Research and Development Process

From here, we will focus on the discussion of research and development process. It will be divided into three different parts in order to help with understanding and reimplementation of the simulation model. Firstly, we will provide the general description related to the current model, including the interpretation of invention process and research process according to different areas and satisfaction level in certain business setting (more details will be talked about in the later section). Secondly, we will talk about the different mappings, how a grid model search works, what a column stands for, and what a row stands for in the grid model, which is the percolation model that we talked about in the beginning of this paper. After providing with the basic understanding of the model, we will talk about the pseudo code in order to help with the reimplementation of the search process. Lastly, according to different implementation for different strategies, we will talk about some implications based on the theoretical background related to different business settings and strategies.

Overview of Business Settings and R&D Process

The main goal of the current simulation model is to apply the different strategies and find out the effect on different business settings. The resource allocation will be generated randomly. Therefore, there will be a very low possibility that two different business setting will have the same resource allocation map. Different sites in a resource map will also have different research obstacle as well, which means if we need to discover and generate revenue from this site, we have to spend certain amount of monetary effort. For different agents or company project managers, R&D process means find innovation sites and revenue with certain amount of monetary effort to overcome the research expenditures.

In different business settings, there will be different number of innovation and research areas, which does not need to be specified, since we only care about the amount of revenue that can be generated. According to different areas, as a company search agent or company project manager, there will be different level of satisfaction level as well. Compared with the real life, when agents or company project managers start innovation process on a certain area, for example, car industry, they will have their own satisfactory criteria. If the current development level reaches the satisfaction level, it might be a better idea, agents stop at the current level and reached out to the other areas to spend extra time on the other areas.

R&D process contains two different parts. The first one is the research process. It mainly corresponds to finding the candidate site for the future development stage. According to the different search strategies, the research stage process slightly different. All of these different strategies are to simulate the possible research process compared with the real-life company level innovation process. We will cover several different strategies in the following section. The second stage is the development stage. Based on the provided candidate sites, the simulation process will process to overcome the research obstacle as mentioned above.

Overview of Mappings

We will talk about the simulation environment, which is a lattice in this section, such as (figure) following. The simulation process is implemented in a lattice model. Within the lattice model, different grids stand for different innovation sites. Therefore, all these grids are created with different site type, site stage, and a resistance value that needs to be overcame to advance site into next site stage.

In the lattice model, columns and rows have their own special meaning for the simulation process. Different columns represent different development area, for example, if a company has five different development plans, such as car industry, IT technology, agriculture, real estate, and medical area, there should be fiver columns in the current lattice model, and different columns stand for different categories. Different rows stand for different technology development level, or satisfaction level. During the simulation process, it is expected that whole process will always look for a cite with higher satisfaction level.

More specifically, in order to help with compute the generated revenue, there are three site types. When there is no innovation possibility in one site, this particular site should be “Not Feasible”. In contrast, there will be another site type, which is “Feasible”. The lattice model uses percolation probability of q to indicate if the site is feasible or not. If the site is feasible, there still should be two different types to differentiate the feasible sites, such as feasible non-revenue generator and feasible revenue generator. From revenue generator, model can retrieve certain amount of money from R&D process for the future use. If the site is identified as non-revenue generator, there will be revenue generated after R&D process, which means a certain amount of money is been wasted. In order to differentiate between “revenue generator” and “non-revenue generator”, revenue generator probability “p” is used.

In addition to site type, all sites also have other properties in the simulation process, which are site attributes. Site attribute includes site resistance value, state perceived the company, and revenue. In order to discover the feasibility and retrieve revenue from a site, simulation needs to put on certain amount of monetary resource to overcome the resistance value. Before the R&D process finishes on a particular site, the site type should be hidden from simulation, which is “Hidden” state, and we used “-1” to represent this hidden state. Once simulation finds out the actual site type, actual site type is assigned into “state perceived by the company”. Similar to site type, there will be three different state perceived by company. “Not feasible” means simulation finds out that there is no innovation possibility. “Feasible” means simulation finds out that there is a possibility that there will be an innovation. “Viable” means simulation actually finds the innovation.

Site revenue is another important site attribute. If simulation finds out the site is “Not Feasible”, it will not proceed to check whether there is revenue in this site. If simulation finds out the site is “feasible”, revenue will be generated. If there is a certain amount of revenue generated, this site is perceived by simulation as “Revenue generator”, and the actual generated revenue is distributed with a preset mean and standard deviation. If the revenue is zero, this means the current site is a feasible site, but not revenue generator.

We will talk about some information related to R&D Process Dynamics. In order to process R&D, no matter what the site type is, there will be an amount of resource draw from a budget. There are two separate process in the main body of R&D process. The first one is “exploration”. With enough monetary effort, the resistance of the site will be decreased under zero. Then simulation can find out the actual site type. If the actual site type is feasible, which can be either a non-revenue generator or revenue generator. During the second stage, which is “exploitation”, simulation turn feasible sites into state viable to retrieve resource.

Pseudo code according to different strategies

In order to help with re-implement the model, we will talk about how computer algorithm works here with demonstration of pseudo code of different strategies. As the original code for this paper, a script was written with Python 2.7 and necessary packages are listed later. The lattice structure is implemented as Numpy matrices. Therefore, site type, site state, revenue, and site resistance value is put into the matrices form. In order to simulate different strategies, the script accepts some user inputs, which are listed in the following table

(will be formulated into the table form)

Percolation Probability (q) Initial Budget per column (b\_initial)

Number of Columns (n) Budget Percent for R&D (b%)

Search Radius (r) Minimum Effort per Column (E\_min)

Resistance Distribution (R\_mean, R\_stand) Number of Time Periods (t\_max)

Strategy (ALL, UD, LR) Revenue Distribution (p\_mean, p\_stand)

Number of Simulation Runs(num\_runs) Concurrence (True or False)

Check Height (True or False)

These parameters can be varied to simulate different business settings, or resource mappings more precisely. From different combinations of these parameters, current model can simulate different resource mappings. The script will continue to process until all resource ran out. The goal is to do the experiment with different strategies according to different user input in order to find out the relative performance of different strategies.

We will be talking about the initialization matrices first. Because of the requirement from simulation process, it is necessary to have three different matrices.

1. Creates three matrices with n columns and r+1 rows
   1. S – Matrix of site type: Initialize site value to 0 (non-feasible) or 1 (feasible) with percolation probability of q. Then initialize the value of revenue generator, which is 1 (feasible but not revenue generator) and 2 (feasible and revenue generator).
   2. R – Matrix of site resistance value: Initialize value with a lognormal distribution with mean equals to R\_mean, standard deviation equals to R\_stand.
   3. L – Matrix of the site state perceived by company: Initialize sites value equals to -1 (hidden state). In order to ensure that the simulation process will not end in the beginning, we change some sites state perceived by company, which with state type of “1”, to “2” with uniform distribution (0,1) and probability of 0.5.
2. Initialize BPF values
   1. BPF serves as the starting search point in every time period. BPF stands for “best practice frontier”. It is calculated as following:

where “j” stands for column number, “i” stands for row number. Therefore, BPF value is the highest row value of a particular column where the site state perceived by company is “2”. If there is no BPF in one column, the corresponding BPF value of the column will be -1. Since all R&D process will start around BPF sites, it is necessary to have some sites with state perceived by company equals to “2” in the beginning row.

* 1. Initialize the total budget: B = b\_initial \* n
  2. Initialize the binary bankruptcy variable (0 – No, 1 – Yes). In the beginning of the simulation, the bankruptcy should be 0 for all columns.

From here, we will be talking about the script implementation according to different strategies. In order to differentiate the functionality of different proposed strategies, we separated strategies into two categories. The first one will be searching direction strategies. The second one will be the search plan strategies.

1. According to user concurrence development check, which is the “Concur” variable
   1. If Concur equals to “True”:

With given BPF list from the previous time step, the model should generate a sequence of column index, which starts from the given BPF column index. Then the script should check whether the BPF in the corresponding column from the generated sequence is greater or equal to zero, since if there is no BPF, we keep the BPF of the column to be “-1”.

If the BPF is valid:

Script should perform the search, and record the necessary information for the future R&D process, which will be talked about next step.

1. According to user only highest BPF site check requirement, which is the “check\_height” variable.
   1. If “check\_height” equals to “True”:

Randomly generated a sequence of column index same as above. Then find out the column with max BPF value. Only perform search on this column.

1. Search for the matrix coordinates around the BPF sites. We will implement all of these searching direction strategies here.

* “ALL” strands for diamond searching strategy. With given BPF sites in all of these columns, perform searching around BPF sites with radius of r like the graph following:

The searching column is from col-r to col+r+1, where col is the column coordinate of the BPF site. As moving from left to right, the searching row range should be from –var to var+1, where var is a helper variable to compute the searching range, and it is compute as , where “i” is the corresponding column index from col-r to col+r+1. Then record all hidden sites coordinates for the future R&D process, and the number of columns that need to be researched. Tips: when implemented the search script, it is necessary to take care of the boundary condition. For example, it is expected to take the maximum value between 0 and searching column number in the left boundary of resource mapping, and minimum value between maximum boundary index and searching column number in the right boundary index.

* “LR” stands for left-right searching strategy. With given BPF sites in all of these columns, perform searching around BPF sites with range of r like the graph following:

In this case, we only take care of the searching from left to right around the given BPF. It is also necessary to take care of the special case in resource mapping boundary.

* “UD” stands for up-down searching strategy. With given BPF sites in all of these columns, perform searching around BPF sites with range of r like the graph following:

In this case, we only take care of the searching from bottom to top around the given BPF site. Similar to “LR”.

1. Determine the necessary monetary effort for the R&D process.
   1. According to the number of columns, and list of column index from the third step, script should assign available budget into these columns. Then around every BPF site, script should compute the budget can be assigned into each hidden site.

If the corresponding “Resistance” value of the site becomes negative, which means there is enough resource put into the site to complete the “exploitation” as mentioned in the previous section, script should assign the site type value into the state perceived by company. If the state is “1”, then record the coordinates.

1. With the result from the R&D process, then the script should check whether these sites can be changed into “2” by checking the corresponding state type.

If the state type is “2”, then change the state perceived by company to “2”, and record the coordinates into a list, and record column index in a separate list.

1. If the list of coordinates of state “2” is not empty, then script should perform another search around all of these sites in a cross pattern. If any of these sites has state perceived by company is “1”, change the state perceived by company to 2, and record the site coordinates and column index.
2. Repeat step 2 to 6 until script runs all of these columns (column order should be randomized)
3. According to the list of coordinates from the previous steps, script should compute the actual revenue generated from the current time step.
4. Update BPF list
5. Update total budget available. If user input “shared” is True:

Calculate the total budget from every column, then assigned budget into every column evenly.

1. Check the bankruptcy, if bankruptcy happened:

then end the script

else: let script continue to run until bankruptcy or reached the maximum time step.

(it’s necessary to add rows into the matrices for the future time steps, therefore, if the maximum row index reached, and it does not reach the max time step and no bankruptcy, script should add rows and initialize the site state, type, resistance value, and revenue, until the number of rows equals to max(BPF) + r.)

Strategy Implication

We have talked about the implementation of the actual script. In this section, we will cover some implications related to different strategies. As mentioned above, there are two main categories of strategies. The first one is the search direction strategy, which includes “ALL” search, “LR” search, and “UD” search. The second one is the search plan strategy, which includes “shared budget” feature, “concurrence” feature, and “highest BPF only” feature.

* Search direction strategy

1. “ALL” search – Diamond Search Strategy

The main purpose of diamond search is to make a more sophisticated decision. Based on diamond search, agents are allowed to switch between different disciplinary, and able to move forward to next technology level. When agents start search process around the BPF site, if he received some information from his company or his colleague, and he was notified that there are some other innovation opportunities that have better pay back, he will think about spending time and resource on the other disciplinary. Meanwhile, agent can also choose to put effort in advance to higher technology level, if he can find the future innovation opportunity, which means that he can potentially have a future innovation opportunity. Intuitively, since there are a lot of choice for agent to select with diamond search strategy, it is expected to be one of the most profitable strategies. With diamond search strategy, agent would like to think about more scenario at each innovation starting point, because he doesn’t want to lose any opportunity to gain profit. However, it is also expected that agent will spend more time during research and development process, since he spent more time in thinking about more options. Depends on company needs, if companies give agent more time, he can spend extra time in making a stricter decision. If companies want agents to provide them feedback within a short time period, agent would like to find some other strategies to save more time.

Diamond search is supposed to fit into any kind of scenario generally. If the resource is accumulated along some disciplinary (columns) or some technology development level (rows), diamond search strategy is inefficient compared with other strategies. It might end up with a deadlock with even a lot of resource left. It might take more expected time to find a candidate site. In real life company innovation, agent might spend much more time to process innovation process with highly skewed resource map.

1. “LR” search – Left-Right Search Strategy (Needs to discuss about the implication with Prof. Wang)

The main purpose of this search strategy is to avoid spending time on some technology development levels that don’t produce desired revenue or even no revenue. In this scenario, some of technology development level for all or several disciplinary have more potential to produce more revenue. Compared with the real company innovation period, agents or their companies are informed that there are opportunities that they can find a huge amount of revenue without seeking a chance for technology development. For example, as the most popular sale strategy, most of high tech companies would like to release their products around a certain period of time in a year.

1. “UD” search – Up-Down Search Strategy (Needs to discuss about the implication with Prof. Wang)

Up-down search strategy is supposed to fit into disciplinary high skewed scenario. Up-down search strategy should act more efficient for the particular scenario. For technology development level highly skewed scenario, it might end up with a deadlock pretty soon, because some of these disciplinary might looks like bad in the beginning, therefore the starting point of these disciplinary might be ignored in beginning, and up-down search strategy does not have the ability to switch between disciplinary generally. Because of the specific setting of this strategy, when agent have the general resource allocation setting, such as the scenario is neither row skewed nor column skewed, it might lose a lot of innovation opportunity with this strategy.

* Search Plan Strategy

1. Shared Budget Feature

Different from the different searching direction, as an overall searching strategy plan, shared budget feaure should be able to fit into different scenario. It can help with diversify the simulation risk. More precisely, agents might be able to receive more revenue, and avoid losing a lot of resource in one particular disciplinary or at one technology development level. However, it might perform comparatively bad in some particular cases. For example, since simulation process will allocate resource again in the beginning of every time step, there is a chance that some disciplinary that performed bad in the several previous rounds still receive same amount of resource as other disciplinary do. It is expected that there will be a huge amount of money wasted.

1. Concurrent Innovation Feature & Highest BPF Site Only Feature

We will be talking about Concurrent Innovation Feature and highest BPF site only feature together, since the way they produce the randomly generated column list are same. For concurrent innovation feature, since there are more searching sites in one searching time period, it is expected to diversify the simulation result. More searching sites can cost more resource every searching time period. However, there is no guarantee that simulation process can find more resource.

Based on concurrent innovation strategy, we actually utilize the same list as used in the concurrent innovation feature. If agent is only looking for the highest technology level, after the list BPF sites randomly generated, only the BPF site with highest BPF height, which stands for highest technology level, will be put into candidate list. There is apparently a tradeoff between more innovation area or efficient development. It can help with saving time and resource in research and development stage. However, it is also possible that agent will lose a lot of potential revenue generator.