.

Reactive architectures, on the other hand, do not utilize a strict world model or any sort of complex symbolic reasoning. Instead, they tend to take actions based on a layered hierarchy [4]. At the lower levels are base, instinctual behaviors. These are things like fight-or-flight reactions. They are not complex behaviors, but reactive agents are very fast to take action in response to environmental stimuli. These layered reactive models are often combined with a higher symbolic planning model. These hybrid agents can react quickly to certain domain events, but they can also make reasoned decisions when complex events occur.

This simulation employs three types of agents - Senators, Presidents, and Historians. The first, the Senator, is a deliberative agent. Senators have all of the properties of a weak agent - they act autonomously, they communicate, and they can react to their environment. They also satisfy the more stringent criteria for a stronger agent. All Senators are acting towards the same goal (or desire). They *want* to pass a bill in congress. At every state that they are in, they have a set of actions that they can take (i.e. intentions). These intentions, while initially random, are guided by a fast treatment learning algorithm called KEYS2. Thus, the Senator intelligently takes steps towards acquiring its desires. While this approach is not as strict as the theorem provers of standard deliberative agents, KEYS2 is able to bias the actions in a manner that is efficient for real-time use. The Senators also have both *personal* and *world* beliefs. Their personal beliefs deal with their own state. Each Senator has a political party, a committee, a support level, a trust level, and other attributes. These are their personal beliefs, known facts that relate only to their own world view. If a Senator needs to know the values for these factors of another agent, they can poll that specific agent. World beliefs are facts that have the same values for all agents. These are things like how many bills have been passed and what parties and committees passed them. These world facts are stored by a separate agent called a Historian and can be polled at any time.

The other agents, the Historian and President are more basic objects. They both meet the qualifications of weak agents, but are arguably not strong agents. They both have desires, but they only take actions in response to the actions taken by Senators. For instance, the President can render a final verdict on a Senator's bill, but it will only do so if a Senator asks it to. The President also contains the learning mechanism that biases the actions of all of the Senators. This learning algorithm only activates when the domain model prompts it to rebias. Likewise, the Historian exists to record all of the actions taken by Senators. It also stores all of the facts known about the domain. It will report this information when a Senator or the President requests it to. Thus, in a sense, the President and Historian are *reactive agents*. They base their actions on environmental stimuli.

4. ACTORY

Actory is a generalized architecture for the development of agent-oriented experiments. It provides a rough framework, but does not actively detail specific agent functions, such as beliefs, desires, and intentions. Rather, such details are left

to the discretion of the user.

All components of an Actory system are contained within the Factory, which is a large encapsulating unit containing a collection of Machines. The Machine is the central working unit. Although it is not required, Machines are the most logical representation of a single unit. Machines have a collection of Transitions, which interface with another collection of States and control the flow of the working system.

A Transition takes the form *From-To-If-Then*, where *From* is the originating state and *To* is the destination state. *If* is a guard, it checks to see if any prior conditions are met before the Machine is allowed to transition to the new state. *Then* is a block that can initiate any side effects that would happen as a result of making this particular transition.

Specific types of agents and the details of the domain may be implemented through subclasses of Machine. Specifically, this simulation of the Senate utilizes three distinct Machine subtypes, or actors - the Senator, the President, and the Historian. The primary role is the Senator, and one-hundred of them are initialized with the goal of passing bills. The President and Historian are reactive agents [16] that, rather than taking deliberative actions towards goals, wait for events to happen and react to them.

4.1 The Senator

Senators, the primary agents within this system, have the following properties:

- Party: Either Democrat or Republican.
- Committee: One of sixteen standing committees (elaborated on in the introduction).
- Trustworthiness: A reputation measure that can be damaged by scandals.
- Likelihood of being caught: If a senator commits crimes, they may be caught. As they commit more crimes, this value rises.
- Bill committee: Which committee the senator's bill applies to. It must pass this committee.
- Bill support: The current level of voiced support for the bill. This may rise by polling other senators, giving a speech, or through bribery. This level may drop if a senator is caught in a scandal.
- A count of the number of times they have proposed a bill. A senator may only present a bill to the floor twice per day.

Senators act selfishly towards their goal of passing a bill. They have several actions available to them in order to act towards this goal. These actions include:

- Gathering support: This is a default state that Senators return to when they are not conducting other actions. When they enter this state, and for each round that they remain in it, they will poll a random senator. If the polled senator gives an affirmative response, the polling senator will receive a small boost to their current support level.
- Presenting: The senator may present to either the bill's relevant committee or to the floor. Which one they present to depends on whether or not the bill has passed the committee. Presenting is optional, but can prove beneficial. When presenting, there is a chance that the senator will gain a random amount of support for their bill. However, they could also lose support if

the other senators dislike the speech. If the senator remains in this state, they will continue to speak. This could net additional support, but also carries a greater chance of losing support.

- Calling for a vote: The senator can call for either a committee vote or a floor vote. Again, this depends on the current state of the bill. All of the relevant senators will be polled for their vote. If 60 senators respond with a "yes" vote, the bill passes on to the next state. If a bill passed the committee, it goes to the floor. If a bill passes the floor, it goes to the president.
- Proposing to the president: If the bill passes on the floor, the senator will send it to the President. This is the final state for the senator. Whether or not the bill passes, the Senator will leave the floor.

The senators are not single-minded in their attempt to pass a bill. There are other activities they can engage in during the operation of this simulation.

- Be polled: At any time, a senator may be polled by another senator. This does not trigger a change in state, it is just an action that returns a yes or no response. The polled senator has a basic level of openmindedness. That level is raised or lowered by a number of factors including political party, committee membership, whether the bill is relevant to their committee, the trustworthiness of the polling senator, whether the bill is relevant to their interests as a member of a certain party, and the current level of support for the bill.
- Engaging in a scandal: The senator can bribe a colleague for their vote. This has a potentially large payoff, but also carries a high level of risk. If they succeed, they gain a large boost to their support. However, their likelihood of being caught goes up. If their colleague declines the offer, they will expose a scandalous senator. Being caught causes the current support level to fall to zero and a loss in the permanent trust level of the senator.
- Investigating a colleague: At times, a senator might become suspicious of a rival, or they might be looking for something to hold against them. They will investigate, and if they succeed, they will expose a colleague embroiled in scandals.
- Calling for a filibuster: The filibuster is a famous delay tactic employed by a party against their rivals. A senator can call for a filibuster if one party carries over 75% of the bills passed that day (note: this is how this system works, the process is more complex in the real senate). All activities stop, and all of the senators go into a suspended state. While in a suspended state, senators of the party that is not filibustering will try to call for cloture. Cloture requires sixty votes to break. Senators of the filibustering party will also vote for cloture if the pressure level grows too high. The goal of this is to prevent a dominating party from passing additional bills.

Senators will continue working to pass a bill until the senate closes for the day or until their bill reaches the President's office.

4.2 The President

Within this modeling system, there exists an agent type called the *Oracle*. The Oracle is intended to be an author-

itative source, a type of reactive agent that sits there and returns decisions when given a query. While this simulation framework could ultimately have multiple types of Oracles, one key one is - The President.

The President renders the final decision on bills. The decision is reached using the same process as when a normal Senator is polled. The President has a base level of open-mindedness (which is higher than that of normal senators, because the President is less likely to veto a bill). This factor is raised or lowered by issues like political party of the senator, trustworthiness of the senator, and the level of support for the bill within the senate. Because the President does not belong to any committees, they have fewer modifiers on their openmindedness level.

The President also reports three scores when the simulation is complete. These include the percentage of bills passed by Democrats, percentage passed by Republicans, and a final simulation score. This final score is the number of bills passed divided by the number of senators (as each senator may potentially pass one bill).

Oracle agents are intended to not only score the output of the system, but to use the statistics recorded by the Historian to bias the system towards jumping to *better* transitions. A subtype of President called PresidentKEYS has been implemented that does this. The learning section will elaborate further on the specific learning mechanisms.

4.3 The Historian

The Historian is a reactive agent used within the simulation as a log of events. It sits there and waits for input from the Senators or President. All of the actions enumerated above for the Senator are modeled as transitions within the system. There are a total of 28 transitions that can be recorded by the Historian.

Some of the events include:

- 1 Gathering support;
- 2 Presenting to committee;
- 3 Voting in committee;
- 4 Presenting to the floor;
- 5 Voting on the floor;
- 6 Committing a scandal;
- 7 Calling for a filibuster;
- 8 Suspended for the filibuster;
- 9 Investigating a colleague;
- 10 Caught by the FBI;
- 11 Presenting to the President;
- 12 Bill defeated on the floor.

Some of these actions can be reached from multiple states. Thus, the Historian logs these events by noting state-to-state transitions. When a log message is sent to it, it records it in a dictionary of (*event, times*) pairs. When the simulation terminates, the Historian will report the final number of times that every event occurred, as well as statistical information like the number of senators, percentage of bills passed, and how many bills each party passed. The Historian keeps a history of past *logs* in an *archive*. These archives are accessed during the President's learning phase. The Historian also keeps track of multiple pieces of data during runtime. These pieces of data can be accessed by both the Senators and the President. Keeping with the notions of agent theory, these facts represent an agent's *beliefs* during the operation of the system.

5. LEARNING

The agents within the system are initially *naive* - given multiple options, they will choose one at random. Some of these options will help them; a Senator might choose to give a speech before calling for a vote, which might give them enough support to pass the bill. However, they might make an equally poor choice. For instance, they might try to call for a filibuster at a time when several other senators from their party are ready to present a bill. Thus, it is desirable to *intelligently guide* the behavior of these agents.

This can be done using techniques from the *treatment learning* field. The standard practice in data mining is to *classify*, to look at an object and make a guess at what category it belongs to. As new evidence is examined, these guesses are refined and improved. Treatment learning [14] focuses on a different goal. It does not try to determine *what is*, it tries to determine *what could be*. Classifiers take past evidence and use that to categorize new data. Treatment learners work in reverse. They take the classification of a piece of evidence and try to identify the factors that led to that classification. In the Actory framework, classifications are deduced by combining the score output by the President with the BORE filter elaborated on below. Treatment learners take those factors and produce a minimal treatment—a set of rules that, if imposed, will change the expected class distribution.

Stated formally, treatment learning is a form of minimal contrast-set association rule learning. The treatments contrast undesirable situations with the desirable ones (represented by weighted classes). Treatment learning, however, is different from other contrast-set methods like STUCCO [3] because of its focus on minimal theories.

The treatments output by these learners are based on the data logs accumulated by the Historian, and take the form of *(Transition, Value)* pairs. The exact number of pairs depends on the exact learner used. The values are rough percentages; i.e., the Senator should call for a vote after giving a speech 15% of the overall operating time. These values can be applied to subsequent rounds as *biases*.

When an agent is going to take an action, it looks at a list of possible transitions. The list of possibilities is accompanied by a parallel array of weights. Initially, all of these weights are equal. After applying the results of the treatment learner, certain actions may have a new probability of occurring. When deciding which action to take, this probability distribution is sorted and Knuth’s random sampling method [12] is used to make a decision.

5.1 KEYS2

The KEYS2 algorithm [9, 11] is based on the assumption that the behavior of a large system is determined by a very small number of *key* variables. It follows that by exploiting these keys, then the system will move towards solutions with *higher scores* and *lower variance*.

This notion of *keys* has been discovered and rediscovered many times by many researchers. Historically, finding the keys has seen to be a very hard task. For example, finding the keys is analogous to finding the *minimal environments* of DeKleer’s ATMS algorithm [7]. Formally, this *logical abduction*, which is an NP-hard task [5].

If a model contains keys then, by definition, those variables must appear in all solutions to that model. KEYS2, our method for finding the key variables, uses a Bayesian

sampling method. Once model outputs are scored by the President, then the key transitions are those with ranges that occur with very different frequencies outputs that are scored *high* and *low*. Therefore, we need not search directly for the keys rather, we just need to keep frequency counts on how often ranges appear in *best* or *rest* outputs.

KEYS2 observes the space of M transition within Actory over a series of “eras”. Initially, every action is taken with an equal probability. During each era, KEYS2 observes the score outputs of Actory and fixes the probability of an increasing number of transitions. During the first era, KEYS2 fixes one probability bias. During the second, it sets two more. It fixes three more during the third era, and so-on.

KEYS (and KEYS2), each era e generates a set of *(transition, bias)* pairings as follows:

- 1: *MaxTries* times repeat:
 - Actory is run with *Biases*[1...($e - 1$)] are biases from previous eras.
 - *Probabilty*(T) of taking transition T is equal to $\text{Biases}[T]$ or $1/(|T| - |\text{Biases}|) * (100 - \sigma \text{Biases})$ if no fixed bias exists.
 - $\text{Score} = |\text{BillsPassed}|/|\text{Senators}|$
- 2: The *MaxTries* scores are divided into $\beta\%$ “best” and remainder become “rest”.
- 3: The *input* mitigation values are then scored using BORE (described below).
- 4: The top ranked *(transition, bias)* pairs are fixed and stored in *Biases*[e].

The search moves to era $e + 1$ and repeats steps 1,2,3,4. This process stops when every mitigation has a setting. The exact settings for *MaxTries* and β must be set via engineering judgment. After some experimentation, we used *MaxTries* = 20 and $\beta = 20$.

KEYS ranks *(transition, bias)* pairs using a support-based Bayesian ranking measure. BORE [6] (short for “best or rest”) divides numeric scores seen over K runs and stores the top 20% in *best* and the remaining 80% scores in the set *rest* (the *best* set is computed by studying the delta of each score to the best score seen in any era). It then computes the probability that a pairing is found in *best* using Bayes theorem. The theorem uses evidence E and a prior probability $P(H)$ for hypothesis $H \in \{\text{best}, \text{rest}\}$, to calculate a posteriori probability $P(H|E) = P(E|H)P(H) / P(E)$. When applying the theorem, *likelihoods* are computed from observed frequencies. These likelihoods (called “like” below) are then normalized to create probabilities. This normalization cancels out $P(E)$ in Bayes theorem. For example, after $K = 10,000$ runs are divided into 1,000 *best* solutions and 9,000 *rest*, the value *mitigation31 = false* might appear 10 times in the *best* solutions, but only 5 times in the *rest*. Hence:

$$\begin{aligned}
E &= (\text{mitigation31} = \text{false}) \\
P(\text{best}) &= 1000/10000 = 0.1 \\
P(\text{rest}) &= 9000/10000 = 0.9 \\
\text{freq}(E|\text{best}) &= 10/1000 = 0.01 \\
\text{freq}(E|\text{rest}) &= 5/9000 = 0.00056 \\
\text{like}(\text{best}|E) &= \text{freq}(E|\text{best}) \cdot P(\text{best}) = 0.001 \\
\text{like}(\text{rest}|E) &= \text{freq}(E|\text{rest}) \cdot P(\text{rest}) = 0.000504 \\
P(\text{best}|E) &= \frac{\text{like}(\text{best}|E)}{\text{like}(\text{best}|E) + \text{like}(\text{rest}|E)} = 0.66 \quad (1)
\end{aligned}$$

Previously [6], we have found that Bayes theorem is a poor ranking heuristic since it is easily distracted by low frequency evidence. To avoid this problem, we augment Equation 1 with a support term. Support should *increase* as the frequency of a value *increases*, i.e. $like(best|E)$ is a valid support measure. Hence, step 3 of our greedy search ranks values via

$$P(best|E) * support(best|E) = \frac{like(best|E)^2}{like(best|E) + like(rest|E)} \quad (2)$$

The set of scores calculated by BORE are sorted, and the *era* (*transition*, *bias*) pairs with the highest scores are fixed in the *Biases* array. These biases are used to guide which transitions are taken in subsequent *eras*.

6. EXPERIMENT

(To be added in future deliverable)

7. RESULTS

(To be added in future deliverable)

8. CONCLUSIONS AND FUTURE WORK

(To be added in future deliverable)

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