Utrecht University

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Artificial Intelligence Master

Fishery village with values

Simulating agents who make decisions based on Schwartz values

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Abstract

Many agent-based simulations that incorporate a decision system based on values, only use the Schwartz value theory in a minimalistic way. This thesis shows how a value framework can be implemented in an agent-based simulation, to create a more complex social system. The simulation combines a social, economical and ecological system, in the context of an Icelandic fishery village. The implementation will be tested with hypotheses, that discuss contemporary relevant themes. On one side the depletion of the fish population due to overfishing, on the other side the migration caused by removing elements in the village. By changing the value distribution, and the interpretation of the real world through the model, interesting results emerge. These results were analyzed, giving interesting insight on strengths and weaknesses of the model. In comparison with more simplistic models, this model allows for an agent to satisfy its most important value through for example his job, while satisfying other values during leisure time activities. Another merit is the possibility to create short-term oriented or long-term oriented agents, by changing the perspectives off the agents. The model does not contain norms or goals, posing some limitation, e.g. agents would deplete their money, removing their possibility to satisfy their values.

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Part I

Background

Chapter 1

Introduction

In the past many Agent-Based Models (ABM)s focused on small aspects of human behavior. In most cases implementing only one complex system, but as the possibilities of the computer grew, more complex ABMs became possible. There are quite a few ABMs that incorporate multiple systems, and become for example socio-ecological or socio-economical (Steinworth et al. [23], Akopov et al. [1]). Yet many of these simulations have a relatively simple social system. Extending the social system requires agents to have a more intelligent decision system, which explains human behavior better. To achieve this the Schwartz [20] values can be used, as they guide selection and are part of human decision making. When making a choice between a set of actions, humans tend to take into account what they value. For example when buying a new car, person A chooses a diesel car because it has a large action radius, which makes it more convenient and thus valuing *hedonism* (pleasure, enjoyment in life). However person B buys an electric car since it uses cleaner energy which is better for the environment and thus valuing *universalism* (equality, unity with nature).

There are a number of ABMs that already use part of the value theory [2, 14, 19, 4, 10]. In Andrews et al. [2] the residents of buildings are given a specific stereotype, this stereotype is defined by the Schwartz values. Dechesne et al. [4] describes an agent based simulation where values, norms and culture are defined and implemented. Here the interplay between those concepts, is tested with regards to non smoking laws. Heidari and Dignum [10] model a rural Icelandic fishery village, with agents having values. The simulation combines an ecological system (fishes and fish reproduction), an economic system (jobs, market and a factory) and a social system (residents, abstract value theory) Heidari [12]. Some Schwartz values are implemented however these values influence the agent's decision making process directly, with little deliberation being made. In general the current ABMs use the Schwartz value theory in a minimalistic way.

The thesis of van der Weide [25] describes a logical framework for deliberation, using Schwartz values. It denotes value trees which put abstract values in context, by connecting Schwartz values with actions through perspectives. As example, a power valuing agent applies for a CEO job of a company. Because of the perspective that being a CEO has authority over people, and authority is good for power. The value trees can be used to compare different outcomes and choose the best action. However the thesis does not include a framework for the compatibility and conflicting relations as described in Schwartz [20]. Some values are compatible with each other. For example the values universalism and benevolence, as they both are concerned with enhancement of others and transcendence of selfish interests Schwartz [20]. This means a person that values universalism should also value benevolence until some degree and vise versa. The relation models opposite values as conflicting. For example universalism and benevolence, versus achievement and power: acceptance of others as equals and concern for their welfare interferes, against the pursuit of one's own relative success and dominance over others. Together with S. Heidari, we will combine the work of Schwartz [20] and van der Weide [25] to create a framework for value based agents Heidari et al. [11].

The context of the ABM will be a small fishery village as is the case in the original fishery simulation made by Heidari [12]. As part of the literature review, the simulation will be analyzed to see what forms of value based decisions this simulation allows for. Using this knowledge to build further and to create a simulation with a more advanced social system, that gives ground to the perspectives needed for the value framework. To add social status creates in addition to a physical aspect, also a social aspect for each action. This can create interesting dynamics between the social system and the economical system. For example, housing, where from a social status perspective it would be good to have the biggest house, but from the economical it would be too expensive and thus not available. This mechanic of social status will be based on work of Petruzzi et al. [16]. An important factor in a person's social status is the job status, where agents with leading functions usually get higher status than lower educated workers Hollingshead et al. [13]. However, this does not directly apply for a traditional fishery village, where the work of fishers is seen as highly prestigious Bjarnason and Thorlindsson [3].

With a fishery village ABM, containing social, economical and ecological systems, it would be interesting to look at contemporary phenomena and the importance of values. Overfishing is currently a serious problem Steinworth et al. [23], as such, governments try to impose policies but the effects are marginal and usually good from one perspective but bad from other perspectives Symes and Phillipson [24]. Especially the smaller fishery villages suffer from the decline of the fish population and introduction of policies Einarsson [6] as their main income is the fishery. Also the closing of a factory within the village can endanger the village existence Skaptadottir [22]. These problems can lead to migration of residents, especially the youth, which could empty out villages in a few decades Bjarnason and Thorlindsson [3]. Based on these phenomena the following research questions are created.

1. What are the influences of different distributions of Schwartz values on a fishery village simulation with regards to its sustainability?
2. What are the influences of different distributions of Schwartz values on a fishery village simulation with regards to its migration of the population?

To answer these research questions, specific hypotheses have been created. Since the fishery village is highly dependent on the fishery and thus the fish population. One of the hypotheses states that a power oriented fishery village will deplete the fish population. This is based on the idea that power valuing agents will perform actions increasing their wealth and resource control, that can deplete the fish population. The other hypothesis focuses on migration, when elements are removed from the village, as each element has its own role in the community. Testing these hypotheses will show the strength and weaknesses of using value based agents in a simulation. Those insights are used in the discussion to evaluate the value based approach in general.

This chapter showed the introduction, and is part of the background. part which serves as a literature review and consists of three chapters. In the next chapter social aspects are discussed which serve as a basis for the social system. The chapter consists of the Schwartz theory, value trees and social status. The third chapter contains analysis of the original simulation made by Heidari [12] and shows possible value trees for this simulation. The methods part consists of chapter four to seven. The fourth chapter proposes the use of an ABM, as method of conducting experiments, and describes the development and design choices of this ABM. The fifth chapter describes the value framework, made with S. Heidari that is used as a decision system for agents Heidari et al. [11]. The sixth chapter describes the simulation in full detail using an Overview, Design concepts and Details (ODD) protocol. The seventh chapter puts forward hypotheses, derived from sociological literature and the context of the simulation. The outcome part consists of results, discussion and conclusion, i.e. chapters eight to ten. The results chapter tests the hypotheses, analyses and discusses the results regarding the hypotheses. The ninth section gives a general discussion, putting forward the strength and weaknesses of this approach, and showing possibilities for future work. The tenth chapter concludes on the thesis as a whole.

Chapter 2

Social aspects

This chapter describes the social aspects used in this thesis. Starting with the Schwartz value theory, which states that every human has ten values, that influence long term decision making. In the next section the work of van der Weide [25] will be explained, who made a logical formalization on value based decision, using value trees. The third section describes social status, to be used as enrichment of the social system in an ABM

2.1 Schwartz theory

We as humans can adhere to numerous values; beauty, peace, creativity, wisdom, etc. The list is almost infinite, as one could bring up any concept and add it to this list. This makes it difficult to get a formal grasp on it. However psychological and sociological research has made this unbounded list into something more concrete (Rokeach [17], Schwartz [20]). According to Schwartz [20], values have the following features.

Value	**Definition**
Universalism	understanding, appreciation, tolerance, and protection for the welfare of all people and nature
Benevolence	preserving and enhancing the welfare of those with whom one is in frequent personal contact (the 'in-group')
Conformity	restraint of actions, inclinations, and impulses likely to upset or harm others and violate social expectations or norms
Tradition	respect, commitment, and acceptance of the customs and ideas that one's culture or religion provides
Security	safety, harmony, and stability of society, of relationships, and of self
Power	social status and prestige, control or dominance over people and resources
Achievement	personal success through demonstrating competence according to social standards
Hedonism	pleasure or sensuous gratification for oneself
Stimulation	excitement, novelty, and challenge in life
Self-direction	independent thought and action; choosing, creating and exploring

Table 2.1: A brief definition of the Schwartz' values by Heidari and Dignum [10]

Values (1) are concepts or beliefs, (2) pertain to desirable end states or behaviors, (3) transcend specific situations, (4) guide selection or evaluations of behavior and events, and (5) are ordered by relative importance. The values are placed in a structure by Schwartz, that consists of ten basic values (Table 2.1), unifying the countless values a human can have.

The values are related to each other, and this is depicted by Figure 2.1. The most abstract classification is formed by the four quadrants: openness to change, self-transcendence, conservation and self-enhancement. Quadrants opposite of each other are in conflict, being very open for change is not compatible with being very conservative. The same holds for a person who values self-enhancement, the improvement of oneself, who can not at the same time value self-transcendence, the improvement of others.

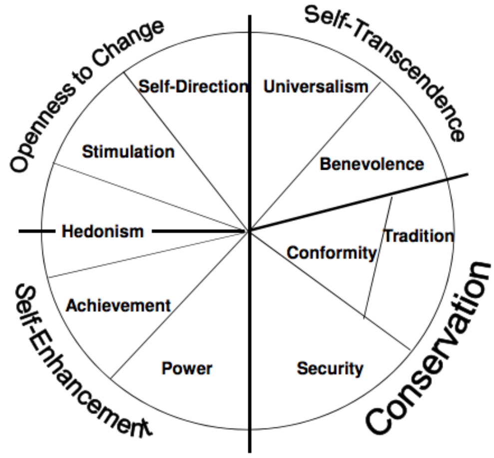


Figure 2.1: Schwartz ten values circle

The quadrants are filled by the Schwartz values in the following manner *openness to change*: part of hedonism, stimulation and self-direction; *self-transcendence*: universalism and benevolence; *conservation*: conformity, tradition and security; *self-enhancement:* power, achievement and a part of hedonism. Since the quadrants are related to each other, the values are also related to each other, by compatibility or conflicting relations Schwartz [21].

Compatibility relation

One constraint of the circular relation means, that values that are next to each other are positively related to each other. Having a high benevolence will usually mean that a person also has a high conformity, value since both contain devotion to one's in-group (Table 2.1). Conformity and tradition, both limit a person's own impulses to apply to the expectations of a group. Tradition and security, are both focusing on stability within society. Security and power, both restrain others for one's own control. Power and achievement, both focus on being better or having higher status than others. Achievement and hedonism, both focus on personal satisfaction. Hedonism and stimulation, are linked through finding personal pleasure. Stimulation and self-direction, promote novelty and change. Self-direction and universalism, both use one's own judge at perceiving and dealing with the world. Universalism and benevolence, both enhance relationships with others.

Conflicting relation

The other constraint is conflicting, i.e. when a value is on the opposite side of another value, e.g. security and self-direction. A high security value will mean that a person will be more risk averse, which leads to a low self-direction value. The conflicting relation is even more clear, when looking at the quadrants. Where openness to change is conflicting with conservation, and self-transcendence is conflicting with self-enhancement, as they are basically antonyms of each other. Valuing one would automatically lessen the amount of value for the opposite quadrant.

2.2 Value trees

The Schwartz value theory is however still too abstract, to directly implement in a simulation. As part of his thesis van der Weide [25] took the abstract value theory and created a formalism, that can connect actions with abstract values, through the use of perspectives. The thesis of van der Weide [25] originally uses expected outcomes as leave nodes of the value trees. However throughout this theses we will use a simplified version, where actions themselves are the leave nodes.

The term used is value tree, which is a tree starting with an abstract value as root node (Figure 2.2). The arrows connecting nodes are either, positively influencing denoted as a straight line, and negatively influencing denoted as a striped line. The perspectives are used to connect abstract values with actions. A perspective consists of the lines and concrete values, between the Schwartz values and actions. For power a concrete value could be wealth, which has a positive influence on power, but also authority or social recognition. Perspectives for hedonism, could be pleasure or enjoying life. Assume there is an agent that can perform the two actions in the figure. The work action is good for the agent's wealth and therefore power, but the agent does not like working, so it has a negative influence on pleasure and therefore on hedonism. The agent does like ice cream and this has a positive effect on pleasure, but it costs some money, which creates a negative influence on wealth.

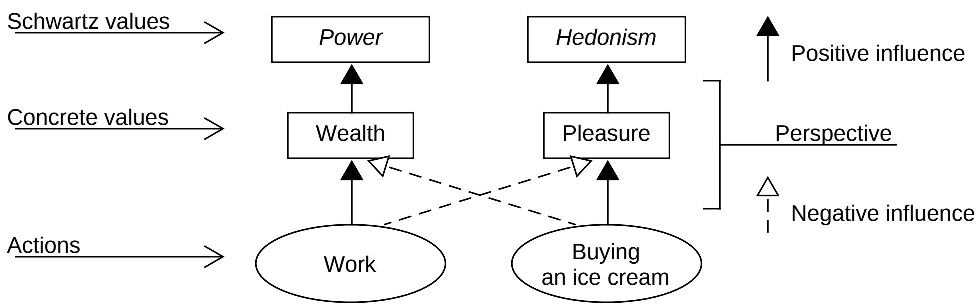


Figure 2.2: Simple value tree: work and ice cream

The agent can now make a decision, if its knows its value priority. When only considering the value tree, an agent valuing power more than hedonism (P > H) will perform work actions, but agents valuing hedonism more than power (H > P), will buy ice creams. Until they run out of money of course.

Value trees are thus an intuitive way of connecting actions to abstract values. They can easily be expanded to include more actions or values and open up the decision process of an individual agent, as an agent can tell why it took a specific action.

2.3 Social status

To be able to implement a social system actions, need to be connected to social status. Literature found on this topic consists on the four factor index by Hollingshead et al. [13]. In the paper social status is defined as being part of the job, education, sex and marital status. The different jobs are given a classification of status, according to their social status. The index tells that the highest status jobs are executives, proprietors of large businesses and mayor professionals. Looking at the fisher job it scores only a 3 out of 9 points, being one of the lowest possible jobs. This is in contrast with information about fishery villages where the job as fisher is usually seen as highly prestigious Bjarnason and Thorlindsson [3].

Chapter 3

Original value based simulation

This chapter describes the simulation by Heidari [12], made in Repast Symphony Java North et al. [15]. There are two papers that show the workings of the simulation. The first paper Heidari and Dignum [9] describes the influence of fishing on the ecology with different distributions of male, female or both male and female fishers. The second paper Heidari and Dignum [10] describes the complete simulation, and what behavior emerges with the population prioritizing different values. The decision process of the agents is value based but in a minimalistic way. Here we will analyze the current simulation, and show the agents with their parameters and actions. Then new possible value trees will be created, in order to see what the possibilities and short comings of the original simulation are. This serves as a basis for the simulation presented in chapter six.

3.1 Human agents

Status

A human agent has a number which represents its status (Table 3.1). From the age 0 to 18 a human is a child (status 1). From the age 18 to 71 the agent can be in one of the statuses: 2, 3, 4, 5a, 5b or 6. After the age of 70 the agent will be retired (status 0). The other job is a job not part of to the standard village jobs.

Nr.	Status	Nr.	Status
0	Retired	4	Fisher
1	Child	5_a	Factory worker low educated
2	University student	5_b	Factory worker high educated
3	Unemployed	6	Other job

Table 3.1: Agent status

Values

Within this simulation the abstract values are represented using the *stay inside the community value* (ISI) and the *survival intention* (SI). These values are the bottom line of an agent's decision making and influence some of the actions. A higher ISI (conservation) value, will make the agent more probable to look for jobs inside the community: a fisher, factory worker or unemployed. A low ISI (openness to change) value will increase the chance of going to university or get an 'other job'. The SI value will influence the fish catch. A high SI value (self-transcendence) will create a limit on personal fish catch, so the fish stocks will be preserved. A low SI value (self-enhancement) will decrease the influence of the catching limit, allowing the fisher to catch more. Here it becomes clear that values directly influence the actions.

Goals

All of the agents have the same goals available, which can be achieved by spending money. They do not have a specific effect on the agent or within the simulation. Thus new goals can be added by the modeler easily. Table 3.2 shows the available goals.

Nr.	Goal	Nr.	Goal
0	Buy bigger boat	3	Buy house in the village
1	Send kids to university	4	Buy high tech boat
2	Attending university	5	Buy a place for poor people

Table 3.2: Agent goals

3.2 Agent actions

Table 3.3 shows the actions, and their preconditions since not all actions are available at all times. The actions are described in greater detail in the following paragraphs. The functions and parameters mentioned, are contained in the `Human.java` class unless specified otherwise.

Actions	Preconditions
Search for a job or education	NOT (status = 0 OR status = 1)
Study	(status = 2)
Catch fish	(status = 4)
Work	(status = 5_a OR status = 5_b OR status = 6)
Give birth	NOT (status = 0 OR status = 1)
Invest in factory	
Complete a goal	Money >= goal cost

Table 3.3: Actions and their preconditions

Search for a job or education

The action *search for a job or education* uses the functions `reCalculateStatus()` and `selectJobToStayInSociety()`. The `reCalculateStatus()` function recalculates the status of an agent every tick. This is dependent on age, only when the age of an agent is between 17 and 70 the job status is adjusted. When the agent 'has a low income, fish stocks are low or with a general probability of 10%' it will search for a new job. It will either search for a job inside the community or outside. When the agent searches inside the community, the `selectJobToStayInSociety()` function, it will either become a fisher (status 4), factory worker (status 5a or status 5b) or unemployed (status 6). The agent will become a higher educated factory worker (status 5b) when it has studied at a university (status 2) and when there is a vacancy for a higher educated worker. When the agent searches outside the community, it will either be a university student (status 2) or the status 'other job' (status 6).

Action name	Relevant methods	Parameter influenced
Search for a job or education	`reCalculateStatus()` `selectJobToStayInSociety()`	`String status`

Study

When the agent is studying (status 2) the parameter `higherEducation` is set to true.

Action name	Relevant methods	Parameter influenced
Study	`reCalculateStatus()`	`Boolean higherEducation`

Catch fish

The agent is able to catch fish when it is a fisher (status 4). The method `catchFish()` is called every tick. The fisher finds the available fish on its patch, and runs the `decideAndHunt(..)` function. The `decideAndHunt(..)` function calculates the percentage of fish to catch, dependent on the SI value (higher SI more fish catch, lower SI less fish catch). After this it will select the fishes that lead to the highest profit, adds them to its inventory (`caughtWeight`) and then the fishes are removed from the simulation using the `die()` function (`Fish.java`). In the `step()` (`Factory.java class`) function, the factory buys all the fish from the fisher, and the fisher gets paid accordingly. The factory processes the fish and earns money using the `setProfit()` function, which increases the factory's profit value.

Action name	Relevant methods	Parameter influenced
Catch fish	`catchFish()`	`Fish.die() remove`
	`decideAndHunt(availableFish)`	`Double caughtWeight`
	`die() [Fish.java]`	`Double money`
	`step() [Factory.java]`	`Double profit [Factory.java]`
	`setProfit() [Factory.java]`	

Work

This action allows agents of status 5_a, 5_b or 6 to earn money. The higher educated factory workers earn the most money. The parameter that gets influenced by working is money.

Action name	Relevant methods	Parameter influenced
Work	`work()`	`Private double money`

Give birth

This action creates a new `Human` with age 0, thus it is a child (status 1). The probabilities of it being a man or a woman are both 0.5. This will add the child to the list and decrease the `numOfChildren` variable of the parent by 1. The `numOfChildren` is the desired number of more children.

Action name	Relevant methods	Parameter influenced
Give birth	`eachStepCalculation()`	`Create a new human (Woman or Man)`
		`List children`
		`int numOfChildren`

Invest in factory

The agent pays a percentage of its money to the factory, in every tick of the simulation. In the function `investInpulicGoods()`, this amount is calculated. Which is then applied in the `addDonation(double donation)` function of the `Factory.java class`. This function adds the investment of the agent, to the donation parameter in the `Factory.java class`. This donation variable is used when the factory has no profit anymore, if that happens the factory uses all of its donated money and adds the money to its profit.

Action name	Relevant methods	Parameter influenced
Invest in factory	`investInpublicGoods()`	`Double money)`
	`addDonation(donation)`	`Double donation [Factory.java]`
	`[Factory.java]`	`Double profit [Factory.java]`

Complete a goal

An agent picks a goal from the possible goals (Table 3.2) with `pickGoal()`. This is random in the current simulation. Every tick the `doesGoalSatisfied()` checks whether the agent has enough money to achieve the goal. If this is the case the agent will spend money, and the property of the goal will be added to the `achievedProperty` list. However as mentioned earlier, having completed a goal will not have an effect on the simulation, e.g. a bigger boat does not allow for better fish catch.

Action name	Relevant methods	Parameter influenced
Complete a goal	`doesGoalSatisfied()`	`Double money`
	`pickGoal()`	`List achievedProperty`

3.3 Value trees

With the actions and influenced parameters described we can create the possible value trees. The value trees serve as basis for the new simulation.

Stereotypes

To give insight in the possible value trees four stereotypical village residents are used, who are based on the four quadrants in the Schwartz value circle (figure 2.1). This has also been done in the designing buildings paper Andrews et al. [2], but their agents had stereotypes based on households. The four types are adolescent (openness to change), mother (self-transcendence), fisher (conservation) and manager (self-enhancement).

Fish catch: Universalism, power and security

This value tree (Figure 3.1) is created around the variable *fish caught*, with the action *catch more fish*. The same applies to *security* as in the previous tree, catching fish increases the income which increases *security*. The mother's perspective is negative on universalism, as she cares about sustaining the ecosystem, which is negatively influenced by catching more fish. The manager cares more about the *power* value and sees catching more fish positively, because of more control of the available resources, increasing its power.

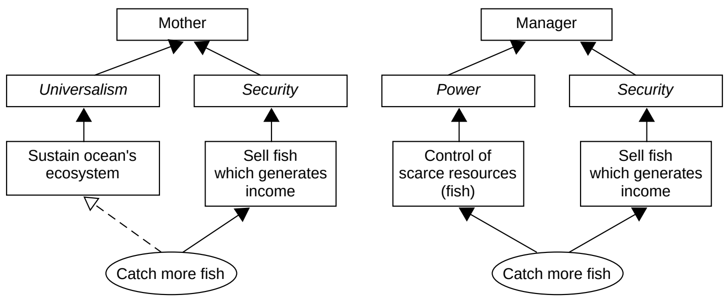


Figure 3.1: Catch fish value tree - Mother vs manager

Invest in factory: Tradition, self-direction and security

This value tree (Figure 3.2) uses the *invest in factory* action. The fisher's perspective is positive on investing in the factory, since this will allow the factory to survive, which both supports its way of life and keeping its job, this in turn positively influences respectively *tradition* and *security*. The adolescent could feel negatively when there is a forced amount that he has to pay, it would feel like a tax system. Therefore invest in factory has a negative influence on self-direction.

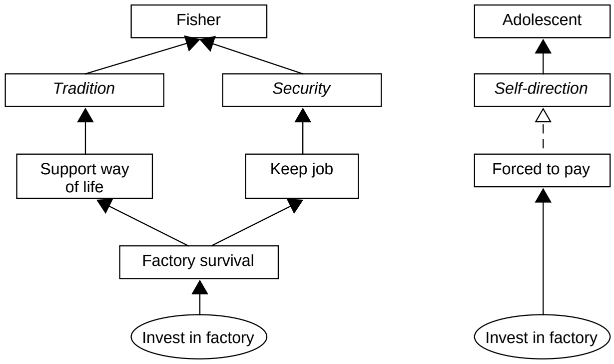


Figure 3.2: Invest value tree - Fisher vs adolescent

Occupation: Self-direction, tradition and security

This value tree (Figure 3.3) shows the influence of different jobs on the perspective of the adolescent and the fisher. Both agents see all the occupations (except for studying) as good for security, as it gives an income. However the fisher sees the traditional job, as supporting the village economy, which makes a traditional way of life possible. The adolescent will however, feel fixed to the fishing community with the *work inside community* occupations, this will negatively influence its freedom, which leads to a negative influence on the *self-direction* value.

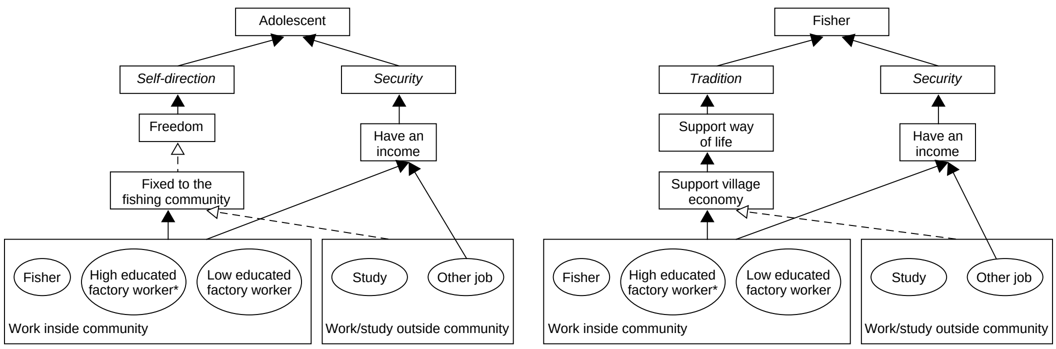


Figure 3.3: Occupation value tree - Adolescent vs fisher

Goals: Achievement

The achievement value tree (Figure 3.4) is build using possible actions and the goals described in Table 3.2. Even though the manager is based on the quadrant that has achievement, he is not the only one capably of having achievement values. Based on their personalities they have been given the appropriate actions. An adolescent values being free from the traditional village. The mother is supportive for the village and for others. The manager cares about freedom and getting the best paid job. The fisher cares about working as a fisher and living in the village.

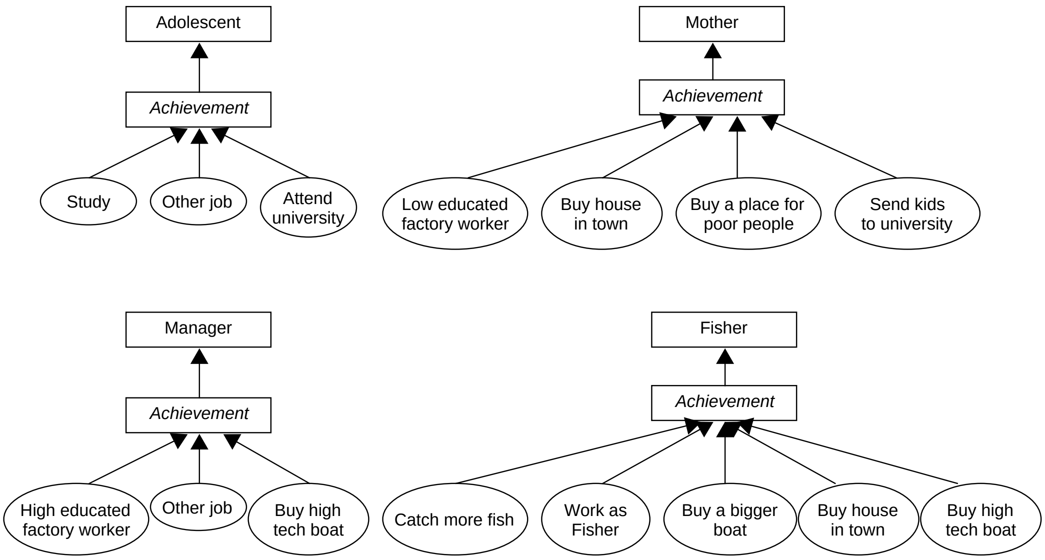


Figure 3.4: Achievement value tree - All perspectives

3.4 Overview

Looking at the value trees it seem that especially security, tradition, self-direction and achievement are very prominent. The values power and universalism are also represented but only in a few occasions. From this it would be interesting to pick values that are both conflicting and compatible with each other, to test the real potential of the framework.

Part II

Methods

Chapter 4

Simulation development

This chapter describes the development of the simulation by showing the design choices made. It gives an introduction leading to the value framework and Overview, Design concepts and Details protocol (ODD), which are chapter five and six respectively. The simulation will be an agent-based model (ABM) since this allows for heterogeneous populations and more complex behavior than other types of simulations. The other popular options are equation-based modeling or a cellular automata Romanowska [18]. The equation-based models see the population as homogeneous, which makes it unfit as method for a simulation, where agents have different values. The cellular automata does not allow for the complexity needed for a value based simulation.

The simulation is modeled using the KISS method Romanowska [18]. The KISS method, or "keep it simple, stupid", is a method where the basis of a simulation starts minimal and becomes gradually more complex, by implementing the necessary elements step by step. This is in contrast with the KIDS method, or "keep it descriptive, stupid", that tries to model all of the complexities at the start and removes unnecessary elements as the research progresses. The sections below describe the changes and implementation within each iteration. An iteration takes roughly three weeks in which development is done, results are analyzed and changes are discussed for the next iteration.

4.1 Iteration 1: Housing and basic social life

This simulation needed a more complex social system than the simulation described in the background section, to be able give content for the use of a Schwartz value framework. The first goal was to create basic social life within the fishery village. This consisted of housing, basic jobs, possibility of getting a relation, child birth, dying of old age and migration. The ticks of the simulation were on a yearly basis. It was decided to have a fixed number of houses, since in most Icelandic fishing villages the ground space is limited. One of the interesting results was, young couples would not be able to find a house and migrate out, since older agents occupied the available houses. Therefore an elderly care was added that could house the residents past a certain age.

4.2 Iteration 2: Extending jobs and economical system

In this iteration the economical side of the simulation has been extended. A number of institutes were created where agents can work. The fishery and fish processing factory are the economical core of a typical fishery village. The school, social care and elderly care are other important elements within the village where residents are dependent on. To provide the institutes with money, a village council has been created that receives funds from taxes. The tax payment is mandatory, thus a donation system has been added to allow agents for a voluntary payment. The donation system gives the options for agents to give extra support to the village or not. For the ecological system a minimalistic fish model has been added, that allows for easy analyzing. The ticks of the simulation are now on a monthly basis as yearly was not fine grained enough for job changing and getting salary. The getting child and aging steps stay at a yearly scale. Added a restriction that agents cannot get a relation with their siblings, to prevent a single family to become a population.

4.3 Iteration 3: Value framework and other institutes

Here the value framework is introduced, agents make decisions based on their values and the global value trees. The values chosen are *power*, *self-direction*, *universalism* and *tradition*, since these were frequent values (see chapter 3) and have both compatibility as conflicting relations. Values were originally drained each time an agent would choose a new job. But this would stop draining when an agent is keeping the job. This new system will eventually make an agent unsatisfied and makes it look for another job. The work outside the village job is added, to give the agents an option of work that does not provide for the village, since the taxes of this job do not go to the council. Working here is penalized, since this job does not provide tax for the village. The school outside allows children to go to school when there are not enough teachers, but this comes at an increased cost. The event hall is added as abstraction of leisure time activities, that allows agents to satisfy values apart from their job. The weekly tick is added for steps like attending the event hall and donation, for more opportunities of value satisfaction. Agents that migrate out are removed from the simulation because retaining them would make the outside world too complex, they also take their spouse and children under 18 with them.

4.4 Iteration 4: Negative influence and migration

The simulation could now generate an initialization run that saves the state of the simulation after running for a few decades. Housing with three different sizes allow agents to rehouse and get a bigger house when they get better jobs. The elderly care had to pay to much for the elderly, the amount was still linear since agents would die at a fixed age. Therefore a mortality function is added that increases the probability of dying when getting older. The council has two options of dividing money, spreading it equally across the institutes (power) and giving the poorest institute the most money (universalism). The social care now pays social benefit for agents that do not have a job. When moving to the elderly care, the elder gives the partner its house. Agents switch their job when they do not get paid enough.

The value framework now allows for actions to have a negative impact on a value. The framework now assigned a number to each value that indicated how well it would satisfy the values (negative number for negative impact). This number is then normalized and used as a probability for making a decision. Working without probabilities would require many logical rules and exceptions. The order of the value framework was changed to (1) drain values, (2) select work, (3) donate and (4) events. This was done to make sure the most important decisions are closer to the drain.

4.5 Iteration 5: Social status and fishing actions

Social status (decision making) has been added to give actions, in addition to a physical component, a social component. This social status gives interesting dynamics, since agents tend to buy a cheaper house, from the perspective of money. However they want a more expensive house from the perspective of social status. Social status also refined the decision process as actions that were the same from the perspective of value trees could have a different impact on the social status and agents could pick one of them according to their preference. Fishers now have different fishing actions with the corresponding value tree. The fishing action is placed after the select work action and before the donation action.

The tank level of agents is now at initialization the same as their threshold. Not doing this would lead to non value compliant behavior, at the start of the run since agents would not have their levels around their thresholds. The decision process at this point (1) filters actions based on values, (2) calculates the best action according to the values and social status, (3) take an action based on a probability.

4.6 Iteration 6: Happiness and values distribution

Happiness is defined for agents, this would influence whether agents migrate out and change their jobs. Migrating is not directly related to being homeless, since homeless persons do not necessarily migrate, especially if they are happy. But now it is related to an agent's happiness, and also dependents on the self-direction and tradition thresholds. If an agent is not happy for some time, it will move out of the village. Agents would swap working very frequently, since it is dependent on values. Work change is now dependent on being unhappy, which decreased the work swap frequency. The *fish less* action is the ecological responsible amount, in the past it would be just a fixed amount but this caused the fish population to deplete when there were many fishers, even though they performed only *fish less* actions. Now the *fish less* is limited based on the repopulation rate of the fishes and total amount of fishers, preventing overfishing when every fishers performs the action *fish less*. Elderly would migrate since they did not receive enough money from the elderly care (which hands out pension). By letting the elderly, that are in the elderly care, pay for their care, this problem was fixed.

The values would drop to quickly, they would drop within weeks not within months. Since values are supposed to make the more longterm decisions, the drain was changed to a lower amount. With the change in drain, some values would be updated too easily. To make the increasing of values more in line with the drain, the amount of increase decreases as the same value is satisfied multiple times within the same tick.

Chapter 5

Value framework

This chapter describes the formalization of the value framework that is used by agents to make value based decisions Heidari et al. [11]. This framework was created by Samaneh Heidari and me, with Dr. Frank Dignum as supervisor. The first section describes the formalization of the value framework, from our paper Heidari et al. [11]. The second section explains the addition of negatively influencing actions into the framework.

5.1 Original value framework

The Schwartz value theory is defined in sociology, but lacks the formalizations needed to be implementable. The thesis of van der Weide [25] defines a formalization that allow for value based decision, i.e. the values trees. The value framework described here Heidari et al. [11], gives the formalization of the compatibility and conflicting relations. These relations are explained in the literature section. It models all of the ten values (Figure 5.1) and uses the value trees from van der Weide [25], to model a value based decision maker.

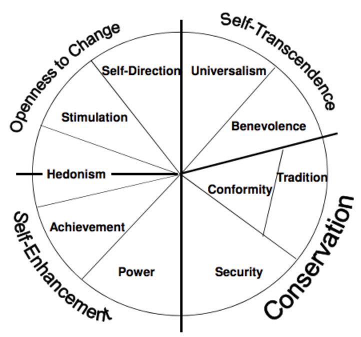


Figure 5.1: The Schwartz value circle

The model works with two sets, the set $Values = \{V_1, V_2, V_3, V_4, V_5, V_6, V_7, V_8, V_9, V_{10}\}$, where $V_1 =$ *Universalism*, $V_2 =$ *Self-direction*, $V_3 =$ *Stimulation*, $V_4 =$ *Hedonism*, $V_5 =$ *Achievement*, $V_6 =$ *Power*, $V_7 =$ *Security*, $V_8 =$ *Tradition*, $V_9 =$ *Conformity*, $V_{10} =$ *Benevolence*. And the second set that indicates how important values are for a person. It is defined for each $V_i \in Values$ as $Importance = [0, 100]$. Any member of $Values$ that is implemented has an $Importance$ value attached to it, defined in the function $\tau : Values \rightarrow Importance$. Here $\tau(V_i)$ gets the importance of value V_i. If $\tau(V_i) = 0$ then the value V_i is not playing a role for the agent, if $\tau(V_i) = 100$ then the agent will always try to satisfy value V_i.

Compatibility and conflicting relation

Schwartz has stated that the values are related to each other (Figure 5.1). Adjacent values have a compatibility relation, in which they have some overlapping features. When a person values a certain value, then the values adjacent will have an importance that is almost the same. For example the values *universalism* and *benevolence* that are both concerned with enhancement of others and transcendence of selfish interests Schwartz [20].

The following condition models that relation.

$$\text{Condition 1: } \forall i, j \in 1..10 \;:\; 0 \leqslant |\tau(V_\mathrm{i}) - \tau(V_\mathrm{j})| \leqslant m_{i,j}, where:$$

$$m_{i,j} = \begin{cases} |i-j| * c & \text{if } |i-j| \leqslant 5 \\ (10 - |i-j|) * c & \text{if } |i-j| > 5 \end{cases}$$

Here c is a constant real number between [1..100], the number 10 represents the total number of Schwartz values and 5 represent the total the number of Schwartz values divided by 2, since we want to measure until the opposite value in the circle (Figure 5.1). The c constant indicates the dependency among adjacent values, a lower c means a higher dependence. By default $c = 20$ since this represents a high dependence between direct adjacent values and a very low dependence, when there are more than 2 values between the compared values. But c can be adjusted according to the modelers preference.

The other relation property is that of a conflicting relation in which values on the opposite side of the circle conflict with each other. According to Schwartz an example of a conflicting relation is: universalism and benevolence versus achievement and power, because transcending to the welfare of others, limits the personal welfare. Condition 2 creates the conflicting constraint.

$$\text{Condition 2: } \begin{cases} \tau(V_i) > 50 & \text{if } \tau(V_j) = 0 \\ 100 - \frac{c}{2} \leqslant \tau(V_i) + \tau(V_j) \leqslant 100 + \frac{c}{2} & \text{if } \tau(V_j) \neq 0 \;\&\; \tau(V_i) \neq 0 \end{cases},$$

$$\text{where } j = (5+i)\%10.$$

The first part states that if $\tau(V_j)$ is not part of the model, then τ of the opposite value V_i should be high enough other wise V_i can be ignored. This ruled is used when there are other motivators like norms and motives, that decide on which action to take. When those are absent, this rule should be dropped. The second part states that the summation of two values should be between $100 - \frac{c}{2}$ and $100 + \frac{c}{2}$.

Decision system

With more importance for a value, an agent would perform more actions that are in line with that value and it would evade actions that are against that value. To model this behavior a decision system, based on a water tank model Dörner and Bamberg [5], has been created. The threshold indicates how important a value is to a person.

Each value ($V_i \in Values$) is represented by a water tank (Figure 5.2). Where each tank has the following parameters: fluid level λ_i where $0 \leq \lambda_i \leq 100$ to indicate how much the value is satisfied, priority $\tau(V_i)$ where $0 \leq \tau(V_i) \leq 100$ to indicate the

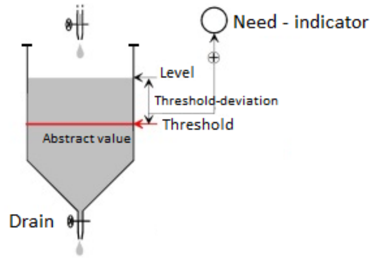


Figure 5.2: Water tank example, where abstract value is $V_i \in 1..10$, level is λ_i, threshold is $\tau(V_i)$ and the drain is defined by the modeler

importance of a value. The drain is set to a constant and should be drained every tick, so it can drain the tanks completely when an agent does not perform actions. To calculate which value should be filled at a given time the following equation is used:

$$\rho = -((\lambda_i - \tau(V_i))/\tau(V_i)) * 100$$

The value with the highest priority ρ, will be used to select an action from the available actions. It is important to note that the actions, should contain the action of 'not doing an action'. For example applying for a job, not doing an action would leave the agent as unemployed. Becoming unemployed can also have its own perspectives, and as such should be modeled as well. All the actions will be checked, but only the actions that are in line with the highest priority value are selected. When an action is performed that increases a certain value, then the filled level λ is updated with the following amount $(100 - \tau(V_i))$. This formula makes values with a higher threshold fill up slower, so they need more actions to be satisfied, thus the agents will perform actions for that value more frequently.

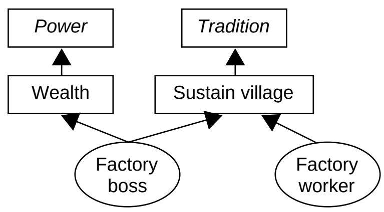


Figure 5.3: Example value tree showing how the action of being a Factory boss and Factory worker has influence on power and tradition.

The value trees are implemented by with Schwartz values as the root node of the tree (Figure 5.3). The concrete values, like wealth and sustain village in this example, are connected to the Schwartz values. The actions are leave nodes of the value trees, in this case the actions Factory boss and Factory worker. Both have a positive influence on sustain village, thus a positive influence on tradition. But only the Factory boss has a positive influence on wealth, and therefore power. In an agent that has a higher priority ρ for power than tradition (P ¿ T), the agent will select the Factory boss action when presented with both actions.

5.2 Framework enrichment with negative influence

The published framework is a good basis for using value based decisions in conceptual models, to avoid personal taste in modeling Schwartz values and having un-uniformed models. It increases the chance of re-usability of models in the future. However the current framework, does not consider negative influence of actions on values. In this chapter, the framework will be enriched and will contain more possibilities in defining the influence of actions. Together with S. Heidari, we defined the formulas for the negative influence on actions.

Value trees

In the original framework a factory boss would, positively influence wealth and therefore *power*. The factory worker action has no impact on wealth, to make a distinction between the jobs. However adding unemployed as possible job creates a problem, as now both factory worker and unemployed have no positive influence on the value tree of wealth, but the factory worker does earn money and the unemployed does not. Another option is to set the factory worker to have a positive influence on wealth, but this releases the distinction with factory boss, who gets paid much more than a factory worker.

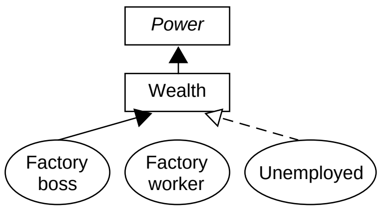


Figure 5.4: Example value tree containing basic positive and negative influences

With negatively influencing actions the factory worker can stay at neutral, while the unemployed would actually have a negative influence on wealth and therefore negative on *power* (Figure 5.4). When there are both a negative and positive influence on the same value, then they cancel each other out and should be removed from tree.

Increase and decrease of the filled level

The original framework uses an increase based on a linear formula (Figure 5.5). The updated framework works with a quadratic increase formula, as this gives a larger difference between increase of low thresholds and high thresholds. The updated formula for the increase amount is $(0.1 \cdot (100 - \tau))^2$ and leads to the curved line depicted in Figure 5.5. Previously an agent that would have 90 *power*, which is a very high amount, got an increase of 10. With only a few actions for that value it would be satisfied completely, with the updated formula the increase amount is 1.21. This amount is so low that the agent should perform actions for that value more often. With this adjustment we want to steer the framework to be more compatible with real world behavior. As a person with almost maximal power, should have a near constant drive to satisfy his power.

The decreasing amount should not be confused with the draining amount, which is a fixed amount of drain for each of the water tank. The decreasing amount is used when an action performs an action that has a negative influence on a value. The decreasing amount is calculated with the formula $(0.1 \cdot (\tau))^2 * 0.5$. The formula is flipped and

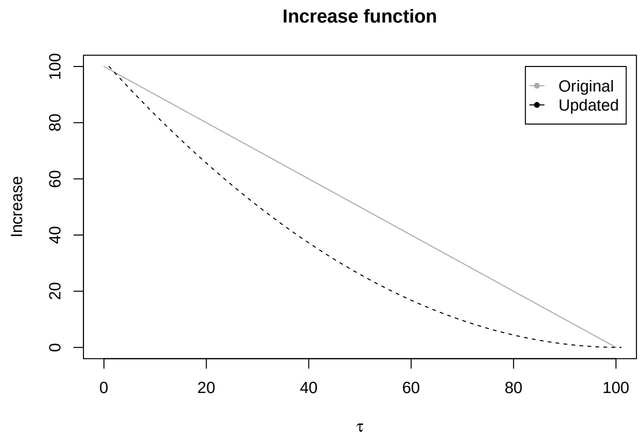


Figure 5.5: Plot of original increase against updated increase

leads to a large decrease for values with a high threshold and a small decrease for values with a low threshold. If a value is important for an agent it should have more impact, when the agent does an action against this value. The multiplication by 0.5 is added to compensate for the draining amount, since there are now two mechanisms of lowering the filled level, draining each step and decreasing by an action. Increasing is only possible through actions.

Enriched decision system

With the addition of the negative influencing actions, the decision system had to be updated as well. It would not be realistic to only look at the most salient Schwartz value. For example when two values, V_1 and V_2, have a positive priority ρ, they both need to be satisfied. And let us assume there are two actions α_1 and α_2, where α_1 has a positive influence on both V_1 and V_2, and α_2 has a positive influence on V_1, but a negative influence on V_2. Both values need to be satisfied, so the best action for the agent would be α_2. But if we only look at one value at a time, which happens in the original framework, two things can happen, since a random action will be chosen from the actions that seem best. If V_2 has the most priority the action that would be chosen is α_1 which would be correct. If V_1 has the most priority then both actions would seem like a good options, however this is not the case.

To solve the problem the updated decision maker looks at all the values that have to be satisfied ($\rho > 0$). A vector w is created with the following rule:

$$n_i = \begin{cases} \rho_i & \text{if } \rho_i > 0 \text{ and } \tau(V_i) > 0 \\ 0 & \text{else} \end{cases},$$

$$w = \begin{bmatrix} n_1 \\ n_{..} \\ n_{10} \end{bmatrix} / \sum_{j=1}^{10} n_j$$

This vector n_i is filled with the priority of values that conform to $\rho_i > 0$ and which have an importance at least larger than zero $\tau(V_i) > 0$. After that the vector is divided by the sum of the elements in the vector, leading to a normalized vector of priorities, that can later be used to compare the actions. In the case that the sum of the vector would be zero, then none of the values matter at that time, and the decision system just passes all of the actions through without any filtering.

Now we define a function that transforms the actions to a vector, which indicates per value whether it has a positive, negative or none effect (φ : *Actions* $\rightarrow$ *Value tree influence*). For each action α it will look at the value tree for that agent, and uses the following rules.

$$\varphi(\alpha) = \begin{bmatrix} m_1 \\ m_{..} \\ m_{10} \end{bmatrix}, \ m_i = \begin{cases} 0 & \text{if no influence on } V_i \\ 1 & \text{if positive influence on } V_i \\ -1 & \text{if negative influence on } V_i \end{cases}$$

The vector consists of numbers that indicate the influence on the value with a $0, 1$ or -1, for respectively no influence, a positive influence and a negative influence. Now it is possible to calculate, for each of the possible actions A, the influence factor ξ of a value by multiplying the vector of an action $\varphi(\alpha)$, with the normalized vector of value priority w. To be able to do the multiplication the vector w is transposed.

$$\forall \alpha \in A, \ \xi_\alpha = w^T \cdot \varphi(\alpha)$$

With the influence factor ξ of each action available the filtering can be done. There are two possibilities, (I) there are some actions with $\xi_\alpha > 0$ and (II) all actions have $\xi_\alpha \leq 0$.

I All the actions that have $\xi_\alpha > 0$ are returned, the rest of the actions are filtered out. This models that an agent would not want to use actions that will negatively influence its values, when there are actions available that positively influence its value.

II The highest ξ value will be determined, and all the actions that have a ξ equal to the highest ξ will be in the filtered action set. This models that in the case there are no positive actions available, the agent will select the actions that have the least negative impact on its values. On first thought it would seem to make more sense of not returning the actions, when all the actions have a negative influence, but considering that the action of doing no action is part of the action set this is not allowed.

The influence factor can be used as preferred by the modeler. As the returned set could contain some actions with a high ξ and some with a low ξ. If a different decision process does not decide between one of those actions, the action with the highest ξ could be chosen. It is also possible to use a probability distribution, with higher ξ actions having more chance of being selected.

Chapter 6

Simulation description ODD

This section presents the simulation[1] in full detail using the Overview, Design concepts and Details protocol Grimm et al. [7, 8], or in short ODD protocol. The simulation has been developed in Repast Simphony North et al. [15].

6.1 Purpose

The purpose of the model is to understand how residents in a fishing village behave based on their perspectives on Schwartz values. In particular which behavior leads to stable societies where residents work, have their own property, start families and perform social events. The research questions focuses on the prosperity of the village as a whole and the migration of residents, which are both contemporary problems.

6.2 Entities, state variables, and scales

The entities that make up the simulation are agents, buildings, boats and the ecosystem (Figure 6.1). The agents live inside the village, but can go into the sea when they are a fisher, or go into the world when they work at the company outside, or go to school at the school outside. Most building types have only one entity, but there can be multiple houses (cheap, standard and expensive).

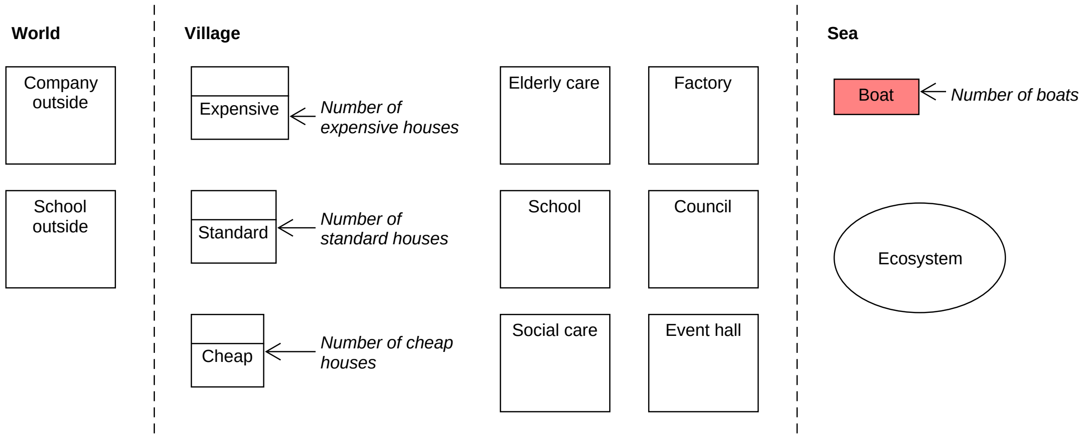


Figure 6.1: Simulation overview: showing the layout of the entities. The italic texts denote parameters names that will be mentioned below.

[1]The code is available at https://github.com/maartenjensen/Social-simulation-fishery-village

Boats are inactive when they are spawned, but can be bought by residents to become active. The ecosystem entity represents the fish.

To initialize the world as illustrated in the figure, a number of parameters are used (Table 6.1). Indicating the amount of houses and starting as well as other general information.

Parameter	Value	Parameter	Value
Amount of ticks per month	4	Building initial money	100.000
Amount of ticks per year	48	Number of houses cheap	16
Initial population size	50	Number of houses standard	10
Individual starting money	50.000	Number of houses expensive	5
Individual starting age min	18	Number of boats	2
Individual starting age max	65		

Table 6.1: General and initialization parameters

Agents

The agents are the residents of the fishing village. They use many state variables (Table 6.2). Each agent has an unique *ID*. The *gender* indicates $true = male$ and $false = female$. The *foreigner* variable indicates that the agent is born in the village if it is $false$, otherwise the variable is *true*. The *children wanted* is a variable used by women that indicates the amount of children they still want to have. The *partner ID* indicates who the partner of an agent is. *Net income* is the salary minus the *necessary cost*. *Necessary cost* consists of living cost, living cost of children and property maintenance cost. The *not happy tick* indicates for how many ticks an agent is consecutively not happy.

State variable	Type	Parameter	Value
ID	Integer	Adult age	18
Gender	Boolean	Elderly age	65
Age	Integer	Elderly care age	85
Money	Double	Max child get age	45
Foreigner	Boolean	Wife age gap min	20
Children wanted	Integer	Wife age gap max	10
Partner ID	Integer	Children wanted min	1
Net income	Integer	Children wanted max	6
Necessary cost	Integer	Probability to get no children	0.1
Not happy tick	Integer	Probability to get a relation	0.5
Status	Enum	Probability to get a house	0.5
School type	Enum	Probability search for a new job	0.033
Parents ID's	List of Integers	Probability to keep previous job	0.9
Children ID's	List of Integers	Probability child action	0.5
Properties ID's	List of Integers	New resident probability	0.05
Social status	Class		
Decision Maker	Class		

Table 6.2: Overview of parameters for agents

Status (Table 6.3) is defined by an Enumerated type (Enum), i.e. a variable that has a fixed number of values that can be indicated with an identifier (Child, Captain, etc.). School type, is a specific state variable for a child. This depicts whether the child goes to the school inside the village or outside the village. Each agent knows the ID's of its parents, children and owned property, they are denoted by the List of Integers state variables. The social status and decision maker (which is the value framework) are classes in the implementation and have their own state variables, they are described below. The right part of the table describes the default parameters that are related to agents. The age integers describe when agents go to the next status. The wife younger parameter gives the maximum age difference between a man and a woman. The probability search for a new job indicates how often an agent searches for a new job when it is not happy. If an agent searches for a new job but, the current job gets through the value filter framework then the probability to keep previous job, decides whether to keep the old job.

Status	Age range	Job title	Social st.
Child	$0 \leq age$ $age < adult\ age$	none	0.5
Captain	$adult\ age \leq age$	Job captain	0.75
Elderly caretaker	$age < elderly\ age$	Job elderly caretaker	0.25
Factory boss		Job factory boss	1.0
Factory worker		Job factory worker	0.25
Fisher		Job fisher	0.5
Mayor		Job mayor	1.0
Teacher		Job teacher	0.5
Unemployed		Job unemployed	0.0
Work out of town		Job work outside village	0.0
Elder	$age\ elderly \leq age$ $age < elderly\ care\ age$	none	0.5
Eldest	$elderly\ care\ age \leq age$	none	0.5

Table 6.3: Status Enum (Social st. means Social status)

As seen in the table 6.3 the status state variable shows the stage of live for agents that are not adult, i.e. child, elderly and eldest; for adults it shows the current occupation. The Age range column shows for each group in which age range they fit. Since adults have the status showing their occupation the job title is also filled in for them. The occupation also shows the social status.

Value framework

The full formalization of the value framework can be found in the chapter before this one. Here we will show the implementation choices and the value trees. The value framework class that each agent has, contains four water tanks that represent the abstract values {*Universalism*, *Tradition*, *Power*, *Self-direction*}. The tank has a filled level that indicates how full the tank is, threshold that indicates the importance of the value (Table 6.4) and a satisfaction count on how many times the value has been satisfied during a tick. The parameters give the capacity of the water tank, and the amount that is drained each tick.

The value trees are described in this section since they serve as parameters for the simulation. They connect the actions to the abstract values through concrete values.

State variable	Type	Parameter	Value
Filled level	Double	Tank minimum level	0
Threshold	Double	Tank capacity	100
Satisfaction count positive	Integer	Tank drain	2
Satisfaction count negative	Integer		

Table 6.4: Parameters for the value framework

The abstract values are denoted with italic in a square box, the concrete values as normal text in square boxes and the actions as normal text in circles. The arrows indicate a positive influence when straight and a negative relation when striped.

The job value tree describes the influence that jobs have on abstract values (Figure 6.2). The group (factory worker, fisher, captain, teacher, mayor and factory boss) is boxed in since they all have the same connection to the concrete values sustain village and be part of the community. The jobs that have a negative influence are work outside village, factory worker and unemployed.

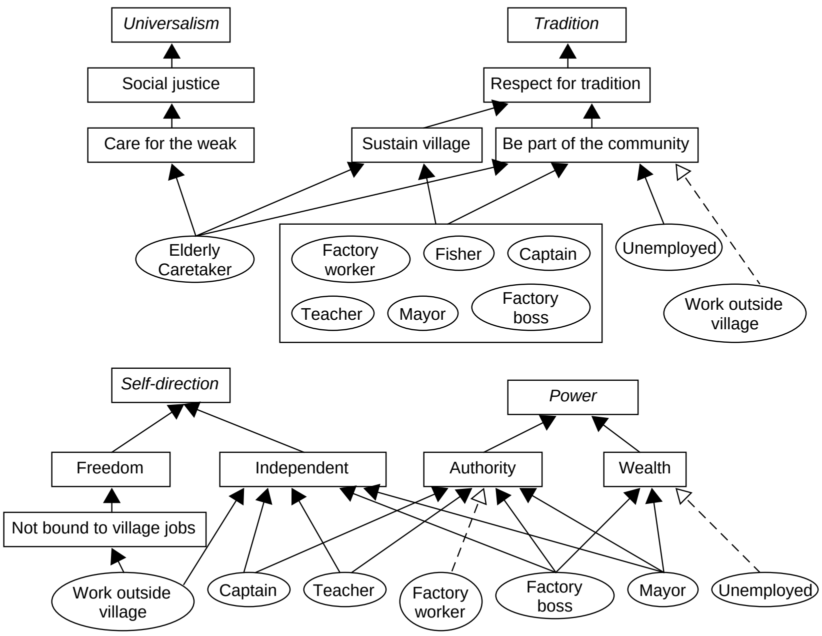


Figure 6.2: Job related value trees

The donation value tree has two actions, donate nothing and donate to council respectively (Figure 6.3).

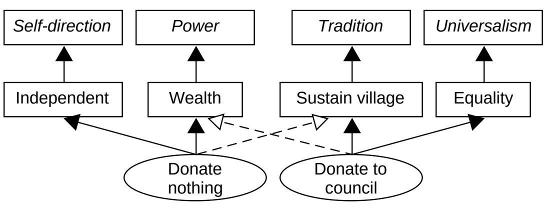


Figure 6.3: Donation related value trees

The event tree describes the influence of event actions on the abstract values (Figure 6.4). The different actions are organize free event, organize commercial event, attend commercial event, attend free event. These actions are all boxed to indicate, they all have a positive influence on be part of the community and on freedom. The organize free event has a positive influence on organize free event and negative influence on wealth. Since these influences neutralize each other the influence on power is negated for organize free event.

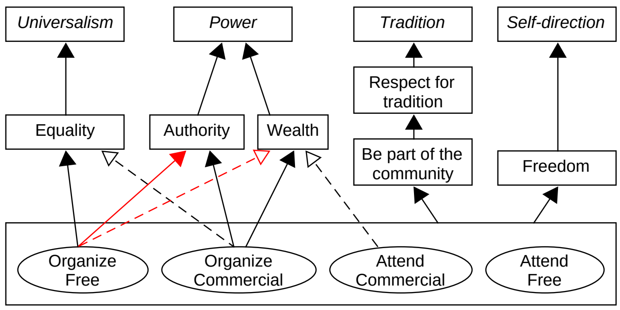


Figure 6.4: Event related value trees

The fishing related value trees describe the influence of different fishing actions on the abstract values (Figure 6.5). There are three types of actions (fish a lot, fish medium, fish less) based on two conditions (fish population is fine, fish population is in danger). The actions that are in red indicate that the fish population is in danger and when this is the case the influences on values change.

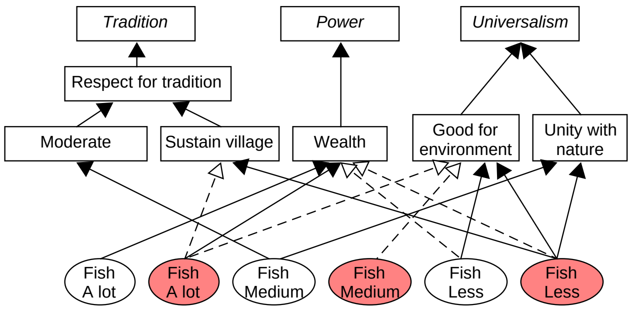


Figure 6.5: Fishing related value trees

Social status

The social status framework is part of each agent and contain eight state variables (Table 6.5). The state variables on the left (wealth job, wealth house, wealth boat and fisher economical) make up the wealth status (influenced by power). The state variables fisher ecological, free events (organizing free events will increase this) and donation make up the altruistic status (influenced by universalism). The social life status (tradition) is made by combining donation and general events (organizing or attending events).

State variable	Type	State variable	Type
Wealth job	Double $[0, 1]$	Fisher ecological	Double $[0, 1]$
Wealth house	Double $[0, 1]$	Free events	Double $[0, 1]$
Wealth boat	Double $[0, 1]$	Donation	Double $[0, 1]$
Fisher economical	Double $[0, 1]$	General events	Double $[0, 1]$

Table 6.5: Social status state variables

The status of agents has influence on the wealth job variable. The amount that is connected to each of the statuses is shown in Table 6.3 under the column named (Social st.). The wealth house is influence by the house type parameters depicted in the Table 6.6. The wealth boat only counts for captains and is influenced by social status parameters in Table 6.11 in the next section. The fisher economical and fisher ecological is also showed in Table 6.6. The event and donation social status parameters are showed in Table 6.7.

House Type	Social st.
Homeless	0.0
Living with others	0.1
Cheap	0.3
Standard	0.6
Expensive	1.0

Fishing action	Social st. economical	Social st.. ecological
Fish a lot	1.0	0
Fish medium	0.5	0.5
Fish less	0.0	1.0
Fish a lot danger	1.0	0
Fish medium danger	0.5	0.0
Fish less danger	0.0	1.0

Table 6.6: House type and fishing social status

Event	General events	Free events
Organize free	1.0	1.0
Organize commercial	1.0	0.0
Attend free	0.5	0.0
Attend commercial	0.5	0.0

Type	Social st.
Do not donate	0.0
Donate to council	1.0

Table 6.7: Event and donation social status

Money

The agents will earn money when they work. For all jobs their salary will be defined by parameters, fish caught or fish processed; and the percentage of salary to tax 6.8. From the tax a percentage, also shown in the table, goes to the council. Fishers and captains get paid dependent on the amount of fish they sell and the fish price. The captain has a multiplier that decides the amount it gets paid compared to a fisher, in this case the default is two so the captain gets paid the cumulative amount of two fishers. A human should have more money than the money danger level, to be able to spend money on events and donations.

Parameter	Value
Monthly cost adult	300
Monthly cost child	150
Monthly cost elderly	150
Salary to tax	50%
Tax that goes to council	50%
Leftover money to donate	10%
Money danger level agent	5.000
No income minimum savings	50.000
Donation without income	50
Property sell percentage	50%

Parameter	Value
Salary teacher	3.000
Salary factory worker	2.000
Salary factory boss	6.000
Salary mayor	4.000
Salary outside worker	2.500
Salary elderly caretaker	2.000
Salary multiplier captain	2
Benefit unemployed	800
Benefit elderly	800

Table 6.8: Money parameters

If its money is lower than the danger level it will try to buy a cheaper house. 'No income minimum savings' indicates how much money an agent needs to donate when it has no job. It will donate the amount of donation without income.

Property

There are many types of properties in the simulation but they share the same common state variables (Table 6.9). The buildings also have location and size parameters, but these are only for visualization purposes and are irrelevant for the results of the simulation. Since agents do not use spatial distance in their decision processes.

State variable	Type
ID	Integer
Buying price	Integer
Monthly maintenance cost	Integer
Savings	Double
Owner ID	Integer

Table 6.9: State variables for properties

Boats

The boats are owned by a captain, the other employees are fishers. Since a boat is a place where agents can work, it contains the possible jobs List of Statuses (Table 6.10), that describes the jobs that this property allows for. Fish caught is influenced by the catch amount and the number of fishers, including the captain, on the boat. When there is no captain, the catch amount decreases by the percentage noted in the table. The catch amounts corresponds to the fishing actions: *fish less*, *fish medium* and *fish a lot*.

State variable	Type
Fish caught	Integer
Boat type	Enum
Possible jobs	List of Status

Parameter	Value
Number of boats	2
Jobs	{*captain,fisher*}
Catch amount less	75
Catch amount medium	125
Catch amount a lot	175
Catch decrease no capt	25%

Table 6.10: State variables and parameters of boat entity

The boat contains the state variable boat type, that indicates the maximum number of employees, including the captain, the buying price of the boat and the monthly cost for the captain (Table 6.11).

Boat type	Max employees	Price	Monthly cost	Social status
Small	4	5.000	100	0.3
Medium	6	10.000	200	0.6
Large	8	15.000	300	1

Table 6.11: Boat type Enum

COMPANY OUTSIDE

This is a workplace that is an abstraction of work outside of the village (Table 6.12. The company has an ID but does not use the other state variables (Table 6.9). The probability of job available is there to model that, working out of the village is not always possible.

State variable	Type	Parameter	Value
Possible jobs	List of Statuses	Jobs	{*work-out-of-town*}
		Probability job available	0.4
		Max workers	100

Table 6.12: Council state variables and relevant parameters

COUNCIL

The council distributes the money received by taxes (Table 6.13). The money is distributed to either the school, social care, elderly care or the factory. The multiplier state variables are influenced by the mayor and indicate how much money is given to each of the institutes. The mayor importance indicates to what extend the mayor has influence on that decision.

State variable	Type	Parameter	Value
School multiplier	Integer	Jobs	{*mayor*}
Social care multiplier	Integer	Mayor importance	0.1
Eldery care multiplier	Integer	Building danger level	30.000
Factory multiplier	Integer		
Possible jobs	List of Statuses		

Table 6.13: Council state variables and relevant parameters

ELDERLY CARE

The elderly care hosts agents that have reached the elderly care age and beyond (Table 6.14). It cannot be owned by an agent as it is part of the general property of the village. The eldest are taken care of by elderly caretakers.

State variable	Type	Parameter	Value
Possible jobs	List of Statuses	Max eldest per caretaker	10
		Jobs	{*elderly-caretaker*}

Table 6.14: Elderly care state variables and relevant parameters

EVENT HALL

The event hall is a place where agents can organize and attend events to satisfy their values. It cannot be owned by an agent as it is part of the general property of the village. The only state variable of the event hall is List of Events which contain the current events (Table 6.15). The minimum event attendees indicates how many attendees are needed before the event is successfully performed.

State variable	Type	Parameter	Value
Events	List of Events	Minimum event attendees	2

Table 6.15: Event hall state variables and relevant parameters

The Event Enum contains the state variables and parameters (Table 6.16). The state variables are the ID of the organizer and a list of ID's for the attendees. The right part of the table shows the two types of events and their parameters.

State variable	Type
Organizer ID	Integer
Attendees ID	List of Integers

Type	Init cost	Att. cost	Att. fee	Max att.
Commercial	30	10	25	6
Free	30	10	0	6

Table 6.16: Event Enum state variables and parameters (Att. means Attendees)

Factory

The factory (Table 6.17) processes fish that is bought from the fishers. The factory boss is the owner of the factory and the factory workers process the fish (with the processing amount per worker). The fish that is processed will be directly sold, therefore there is no need for such a state variable. The max employees number is limited by the parameters factory min worker and factory max workers. When there is no boss in the factory, processing decreases by the amount given in the table.

State variable	Type
Max employees	Integer
Fish unprocessed	Integer
Jobs	List of Statuses

Parameter	Value
Factory price	10.000
Jobs	$\{worker, boss\}$
Factory initial max workers	10
Factory max workers	50
Factory min workers	3
Buy price fish unprocessed	5
Sell price fish processed	10
Processing amount per worker	750
Processing decrease with no boss	25%

Table 6.17: State variables and parameters of factory entity

House

The houses can be bought by agents to live in and start a family. A house contains the state variable house type, which has three forms (Table 6.18). The number of houses of each type is denoted in table 6.1.

House type	Price	Monthly cost
Cheap	25.000	300
Standard	50.000	600
Expensive	75.000	900

Table 6.18: House types

School

There are two schools, one is situated inside the village (referred to as inside school) and the other is situated outside the village (referred to as outside school) (Table 6.19). The inside school is cheaper for children but is only available when there are enough teachers. The teacher job is available to agents who are of adult age.

State variable	Type	Parameter	Value
Inside school		Inside school	
Possible jobs	List of Statuses	Max children per teacher	10
		Pupil monthly fee	25
		Jobs	{*teacher*}
		Outside school	
		Pupil monthly fee	100

Table 6.19: Inside and outside school state variables and relevant parameters

Ecosystem

The ecosystem contains the fish population which is the main source of income for the village. It is abstracted to only one number which makes it easy to manipulate and analyze it (Table 6.20). The allowed catch for *fish less* is a variable that is calculated after the fish has repopulated and indicated how much fish fishers can catch. The parameters are used to calculate the repopulation and maximum amount of fish.

State variable	Type	Parameter	Value
Fish	Double	Initial fish\max fish	200.000
Allowed catch for *fish less*	Integer	Fish max repopulate upper	150.000
		Fish max repopulate lower	50.000
		Fish danger level	75.000
		Fish repopulate amount	2.000

Table 6.20: State variable and parameters of ecosystem

Scales

The spatial relations between entities in the model is shown in Figure 6.1 and illustrates a small fishery village. The spatial relation is only relevant for illustrative purposes and has no influence on the results of the simulation. The temporal scale is related to the parameters amount of ticks per month / year (Table 6.1). There are three time units, the smallest being a tick which is roughly a week. Every four ticks makes up a month and which leads to 48 ticks being a year. The following section shows the scheduling and what actions are performed in which ticks.

6.3 Process overview and scheduling

The model performs discrete steps that come in three temporal forms: tick, month and year. There are five processes that have a temporal time and are executed in a serial order. The processes are depicted using pseudocode that shows which entity performs what changes to the simulation.

Process 1 (Year): Aging and spawning

The model starts with a process that is called each year that deals with aging and the spawning of agents by migration or birth (Alg. 1).

Algorithm 1: Process 1 (year) - aging, migration and family

```
foreach Individual do
    age + 1
    if age == adult age then
        status = unemployed
    end
    if age == elderly age then
        status = elder
        stop working
    end
    if age == elderly care age then
        status = eldest
        go to elderly care
    end
end
if Probability migration ≤ Random([0, 1]) then
    Create new migrated individual
end
foreach Woman do
    if want/can get a child then
        Birth of a child (age = 0)
    end
end
```

If a new migrated agent is created it will get a new unique ID, a random gender, the migrated state variable is true, the age is between agent starting age min and agent starting age max and starting money is agent starting money (Table 6.1). Other state variables are set to default where status is Unemployed, partner and workplace are undefined (-1) and other money related variables are set to 0. The water tanks of the individual's decision maker are set using the determined distribution (See Submodels).

After the migration each woman decides whether to get a child. A child will be spawned if the woman is living together with its partner, has its state variable *children wanted* > 0, its age $<$ *max child get age* and the probability of *probability to get a child* is matched.

Process 2 (Tick): drain tanks and not happy tick

In this process the not happy tick is set and the water tanks of each individual, who is either an adult or elder (not eldest), are drained (Alg. 2). The not happy tick is increased when an agent is not happy and reset when an agent is happy. After that each of the water tanks' filled level is decrease by the drain amount (Table 6.4).

Algorithm 2: Process 2 (tick) - water tank

```
foreach Individual ∈ {Adults, Elderly} do
    if is happy then
        not happy tick = 0
    else
        not happy tick ++
    end
    foreach WaterTank do
        drain tank
    end
end
```

Process 3 (Month): School, housing and relations

The third process happens every month (Alg. 3). In this process a number of things are done: in the school and elderly care excessive employees are fired, agents select a house, children select their school and relations are formed.

The school inside the village and the elderly care both have employees from within the village, teacher and elderly caretaker respectively. The job vacancy is bound to the number of pupils or eldest within the village. The maximum number of eldest per caretaker is given in Table 6.14 and the maximum number of pupils per teacher is given in Table 6.19. In the function fire excessive employees, the teachers and elderly caretakers that are in excess are fired.

Agents who are adult or elder, buy a house when they need a house (when they still live with their parents) and when there is a house available (they have enough money to buy a vacant house). If an agent can not afford its house or its partner already has a house, the agent sells its house.

The children select the school they go into. The only check is whether there is a vacancy for the school inside the village. Then the children will go there, if there is no vacancy they go to the school outside the village.

In the relation step, there is a check whether the agent is single and whether there is a possible partner. The possible partner should be single, adult and there is a range of age that is given in Table 6.2. When a man is looking for a wife the following rule is applied, $age_{woman} \geq (age_{man} - \textit{wife age gap min})$ and $age_{woman} \leq (age_{man} + \textit{wife age gap max})$. There is also a check on whether they do not have the same parents and whether one of them already had a partner. When a relation is set between two agents their partner ID variable is updated. The children wanted variable is set to zero with a probability of *probability get no children* and else it will be set to a random number between *children wanted min* and *children wanted min* (Table 6.2).

As final step in this process a value based selection on work is performed. This relates to the value tree of Figure 6.2. When an agent is not happy (see section 1.7) or is unemployed, then with probability to search for a new job $\leq Random([0, 1])$,

Algorithm 3: Process 3 (month) - school, housing, relations

```
foreach Object ∈ {School inside village, Elderly care} do
    fire excessive employees
end
foreach Individual do
    if Individual == (Adult or Elder) then
        if Need house then
            if house available then
                buy house
            end
        else
            if partner also has a house or not enough money for house then
                sell house
            end
        end
    end
    update social status house
end
foreach Child do
    if vacancy in village school then
        set school = inside village
    else
        set school = outside village
    end
end
foreach Individual ∈ {Adults, Elderly} do
    if is single and there is a possible partner then
        set relation between agent and possible partner
    end
end
foreach Individual ∈ {Adults} do
    if (not happy or unemployed) and probability search for a new job
      ≤ Random([0, 1]) then
        value/social status based selection on available work
    else
        value/social status based selection on current job and factory
          boss/captain
    end
    apply value/social status influence of work
end
```

the decision process will be started. The agent receives the available jobs, and uses the value framework and social status to decide the best action for the job. The full decision making steps are described in section 1.7. If the agent is not looking for a job, but there is a vacancy for captain or factory boss, then it will use the value based decision on those possible jobs. In this step the agent also updates the values and its social status based on its selected or current job.

Process 4 (Tick): Fishing, donation and events

The fourth process happens every tick (Alg. 4). This process handles events, the ecosystem, fishing actions of fishers and donations.

Algorithm 4: Process 4 (tick) - events, fishing and donation

```
foreach Event Hall do
    clear the state variable: Events
end
foreach Ecosystem do
    Increase fish amount
end
foreach Boat do
    if has captain then
        captain does a value/social status based action
    else
        random fisher does a value/social status based action
    end
    apply value/social status influence of fishing action
end
foreach Individual ∈ {Adults, Elderly} do
    value/social status based decision on donation
    apply value/social status influence of donation
end
foreach Individual ∈ {Adults, Elderly} do
    value/social status based decision on event
end
foreach Event Hall do
    Perform events → payments of events
    apply value/social status influence of event
end
```

The ecosystem calculates the amount of fish that repopulates (the formula is given in section 1.7 sub-models). Since the repopulation amount is dependent on the current amount of fish.

The captain in each boat, or one of the fishers if there is no captain, will now select a fishing action that each of the fishers on that boat will perform. Using the value tree (Figure 6.5) and the relevant social status (Table 6.6). Fishing will increase the fish caught variable on the boat and decreases the amount of fish in the Ecosystem. After fishing, the action will influence the values and social status of the fishers.

Donation is also based on values and social status, the corresponding value tree is given in Figure 6.3 and the social status in Table 6.7. After selection the influence is applied. Agents that do not have enough money will not participate in donation.

Here agents will choose to organize or attend events, based on value based decision for the event actions based on the value tree (Figure 6.4) and social status (Table 6.7).

Perform the social events that are chosen by the agents. When an event has a number of attendees $\geq$ min event attendees, then the event will be performed and the values/social status will be updated accordingly.

Process 5 (Tick): Salary, costs and migration

The last process describes selling and processing of fish, income, payments, council money distribution and migration/death of agents (Alg. 5).

Algorithm 5: Process 5 (month) - Salary, costs and migration

```
foreach Boat do
    sell fish to Factory
end
foreach Factory do
    process fish
    if unprocessed fish > 0 then
        if worker count = maximum workers and maximum workers < factory
         max workers then
            maximum workers += 1
        end
    else
        if maximum workers > factory min workers then
            maximum workers -= 1
        end
    end
end
foreach Individual do
    share money with partner
end
foreach Individual do
    get income (salary or benefits)
    update social status work and boat
end
foreach Individual do
    pay necessary costs
end
foreach Council do
    distribute money
end
foreach Individual do
    if human dies probability < Random([0, 1]) then
        die
    end
    if age >= adult age and age < elderly care age then
        if not happy tick ≥ calculated tick and migrate chance
         ≤ Random([0, 1]) then
            migrate out of town
        end
    end
end
```

Boats sell their fish to the factory for the price given in Table 6.17.

The factory processes the fish dependent on the amount of workers and sells it afterwards. The amount a worker can process is given in Table 6.17, when there is no boss the efficiency decreases by *processing decrease with no boss.* If there is still fish left to process, the factory will increase the maximum amount of employees. If there is no fish left, the factory will decrease the maximum amount of employees. The value is bound by the *factory min workers* and *factory max workers* see factory table.

If an agent has a partner, it shares its money with the partner to equalize the money in couples.

After this the agents receive their income. This income is either a salary from their job, a social benefit when unemployed or an elderly benefit. Tax is paid on the salary and the income is shared with the partner. In this step the social status is calculated, based on the type of job and for captains, additionally, the type of boat.

The agents pay living cost (Table 6.8), their children's living cost and property maintenance. When an agent has a partner, the living cost and property maintenance are shared. The summation of costs make up the necessary cost.

The council distributes money based on the values of all agents and 10% based on the mayor's values. The council can either give each building the same amount of money or divide the money based on which building (from school, social care, elderly care and factory) needs it the most. The values that influence this choice are power and universalism.

The human death probability is calculated by a formula given in section 1.7 sub models. When an agent dies it is removed from the simulation. It will give the house and money to the partner. If it has no partner, it will sell the house and distribute the money to the children. Also a negative amount of wealth will be distributed to the family (as debts).

The other way an agent can leave the simulation is to migrate out of town. When an agent is not happy there is a probability it will migrate. This probability is dependent on the self-direction and tradition threshold. A higher threshold leads to a higher change to migrate. When migrating the agent will take family members with him, the husband or wife and children that are younger than 18.

Process 6 (Tick): Visualization

In the last step the agents are moved around which is for visualization purposes only and does not affect the simulation itself. Therefore it is not discussed further.

6.4 Design concepts

Basic principles

The model describes social, ecological and economical dynamics in a fishery village. The sociological system consists of humans with Schwartz values and a notion of social status. The ecological system consisting of the fish, which are a limited source of income for the village. Adjusting that resource or the perspective of agents on that resource can lead to interesting behavior. The economical system contains fish selling, housing and distribution of money through the council.

The theory used to drive the decision making of agents is based on the Schwart value theory, this theory has been transformed into a framework that is used in the simulation. Different types of populations with varying Schwartz values can create different results in the simulation. Exploring the impact of changes in the values, perspectives or systems is the purpose of this study.

Emergence

The dynamics that emerge from the system, is that there will be a sustainable village. Since every agent has the incentive to work and contribute to the village. However this dynamic can be disturbed when the fish ecology depletes, or when agents start caring less for the village jobs and begin to work outside of the village. The agents will change their behavior based on work availability, since this will give them a particular job, allowing them to satisfy certain values. The difference in value satisfaction leads to different behavior on donation and events. The fish ecosystem also influences the behavior of agents as this is the main source of income. In the case the fish population depletes, the money has to come from another source like working outside and this also depends on whether the agents donate or not.

Adaptation

There are a number of adaptive traits within the agents. Dependent on the action set they get, they perform certain actions. The agents choose a job based on the available jobs, the individual's value priorities and social status. The agents will search for a house, dependent on their income and money they will buy a house. An agent that has a house and a partner will get children, this part is adaptable by the number of agents already living in the village. These basic behaviors make the sustainable village live emerge. The agents can also go to social events, donate and for fishers there are special fishing actions. These actions have influence on an agents money, values and social status. The latter two define an individual's happiness which can be a measure of success.

Objectives

The objective of an agent is to become and stay happy (it is defined in section 1.7). In order to be happy, the agents want to satisfy their values and their social status. But to be able to do this they are also dependent on the prosperity of the village itself. Gaining money can also be seen as an objective, but this is not directly chained to happiness. As some agents (low on power) can be completely happy without the expensive house and wealthy job, because they value other things in life, for example being good for the environment.

Learning

The agents themselves do not learn. The factory can learn by changing it's maximum number of employees over time dependent on the available unprocessed fish. When there is still fish left after a processing step the maximum number of employees is increased by one. When all the fish is processed in a step, the maximum number of employees decreases by one.

Prediction

The agents do not predict the influence of their actions in most of the cases. They satisfy the values that need to be satisfied. They do actions that tend towards certain future gains, like getting a job, which will give money. They however do not plan to get a house and therefore get a job.

Sensing

Agents can sense their family members, money, age, gender, available jobs, available actions to perform (select job, event organize) and potential partners. The spatial scale does not influence the sensing of the agents, they know some things regardless of their position. Fishers and captains can sense the danger level of fish, which influences their action set regarding fishing.

Interaction

The agents have direct interactions with their partner, since they start to live together, get children and share money. They pay their children money for living cost and the children live in the parents house, when they do not have a house of their own. Also when a parent migrates out of the city, it takes its partner and children with. There is also interaction between agents due to events. In which some will organize an event and others will join them. Other interactions are between fishers selling fish to the factory, thus influencing factory employees. The agents in the village paying tax to the council which in turns invests the money into village facilities.

Stochasticity

There are a number of stochastic choices. These are based on the probabilities: search for a relationship, get a child, search for a house and search for a new job. Also the company outside has a probability to indicate whether the job is available or not. But they are not completely random as they are dependent on other factors as well. E.g. the search for a relationship is dependent on whether there is a possible partner available. Another stochastic part is the initialization of a new agent where its age (if it is not a baby) is randomly determined, and more importantly the values are drawn from a distribution, given by the input parameters which is also a stochastic process.

Collectives

The agents who work on a boat form some sort of a collective. Where the captain influences the fishing action to execute. But the amount of fishers on the boat influences the amount of fish being caught.

Observation

Interesting data to collect from this simulation is the behavior of the agents. The jobs they have, the age distribution, the events and donation patterns, the values over time. Putting such data next to each other can show interesting results, since it might happen that when a certain job is not possible, agents will find other ways of satisfying their values. Another thing that might be interesting is to show macro level behavior like fish population or migration next to micro level behavior like the captain decisions and agents values.

6.5 Initialization

For the initialization the default parameters in section entities, state variables, and scales are used. There can be exceptions but these will be denoted. To analyze the simulation an initialization run will first be done in which the simulation will be run for a couple of decades. This will create the necessary population to start experimenting with, as the raw initial population does not have children and relations and ancestors. With an initialization run these bonds are formed and create a more realistic starting population. The abstract values can now be varied, and by using the initialization run data as starting point, it is possible to see how those values influence the simulation. Sometimes parts of the code will be changed, in order to see the effect of e.g. removing an element, the definition of happiness.

6.6 Input data

The model does not use input data to represent processes over time.

6.7 Submodels

This section represents the submodels and formulas that are represented in the section 'Process overview and scheduling'.

Aging and mortality

The agents age, and go through different cycles in their life span. They go from child $[0, 17]$ to adult $[18, 64]$ to elderly $[65, 84]$ and eldest who go into elderly care $[85, max_{int}]$. The formula to calculate an individual's mortality is called each month and decides with a probability check whether the agent dies. The formula has the form:

$$\frac{1}{24} \cdot \left(\frac{1}{125} \cdot age\right)^5$$

For the first decades the probability of dying is really low but afterwards the probability rapidly increases (Figure 6.6). This is a simple abstraction of a real human mortality distribution.

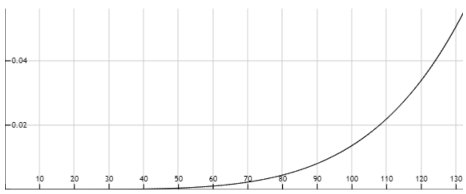


Figure 6.6: Mortality function

Ecosystem

The ecosystem is a submodel of the simulation, that simulates the fish population. The ecosystem will without interaction of humans, stay stable at the *max fish* level (Table 6.20). The timespan of running the simulation will be a few decades, which is usually not the timespan in which huge changes to such an ecosystem happen.

The idea behind the stability is that at the *max fish* level the repopulation rate is equal to the dying rate of fish, since there is a limit of available food. When the fish amount decreases there is more food available per fish, thus more fish survive and the population grows. For the fish amount larger than *fish max repopulate upper* the repopulation rate is calculated with:

$$repopulate\,amount \cdot max \left\{ 0, \frac{max\,fish - fish}{max\,fish - fish\,max\,repopulate\,upper)} \right\}$$

A fish population between *fish max repopulate lower* and *fish max repopulate upper* has a repopulation rate that is equal to *fish repopulate amount* from Table 6.20. Here the fish population is at an ideal growth rate.

Below *fish max repopulate lower* the fish population shrinks so much that the repopulation rate descreases again. This models that there are fewer fish who can repopulate thus there is less offspring. The following formula gives the repopulation rate for a fish amount smaller than *fish max repopulate lower*.

$$repopulate\,amount \cdot max \left\{ 0, \frac{max\,fish - fish}{max\,fish - fish\,max\,repopulate\,upper)} \right\}$$

Social status

The social status implementation uses elements from Petruzzi et al. [16]. Each agent has a number of state variables to indicate status (Table 6.5). The wealth house variable is updated every tick dependent on the house type the agent has (Table 6.6). The formula used for updating is

$$s'_h = s_h + 0.1(v - s_h)$$

where s_h is the social status for wealth house and v is the value retrieved from the current living place. All of the social status indicates are updated using this formula. There are three groups of social status:

- **Status (power):** wealth job, wealth house, wealth boat and fisher economical
- **Altruistic (universalism):** fisher ecological, donation and free events
- **Social (tradition):** donation and general events

The social statuses of each of the groups are calculated by taking the average of the values of a group. When an agent is not a fisher the fisher economical, fisher ecological and wealth boat are not taken into account. To get the final social status the following formula is used.

$$w_p = \frac{power_{threshold}}{100}, w_u = \frac{universalism_{threshold}}{100}, w_t = \frac{tradition_{threshold}}{100}$$

$$social\,status = \frac{w_p \cdot status + w_u \cdot altruistic + w_t \cdot social}{w_p + w_u + w_t}$$

As seen in the formula the weights are calculated using the thresholds from the value framework. Agents who value power will have a high social status, when doing actions like buying an expensive house or fishing a lot. While agents who value universalism will go for the altruistic group and here it is more important to do donations, organize free events and fish ecologically responsible.

Happiness definition

To give meaning to the satisfaction of values and the social status, happiness has been introduced. In real life there are many factors contributing to happiness, but they are not very clearly defined. Therefore the happiness will be defined here, by combining the social status and satisfaction of values in the following manner. Am agent is happy if (I) at least half of its values (2 values since there are 4 values modeled in total) are satisfied, a satisfied value has $\lambda_i >= \tau(V_i)$, and (II) the social status is larger than 0.25. This definition is used in the model to decide when to switch jobs or when to migrate out of the village.

Decision making

The decision making happens based on the value framework (see chapter 'value framework') and the social status. Figure 6.7 shows the global decision process containing all elements. It is divided in the agent's mind components and the rest of the simulation. Social status is on the edge of both blocks since it is defined by the agent itself and the other agents.

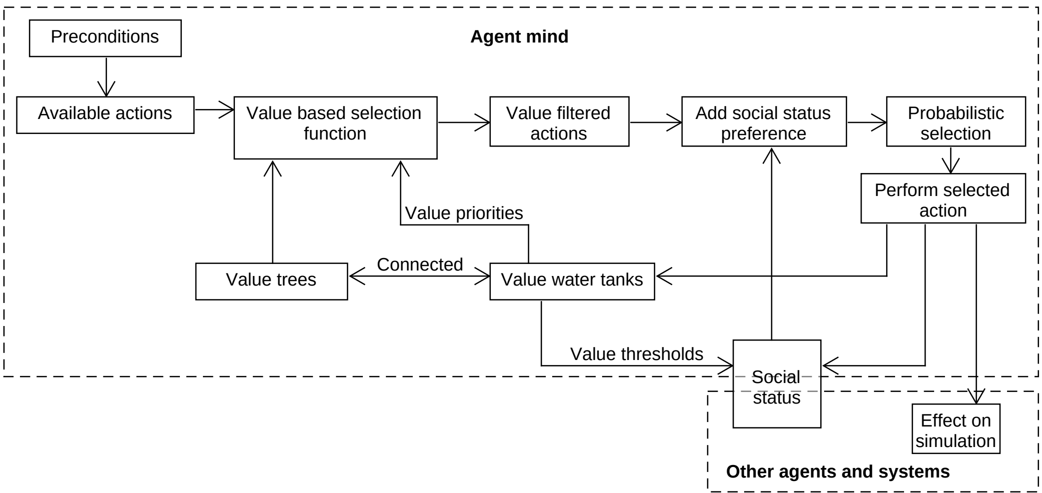


Figure 6.7: Full value based and social status decision scheme

The *preconditions* decide which actions are available for the individual. Those available actions are used in the *value based selection function*, where a selection is made based on the value trees and the priorities for each value (described in 'Value framework'). The value filtered actions that are returned each have an influence factor ξ.

For each of the *value filtered actions* the social status preference ψ is added. This ψ is calculated by the eventual impact on social status. Using the thresholds τ of tradition, power and universalism and normalizing them, and multiplying them by the social status belonging to that action.

An example is the fishing action, where normalized power is multiplied by social status economical and universalism is multiplied by social status ecological (Table 6.6). This added together gives the social status preference ψ for that action (a value where $0 \leq \psi \leq 1$). To give an indication how good an action is the influence factor ξ and the social status preference ψ are applied in the following function.

$$max(\xi + \psi, 0.01)$$

The action is now selected using a *probabilistic selection* method based on the outcomes of the previous formula. Each of them are normalized and one of them is selected by probability. The selected action is performed by the individual. This updates the social status, the water tanks filled level and has some action specific effect on the simulation.

In the case of a positive influence for a value, the drain will be removed for that tick and the filled level will get the increased amount added to it. With a consecutive action during the same tick for the same value, the increase amount will be halved. This rule is applied for further actions that satisfy the same value in the same tick. The same holds for the decrease amount, apart from the drain rule.

Chapter 7

Hypotheses

This chapter shows the hypotheses used to answer the research questions. In psychological research, the context for the hypotheses is derived from the literature. With ABM research, the context is instead created by defining and implementing the simulation. Therefore the hypotheses are shown after the ODD chapter.

7.1 Hypothesis 1:

Research question: What are the influences of different distributions of Schwartz values on a fishery village simulation with regards to its sustainability?

The most prominent part of contemporary fishery villages, with regards to sustainability is the thriving of the fishery. The fishery provides not only income to the fishery village, but also job opportunity and a way of life. But the fishery is completely dependent on the fish, with no fish population the fishery will collapse. This may propagate to the sustainability of the village itself. The interesting value to look at with regards to fishing is the power value, as this depicts the need for individually controlled resources and personal wealth. It can be expected that fishers who value power, overfish and this could cause a depletion of the fish population.

In the ABM the fish population depletion is only dependent on the actions of the fishers. The captain decides the actions, based on the value tree and social status. Figure 6.5, repeated from the ODD, shows that, the action to catch the most fish has a positive influence on power and the action to catch the least fish has a negative influence on power. Based on this, we would expect power oriented captains to frequently fish as much as they can. The role of social status can increase the amount of fish caught further, as shown in the social status chapter, captains with high power are more likely to buy bigger boats which allow them to catch more fish. This combination of mechanics could lead to the eventual depletion of the fish population.

The hypothesis derived from these expectation is:

With a power oriented village the fish population will deplete to zero.

7.2 Hypothesis 2:

Research question 2: What are the influences of different distributions of Schwartz values on a fishery village simulation, with regards to its migration of the population?

A fishery village Usually consists of interdependent autonomous objects that are strongly connected to each other, since they each fulfill a specific role. Removing an element can have big effect on the village. The literature describes a case where a factory owner quit and the factory was closed Skaptadottir [22], leading to many villagers losing their job. With as added effect that the original trawler (boat) had to be transformed to a freezing trawler even changing the work of the fishers. In Bjarnason and Thorlindsson [3] shows how lower quality of school life increases migration.

The fishery has a factory that processes the caught fish and gives job opportunities. The school provides a place for the children to learn. The event hall can be used for leisure time activities. Removing such an element may lead to certain groups of agents being left at a disadvantage and tend to migrate.

The hypothesis derived from these expectation is:

Removing an element from the fishery village will increase migration out of the village.

Part III

Outcome

Chapter 8

Results

This chapter describes the results to test the previously stated hypotheses. The first section shows hypothesis 1, the running condition and the results. The second section gives expected behavior, then analyses and discussion the results of the first section. For hypothesis , section three and four are used.

8.1 Results 1: Power vs fish population

Hypotheses 1: With a power oriented village the fish population will deplete to zero.

Run conditions value tree changes

The parameters for the run are the default parameters shown in the ODD analysis. The initialization run is run for 50 years (2400 ticks). There are a total of five initialization runs, that are used as starting population. For each power setting there are 50 runs, created by running each of the five initialization runs 10 times. The power settings range from 50 to 100 power, with a difference of 10 between each.

The value trees can have many perspectives, therefore some changes are made from the original value trees, to test the influence of those changes. The trees defined in the ODD will now be mentioned as *standard tree.* The following variations are used for the simulation runs.

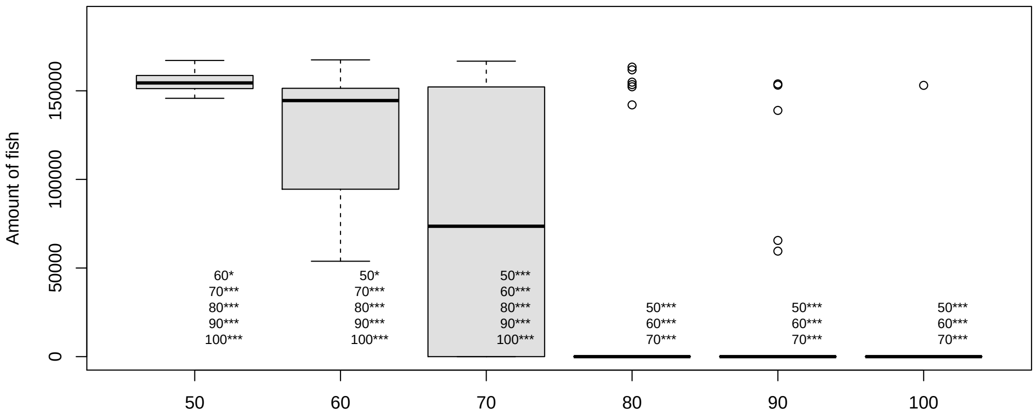
1. *Event Tree:* There are two types of social events in the simulation: free and commercial. At the moment attending a commercial event costs money and therefore is bad for wealth, and thus bad for power. A different perspective could be that commercial events are for the richer agents and depict status. This would positively influence power through the concrete value of status.

2. *Fish Tree:* The *fish a lot* action is good for wealth. But this perspective could change as the fish population gets in danger. When looking at the broader picture, one could say that fishing a lot would deplete the whole fish population, which is eventually bad for a fisher's income. Thus, the adjustment here is that *Fish a lot* gets is seen as negative on the perspective of wealth instead of a positive. This is a change that reflects long term wealth. While the *standard tree* is more in terms of short term wealth.

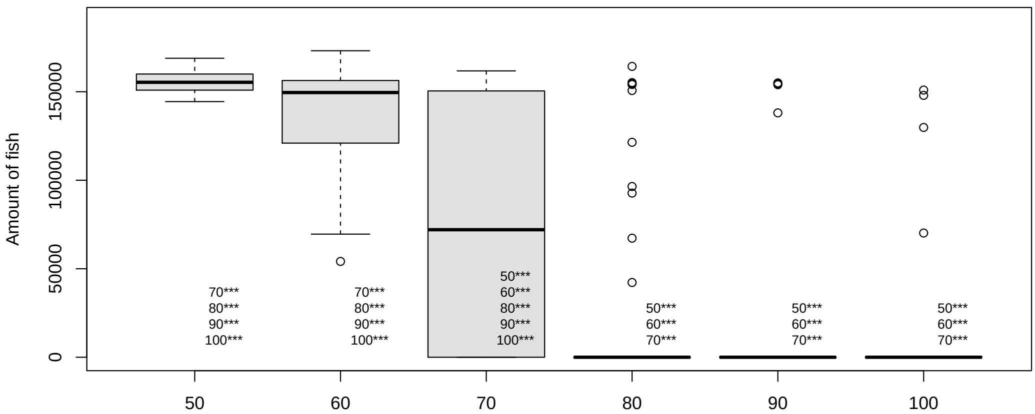
Outcome fish population

The final fish population distribution is plotted in the three figures, where each power setting has its own boxplot (Figures 8.1a to 8.1c). To test for significance an ANOVA test has been performed on the data. Significance has been found between the different power levels in the *standard tree*: F (5, 294) = 133.3, $p < 0.05$ (Figure 8.1a), and the *event tree* F (5, 294) = 91.14 $p < 0.05$ (Figure 8.1b) and with the *fish tree* F (5, 294) = 45.65 $p < 0.05$ (Figure 8.1c).

(a) **Power vs fish population - Standard tree**



(b) **Power vs fish population - Event tree**



(c) **Power vs fish population - Fish tree**

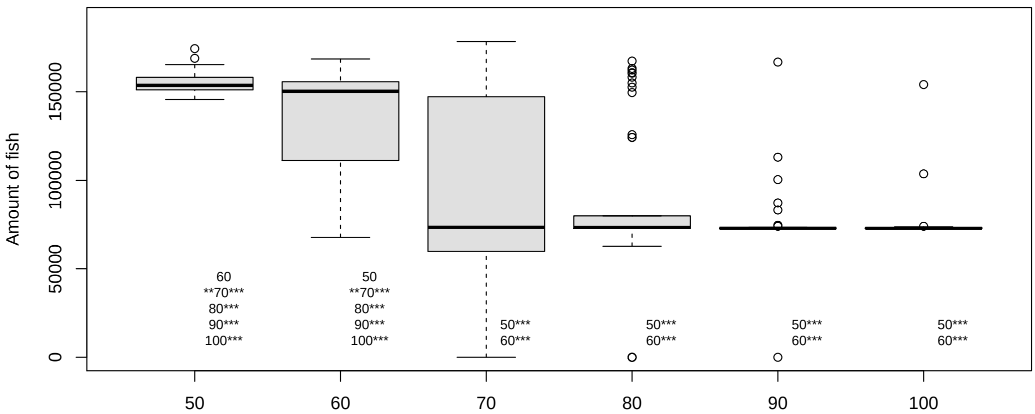


Figure 8.1: Indicates the amount of fish at the end of the run for different power settings, the different tables represent the different value trees used. Significance is indicated with $p \leq 0.05$ = *, $p \leq 0.01$ = **, $p \leq 0.001$ = ***

With the ANOVA test returning a significant difference, we performed a Tukey's HSD test to measure significance between different power settings within each of the figures. The numbers next to the boxplots show to which settings there is a significant difference, with asterisks indicating the p-value.

In the *standard tree* (Figure 8.1a) and *event tree* (Figure 8.1b) we see that the further the mean fish population goes down, the higher the power setting, and with very high power settings (80, 90 and 100), the fish population depletes in almost all of the runs. In the 70 power runs the result is very dispersed, with 50 and 60 power the fish population usually survives. There is no significant different between the *standard tree* and *event tree* results. Figure 8.1c shows different results for higher power settings. Instead of completely depleting the fish population, it converges to roughly the danger level (75.000).

Run conditions mixed power

In real life people do not have completely the same value priorities. This subsection shows, a population where the agents have mixed power priorities. The power settings are 50 power for 50% of the population, with 60, 70, 80, 90 or 100 power for the other 50%. And 60 power for 50% of the population, with 70, 80 and 90 power for the other 50%. Each setting got 50 runs where 10 runs, are done with each of the five initialization populations. The standard value trees are used.

Outcome mixed population

The ANOVA test returned a significant result for the fish population based on mixed power populations F (7, 392) = 12.76, $p < 0.05$. Figure 8.2 shows the results and indicates the significance between power mix settings. The results show that the higher the average power of the population, the lower the amount of fish. But the variance is slightly higher compared to results from the single power runs, for example when comparing mixed 50-70 power with pure 60 power.

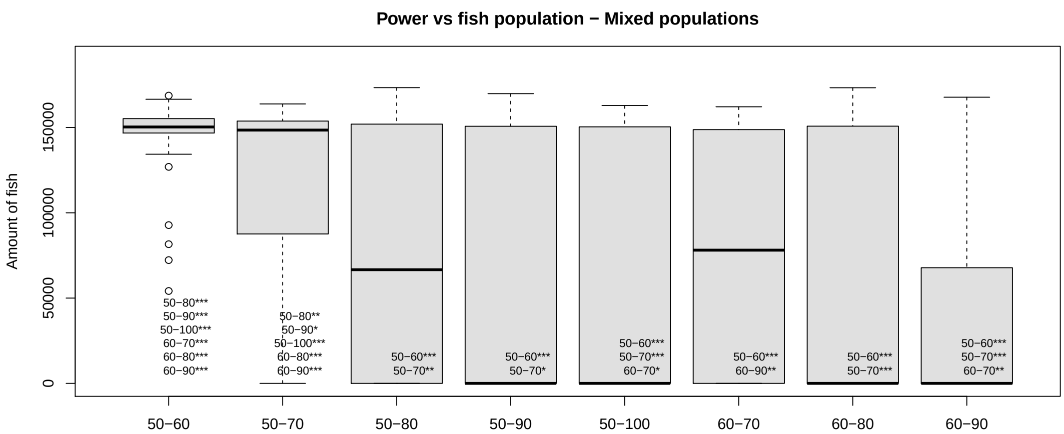


Figure 8.2: Indicates the amount of fish at the end of the run for different mixed power populations. Significance is indicated with $p \leq 0.05$ = *, $p \leq 0.01$ = **, $p \leq 0.001$ = *** $p \leq 0.05$ = *, $p \leq 0.01$ = **, $p \leq 0.001$ = ***

8.2 Results 1: Analyses and discussion

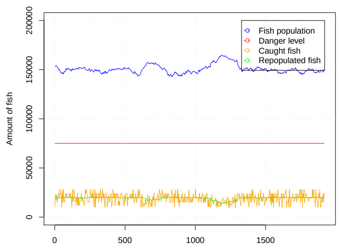
This section shows analyses and discussion of the results for hypothesis 1. Each section first provides some context by telling what is expected, then discusses the actual behavior.

Fish population over time

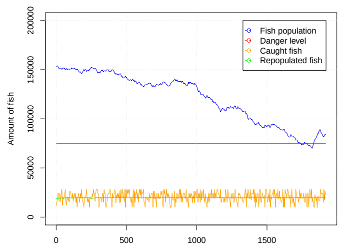
The fish population will stay at a value of 20.000 without human interaction. Introducing fishers can decrease the fish population, this is mainly dependent on how much they fish. It can be expected that increasing the power value, will cause the captain to perform more *fish a lot* actions, which causes the fishers to *fish a lot*, depleting the fish population.

Figure 8.3 shows the fish population for single runs over time. The fish population is shown in blue, the red line indicates the level at which the fish population is in danger according to the residents. This shows that a population with power 50 remains stable. As power increases the fish population decreases faster, with a power of 60 it manages to stay just above the danger level, at the end of the run. For a power 70 population the fish population depletes quite rapidly. The moment it hits the danger level it depletes less quickly, but at tick 1350, it starts depleting completely. With higher power settings the depletion slope becomes even steeper.

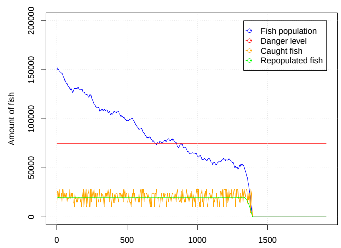
(a) **Ecosystem - power 50**



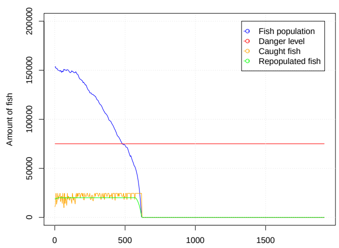
(b) **Ecosystem - power 60**



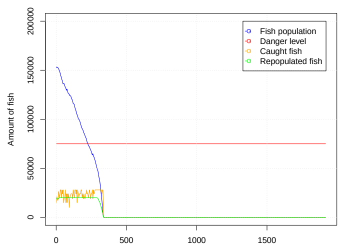
(c) **Ecosystem - power 70**



(d) **Ecosystem - power 80**



(e) **Ecosystem - power 90**



(f) **Ecosystem - power 100**

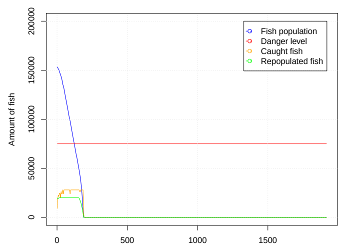


Figure 8.3: Fish population single run, with different power settings

Captain behavior and values

The ecological system is visible through the fish population plots, this shows the macro level phenomena. The following plots repeats the micro level behavior of captains on boats, by showing the actions and the water tanks' filled levels and thresholds. There are two boat, but this section shows only the most interesting boat. The plots with both captains can be found in the appendix. The fish action value tree, first mentioned in the ODD, is repeated here (Figure 8.4). It shows the three actions *fish a lot*, *fish medium* and *fish less*. The red circles indicate the actions, when the fish population is in danger.

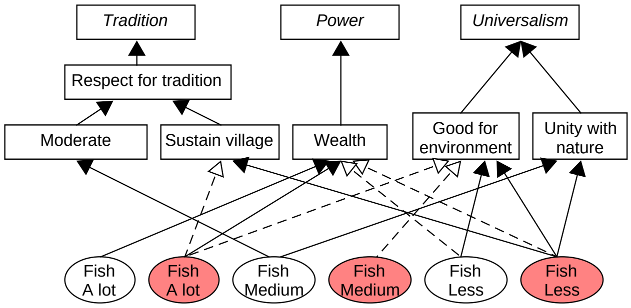


Figure 8.4: Fishing related value tree

Power 60: The fish population survives

A power 60 distribution is a mild distribution that leads universalism and self-direction values to be around 40. The fish population is not expected to deplete completely. The decline of fish will probably be slow, and when below the danger level the universalism and tradition values will prevent the frequent use of *fish a lot* actions (Figure 8.4).

Looking at the results, the fish population usually survives when there is a power 60 population. This is shown by Figure 8.5a, where the fish population is higher than zero at the end of the run. The interesting behavior can be found in the captain action (Figure 8.5b). The graph shows the frequency of actions in two different ways, the thinner more vague color shows the frequency, which is averaged on every three months (12 actions can be performed in that timespan). The thicker clearer color shows polynomial functions of degree 4 that are fitted to the averaged data and show

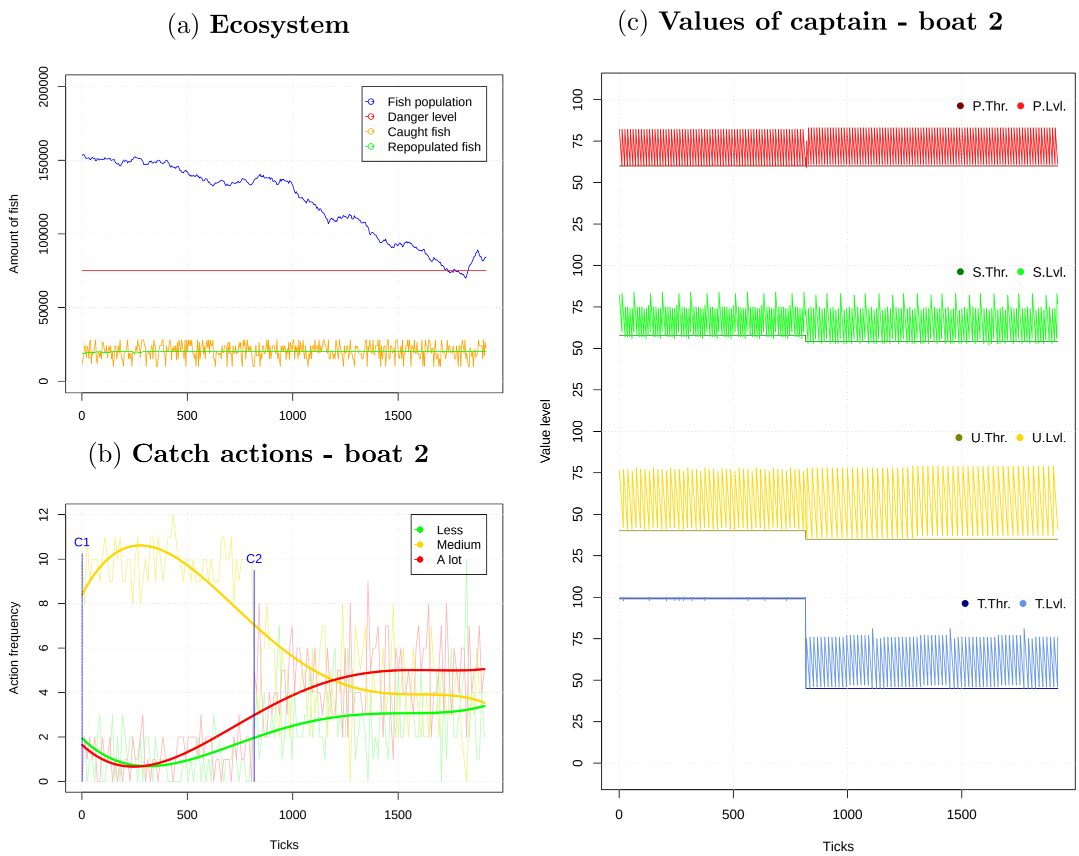


Figure 8.5: Behavior and values of captain - power: 60, value tree: *Standard tree*

the general trend. The blue lines indicate the points where the indicated captain start working at the boat.

The trend line shows that captain C1, performs mostly *fish medium* action and hardly any other actions. During this time period the fish population stay relatively stable, it declines only slightly. The second captain, C2, performs all actions, but prefers the *fish a lot* action. The effect of the action choices of captain C2, can be seen in the fish population, as it starts to decline even more. A small interesting spike can be seen near tick 1900, where the fish population dips below the danger level. At this point the captain performs more *fish less* actions, which is shown by the green spike.

To explain the action choices of the captains, Figure 8.5c shows their values. The P, S, U and T are respectively power, self-direction, universalism and tradition. Thr. means threshold and Lvl. indicates the filled level. Table 8.1 shows the value thresholds in numerical form and gives extra information about the captain. One interesting thing that is shown in Figure 8.5, is that captain C1, has an exceptionally high tradition. The captain performs mostly *fish medium* actions, since *fish medium* action satisfy tradition (Figure 8.4). This is in contrast with the other captain C2, who performs more *fish a lot* actions. Even though they both have the same power threshold. This shows that, the same level of values does not necessarily mean the captain performs the same actions. For captain C1, the extremely high tradition value, overrules the power action. The captain still manages to keeps its power satisfied, probably by performing other actions like donating and organizing events.

Boat	Captain	Start	End	P. Thr.	S. Thr	U.Thr	T.Thr	Boat capacity
2	C1	1	816	60	58	40	99	8
2	C2	817	1920	60	54	35	45	8

Table 8.1: Captain information - power: 60, value tree: *Standard tree*

Power 80: The fish population depletes

The fish population is expected to deplete since the population values power a lot. Since the power value is so high, the other values tradition and universalism cannot compete with the power value if the fish is in danger.

Figure 8.6a shows that, the fish population depletes with a power 80 population. Captain C1, performs mostly *fish a lot* actions (Figure 8.6b). This is because of its high power (Figure 8.6c). However the captain also performs the *fish medium* actions and even some *fish less* actions. At tick 149 captain C2 controls the boat, even though this captain has the same value priority as the first captain, i.e. $P > T > U > S$. The difference is shown not in the threshold, but in the filled level. While captain C1 had its power filled level above the threshold, captain C2 has its power below the threshold. This creates an increasing need to satisfy power, thus increasing the frequency of *fish a lot* even further. At tick 500, where the fish gets in danger, another interesting thing happens to the values of captain C2. The tradition value filled level drops below the threshold. This is expected, since the fishing value tree shows a negative impact on tradition, when the fish population is in danger and the action is *fish a lot*.

(a) **Ecosystem** (b) **Catch actions - boat 1** (c) **Values of captain - boat 1**

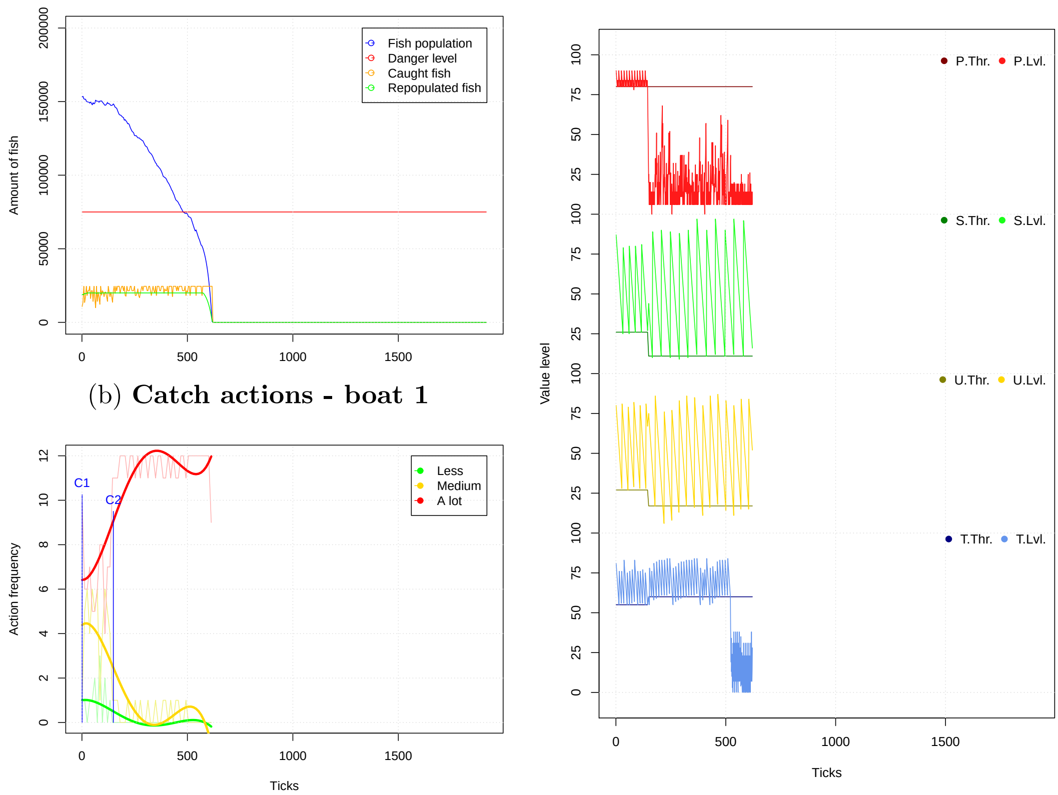


Figure 8.6: Behavior and values of captain - power: 80, value tree: *Standard tree*

Boat	Captain	Start	End	P. Thr.	S. Thr	U.Thr	T.Thr	Boat capacity
1	C1	1	144	80	26	27	55	8
1	C2	149	621	80	11	17	60	8

Table 8.2: Captain information - power: 80, value tree: *Standard tree*

Standard value tree vs Event value tree

Figures 8.1a and 8.1b show that there is hardly any difference between the *standard tree* and the *event tree*. However a change was expected, since this gives the agents more chances of satisfying their power value.

The unexpected result could be caused by the order, in which the value based actions are performed. As described in the ODD the order is: (1) draining of values, (2) select job, (3) fish action, (4) donations and (5) events. An action valuing power has a high chance of already satisfying it, in steps 2, 3 or 4. Especially a captain who gets power from its job automatically and when it perform the *fish a lot* action. The effect of changing the *event tree* is therefore marginal, because of the order of value based actions. Changing the order around or having a random order, may create interesting new results where captains get their power value satisfied and do less *fish a lot* actions.

Power 80 with fish tree: The fish population survives

It is expected that the fish population will survive, due to the change in value tree. The fish population will deplete until the danger level, after that point the *fish a lot* action becomes bad for power. This stops the captains, and thus the fishers from performing this action. The moment the fish population is healthy again, the captains will perform the *fish a lot action* and decrease the fish population until it is at the danger level.

Figure 8.7a shows the fish population depleting, until it reaches the danger level, after which it stays at the same level. There are three captains in this time period (Table 8.3) on boat 1. The first captain C1, initiates with mostly *fish a lot* actions, but at the point where the fish population reaches the danger level, it switches to many *fish medium* actions (Figure 8.7b) and some more *fish less* actions. The values of captain C1 are satisfied until the point, where the fish population is in danger. At this point both tradition and power drop drastically. With two values constantly below the thresholds, the chances are high for this captain to become unhappy, and quit the job.

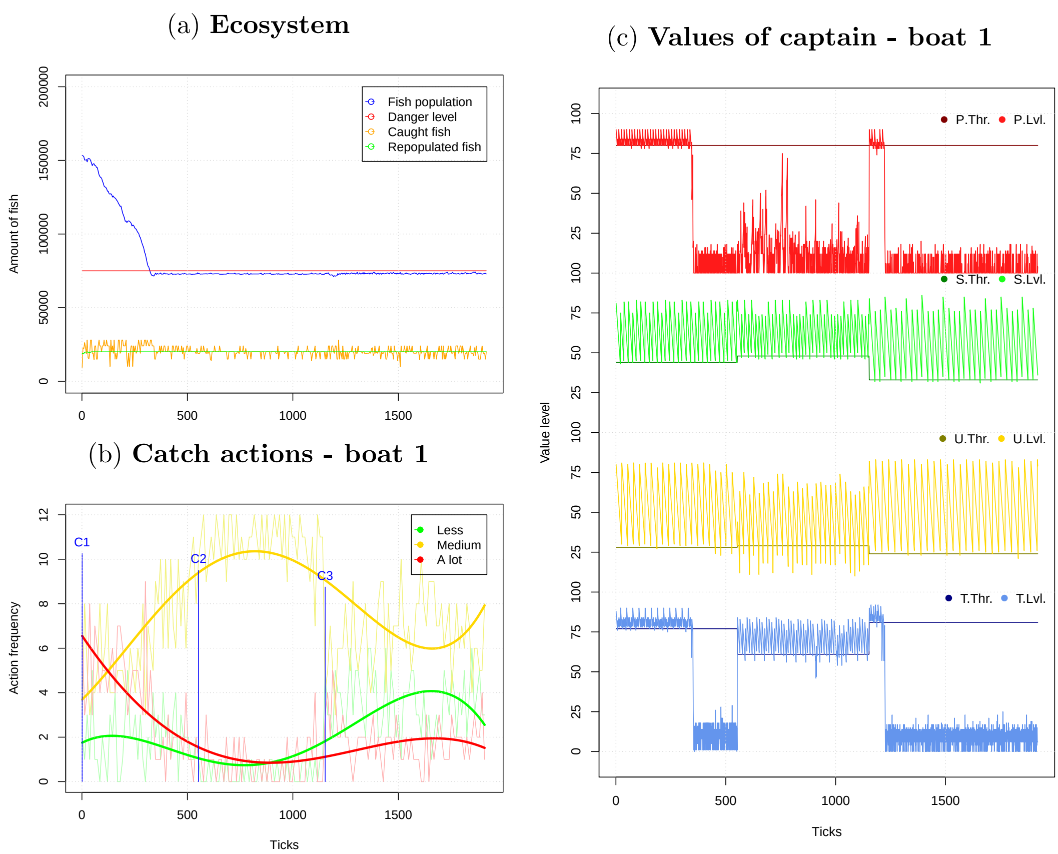


Figure 8.7: Behavior and values of captain - power: 80, value tree: *Fish tree*

Boat	Captain	Start	End	P. Thr.	S. Thr	U.Thr	T.Thr	Boat capacity
1	C1	1	552	80	44	28	77	8
1	C2	553	1152	80	48	29	61	8
1	C3	1153	1920	80	33	24	81	8

Table 8.3: Captain information - power: 80, value tree: *Fish tree*

The second captain, C2, performs even more *fish medium* actions and shows roughly the same behavior throughout its career. Note that the universalism value of this captain drops below the threshold further than for other captains. This can be explained by looking at the fishing value tree, which shows that both the *fish a lot* and *fish medium* have a negative impact on universalism.

The last captain C3, starts out with satisfied values in the beginning and has more frequent *fish a lot* actions, but quickly looses power and tradition. Following up on this the captain performs mostly *fish medium* actions and even more *fish less* actions than the *fish a lot* actions.

8.2.1 Quota

Another way to prevent overfishing that is applied in contemporary fishery is the use of a quota. This would also be interesting to apply within this simulation. The quota would be enforced, when the fish population is in danger and the population notices 'negative' changes in either the economical or social system. Concrete examples to look at are for example the happiness of people, migration and average money.

However when the fish population dropped below the danger level the effect was not noticeable on the happiness, migration and average money. The fish catch is decreased a bit, but not enough to reach the village as the factory is still making money. Even a complete depletion of the fish population is in terms of short term wealth a positive thing, since all fishers become unemployed and some start to work as factory worker, temporarily increasing the fish processed at the factory, giving a temporary boost to the economy. It is only after the factory runs out of fish, the village population gets hit by the depletion of fish. Yet this seems realistic, usually the majority of people, apart from some activists, do not put real effort until the effect are really obstructing the standard way of life. In most cases people will do what they have always done until it is too late.

8.3 Results 2: Removing basic needs vs migration

Hypotheses 2: Removing an element from the fishery village will increase migration out of the village.

Run conditions one element removed

The parameters for the run are the default parameters shown in the ODD analysis. The initialization run is run for 50 years (2400 ticks). There are a total of five initialization runs, that are used as starting population. There are five different value settings: all values at 50, self-direction 70, universalism 70, tradition 70 and power 70 (indicated by 50, s70, u70, t70 and p70 respectively). The elements that are removed are described in Table 8.4. For each value setting and each element setting there are 50 runs.

Removed	Description
None	No change to the simulation, serves as a control group
School	Removing the school inside the village forces people to move their children to the school outside the village, bringing in additional costs. The job of teacher is not available anymore.
Factory	There is less job opportunity, the Factory worker and Factory boss jobs are not possible anymore. Fishers can sell their fish to an abstract factory for 4 money per unit of fish, instead of 5.
Event hall	Removing the event hall removes the opportunity for residents to satisfy their values through events.

Table 8.4: Running conditions per removed element.

Outcome removing one element

Figures 8.8a and 8.8b show the impact on migration given different conditions. The first plot (Figure 8.8a) shows the count of migration initiative takers, which are adult or elderly residents, that decide to migrate and take their spouse and children under the age of 18 with them. The second plot shows the amount of children under the age of 18 that migrated (Figure 8.8b). The children migrate due to the decision of one of their parents, as children are not able to migrate only by themselves in this simulation.

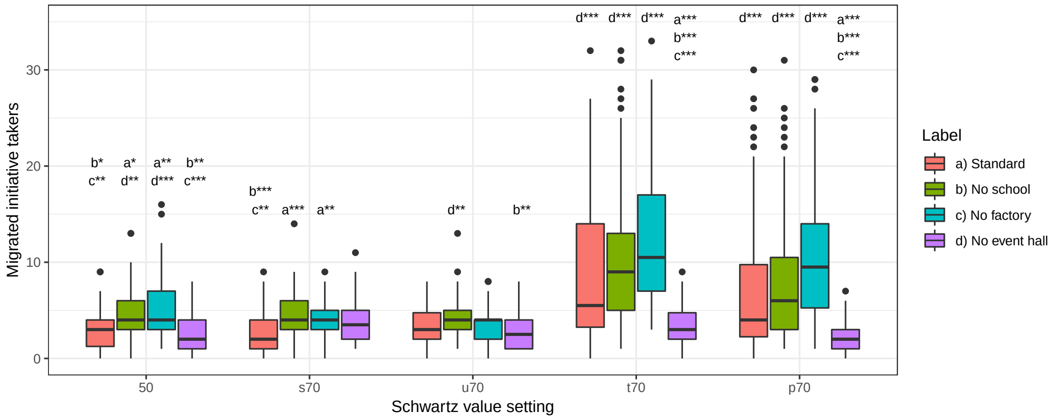
To test for significance an ANOVA was performed with groups that were separated by the abstract value priority (Table 8.5). With the TukeyHSD test the significance difference per agent run condition was calculated. Significance is indicated with asterisks above the boxplots (Figures 8.8a and 8.8b).

Setting	F(Df ind, Df res)	All 50	S. 70	U. 70	T. 70	P. 70
Initiative takers	$F(3, 196) =$	9.263	5.925	4.928	15.42	14.64
Children under 18	$F(3, 196) =$	20.76	10.74	15.5	9.47	12.23

Table 8.5: The results of the ANOVA where each group consists of the settings standard, no school, no factory and no event hall. The F values are shown where every result has a $p < 0.05$

For all values at 50 and self-direction at 70 there seems to be a significant effect when the school and factory are removed. But this effect is marginal as there is

(a) **Initiative taker migration with different elements removed**



(b) **Children under 18 migration with different elements removed**

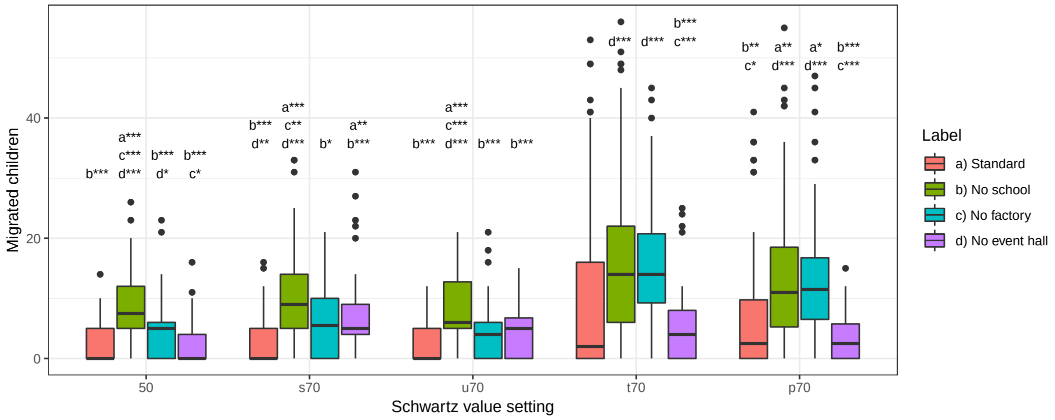


Figure 8.8: Indicates the amount of people that migrated throughout the run. Significance is indicated with the label and the p-value is indicated with asterisks $p \leq 0.05 = *$, $p \leq 0.01 = **$, $p \leq 0.001 = ***$

only a small difference in the amount of migrated initiative takers, and for the other value settings there is no significant difference. However Figure 8.8b shows that when removing the school there is a significant increase of children, that migrate for most of the value settings. This is not the case for the removal of the factory, which has no significant change in children migrated compared with the standard setting. A surprising result shown by the figure is that the removal of the event hall leads to either no significant difference, or with value setting tradition 70 and power 70 to a significant decrease in migration.

Run conditions multiple elements removed

The removal of the event hall lead to unexpected results. There could be multiple reasons for the decrease of migration when the event hall is removed. To further explore this anomaly it would be interesting to see what happens, when another element is removed along with the event hall. The chosen element to be removed is donation since this could serve as a way of satisfying values, when the event hall is removed. But when both are removed, this could lead to increased migration.

The additional conditions are described in Table 8.6, the standard and no event hall are not described here as we already have results from them. The run settings are the same as in the previous run: all values at 50, self-direction 70, universalism 70, tradition 70 and power 70 (indicated by 50, s70, u70, t70 and p70 respectively). For each value setting and each element setting there are 50 runs.

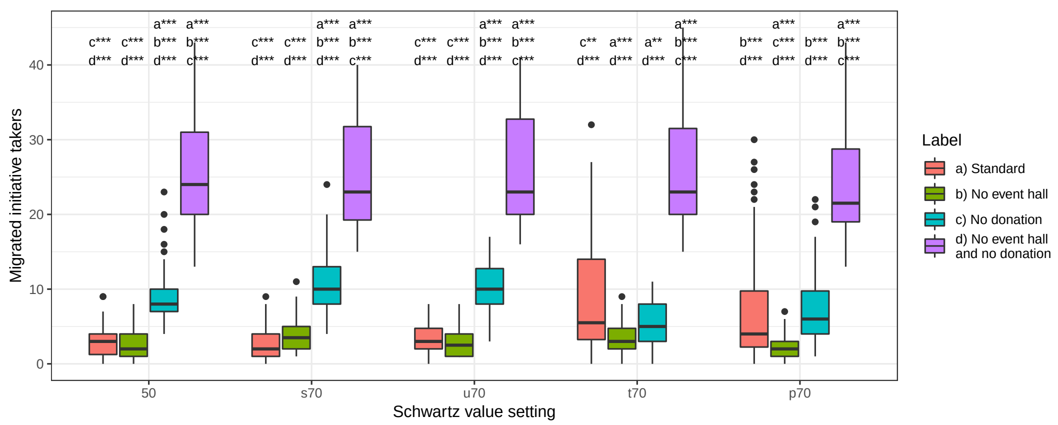
Removed	Description
Donation	Removes the possibility of donation and getting value satisfaction from donating as well as not donating.
Both	Removing both the event hall and the option to donate. This will make value only satisfy able through job selection and fishing.

Table 8.6: Running condition of no donation and; no donation and no event hall

Outcome removing multiple elements

Figures 8.9a and 8.9b show the migration results with the new settings. An ANOVA followed up by a TukeyHSD was performed to identify any significant results. The results of the ANOVA are shown in Table 8.7. The TukeyHSD significance is shown in the figures by an asterisk.

(a) **Initiative taker migration with multiple elements removed**



(b) **Children under 18 migration with multiple elements removed**

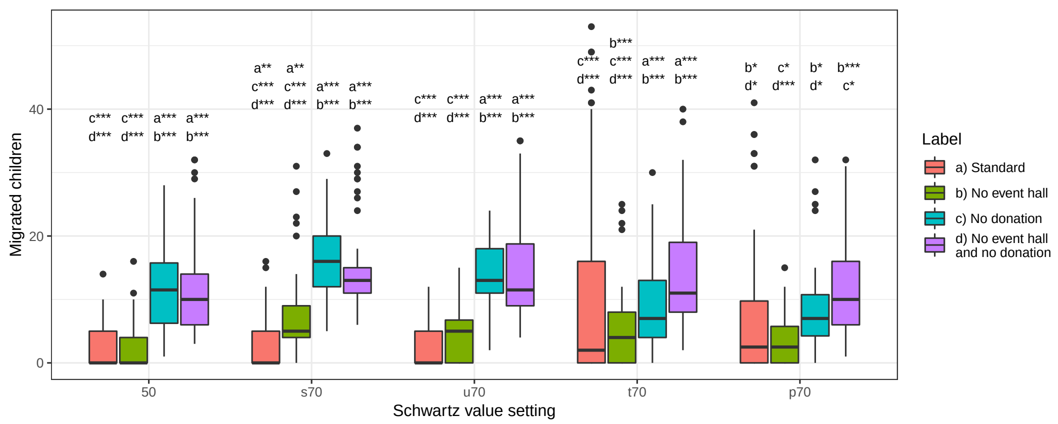


Figure 8.9: Indicates the amount of people that migrated throughout the run. Significance is indicated per bar with $p \leq 0.05 = *$, $p \leq 0.01 = **$, $p \leq 0.001 = ***$

The removal of the event hall has a decreased effect on migration, compared to the standard run. However the removal of donation increases the migration of initiative takers for value settings 50, s70 and u70 (Figure 8.9a). For a power oriented village it has no effect, but for a tradition village it has less variance above the median. The

Setting	F(Df ind, Df res)	All 50	S. 70	U. 70	T. 70	P. 70
Initiative takers	$F(3, 196) =$	264.2	276.1	313.7	137.3	112.8
Children under 18	$F(3, 196) =$	45.94	52	60.92	5.549	9.952

Table 8.7: The results of the ANOVA where each group consists of the settings standard, no event hall, no donation and 'no event hall and no donation'. The F values are shown where every result has a $p < 0.05$

trend in initiative takers and children migrated is roughly the same for no donation. The figure shows higher migration when donation is removed and lower migration, with the event hall removed. When both are removed the migration increases substantially for the initiative takers for all the value settings. For the children the migration is higher than the standard, but not such a substantial increase as for the initiative takers.

8.4 Results 2: Analyses and discussion

This section gives an explanation of the results by showing a single runs and the behavior of migration within these runs. Each section is provided by a small expectation followed by analyses and discussion.

No school

Removing the school forces parents to send their children to the school outside. This costs substantially more and can put parents with many children at a disadvantage. The teacher job is also removed, as agents could only work in the school inside the village.

When there is no school, the migration of children under 18 is higher than during standard runs. Children are dependent on their parents for migration, and thus the initiative takers of a single run are shown (Figure 8.10). The graph shows the values thresholds of the agents, the agent of age 25 had 5 children and the agent of age 37 had 6 children.

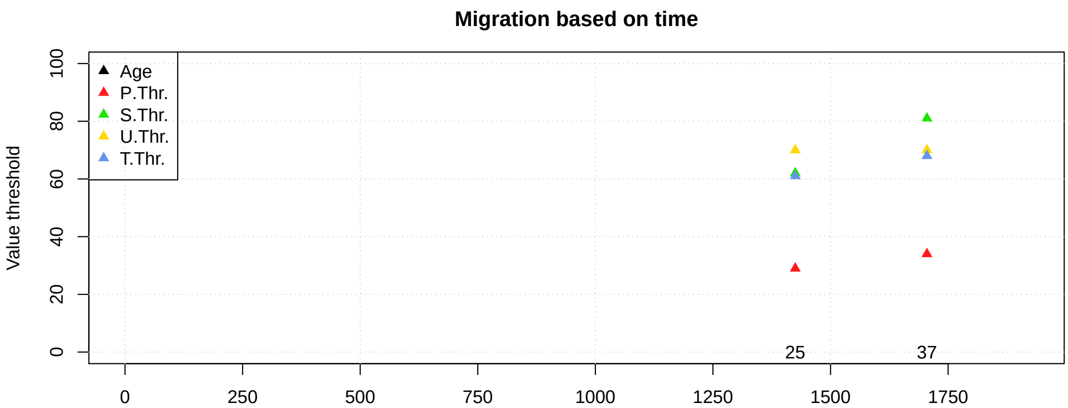


Figure 8.10: Migration of initiative takers for universalism 70 and no school. Agents are indicated by a notion of their age and the four value thresholds. In this case the resident of age 25 had 5 children and the resident of age 37 had 6 children.

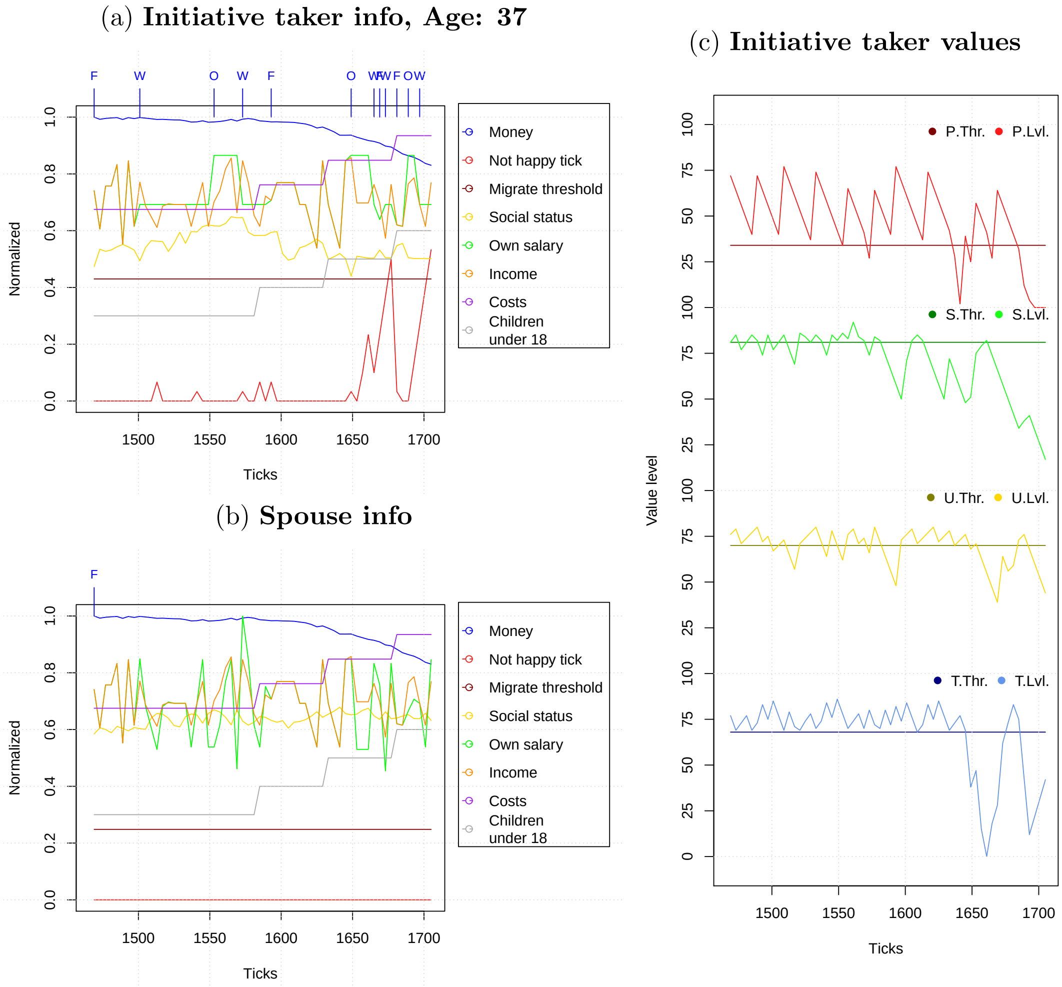


Figure 8.11: Information and values of last 5 years of migrated agents. The status of the agents is indicated with a character F: Fisher, O: Work out of town, W: Factory worker

Figure 8.11 shows that the agent of age 37 is relatively happy until tick 1650, since it can satisfy its values and its social status is larger than 0.25. The agent is switching jobs frequently, combined with performing events and donations, as it still has money, to satisfy its values. We can see a fluctuation of income, happening because its spouse is a fisher (Figure 8.11b), but this is no problem as the money level stays relatively stable. The couple decides to get more children, which increases their living cost substantially, to a point where it exceeds their income. As the living costs become higher than the income the agent cannot satisfy its values through donation and events, as these cost money. The values begin to drop more frequently and further below the thresholds (Figure 8.11c and the agent is changing jobs more frequently. At the same time it can be seen that the *not happy tick* is increasing as less than 2 values are satisfied. The moment the not happy tick gets above the migrate threshold, the agent has a chance to migrate. Around tick 1675 there is a short peak, but this gets restored by becoming a fisher which satisfies tradition and universalism. The fisher job is not sustainable as self-direction keeps decreasing, due to the actions of the captain. At the second peak of being not happy the agent migrates.

This shows how the increase of costs, above the income can prevent agents from satisfying their values. With no school in the village, the children go to the school outside of the village, increasing the costs even more. This gives families with many children more chance to migrate, as only by having a well paid job, those families can sustain, but those jobs are limited.

Power 70 standard run vs no event hall

The event hall is an abstraction of leisure time activities, to satisfy values. It is expected that removing the event hall leads to agents, not being able to satisfy their values enough. This can lead to migration of those agents.

In the standard run there many agents migrate with power and tradition oriented populations. In power and tradition oriented villages it is expected that there is more overfishing. For power the *fish a lot* action is performed more often and *fish less* is performed less often. In traditional villages many agents will take the fishing and factory worker job which creates an efficient fish processing system, but creates a higher chance of fish depletion as there are so many fishers. Figure 8.12 shows a standard run where the fish population was depleted at tick 469, followed by massive migration.

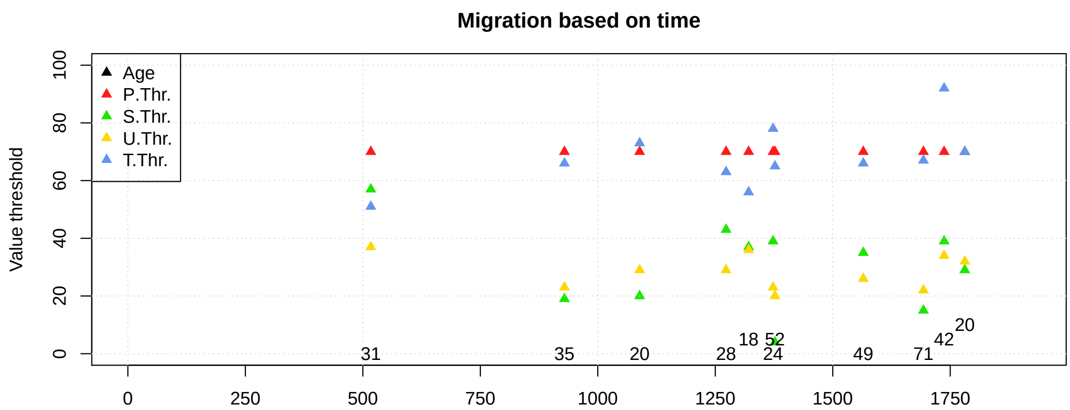


Figure 8.12: Migration of initiative takers for power 70 and standard setting. The fish population was depleted at tick 469

In the case of no school or no factory the same increase in migration is seen, but with no event hall the migration is decreased. Figure 8.13 shows a run where the fish population also depleted (at tick 813) but no massive migration follows. The main

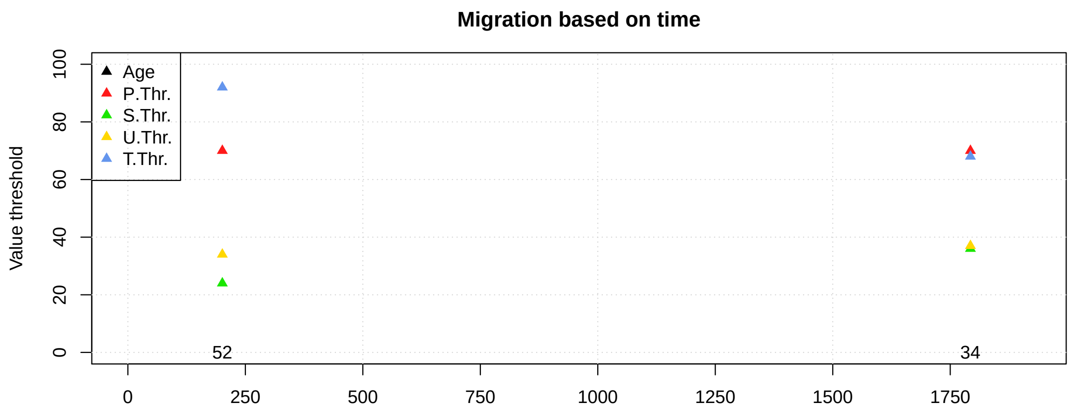


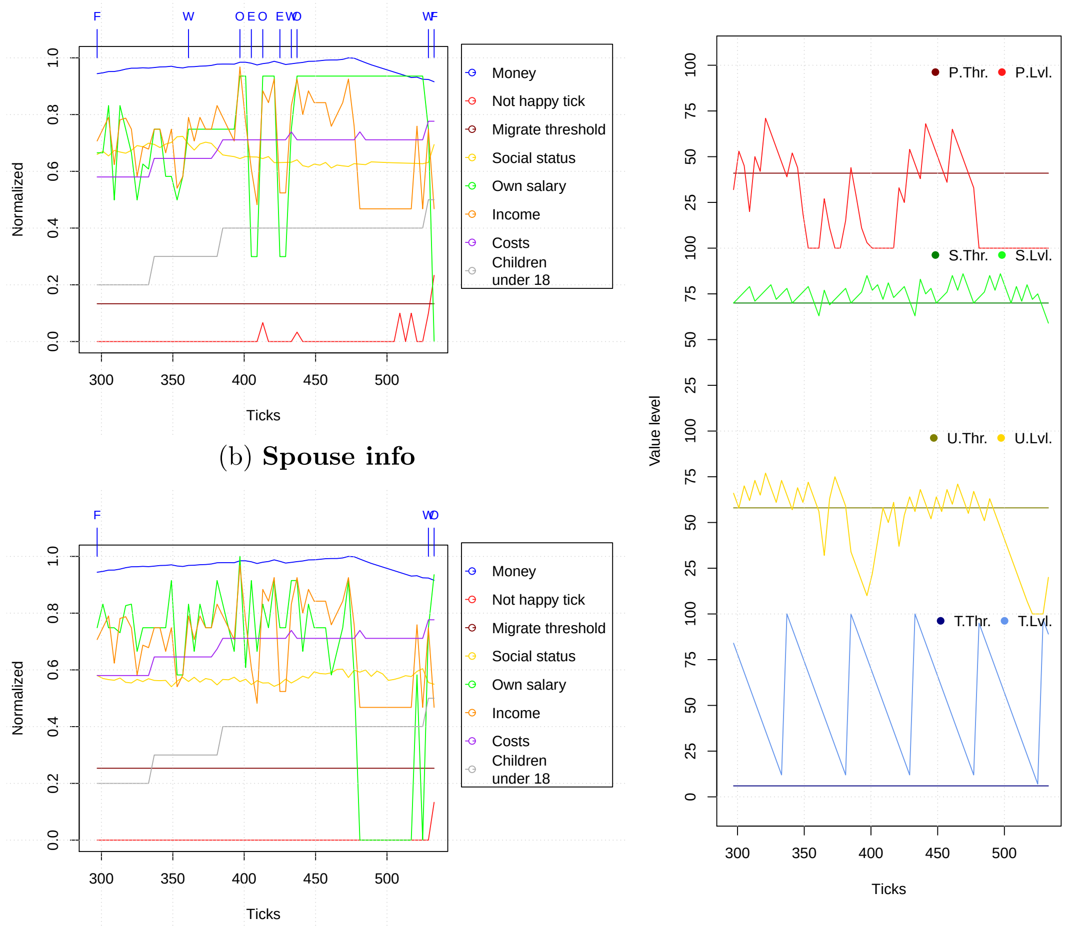
Figure 8.13: Migration of initiative takers for power 70 and no event hall. The fish population was depleted at tick 813

problem within these populations is overfishing, that leads to no income and with no income the population starts to migrate. However removing the event hall slows down this process between fish depletion, money loss and migration. The event hall allows agents to spend their money and gain some values, or with the commercial event also gain some money. However the money is not an investment for the village itself, as is donation. Removing the event hall, stops the agents from spending their money on events. Thus the money stays with the agents, until they decide to donate and with donations the money goes directly into the council, which supports the village.

No donation

The agents in the village contribute to the village by working and paying taxes. There is also a voluntary contribution which is donation, and this can be used to satisfy values. It is expected that removing donation will increase migration, as it has an impact on both values and support for the village.

There is a change in the migration when donation is removed for all values at 50, self-direction at 70 and universalism at 70. But no significant change in a traditional or power oriented village. This change will be explained here with a self-direction population as example. Figure 8.14 shows the information and values of an agent who migrated at tick 533, together with the information about the spouse.



(a) **Initiative taker info**

(b) **Spouse info**

(c) **Initiative taker values**

Figure 8.14: Information and values of last 5 years of migrated agents. The status of the agents is indicated with a character F: Fisher, O: Work out of town, W: Factory worker, E: Elderly caretaker

The agent has trouble with satisfying its power and universalism values. This has become harder because of the removal of donation. The only ways of satisfying power and universalism is through organizing events or with certain jobs. The agent struggles, but manages to keep at least two values satisfied for most of the time, tradition is also very low so very easy to satisfy. However at time tick 475 the spouse starts earning nothing and this decreases their income. With an income lower than the necessary costs, it cannot perform events and not satisfy its high need of self-direction. Because of the high self-direction and very low tradition, it has a low migration threshold and migrates almost immediately.

The income of the spouse decreased at time tick 475 and can be explained by Figure 8.15. These figures shows the amount of workers per type of job, with unimportant jobs being left out. This population of self-direction agents almost immediately gave up their factory worker job for a job as *worker out of town*. Leading to the decrease of the factory savings and eventually a bankrupt factory. At this point the factory tries to buy fish with the money gained from the council, but due to the low amount of factory workers and the expensive boss it is not able to gain profits. The point the factory becomes bankrupt is also the point where the spouse does not get money for its work as a fisher (Figure 8.14c).

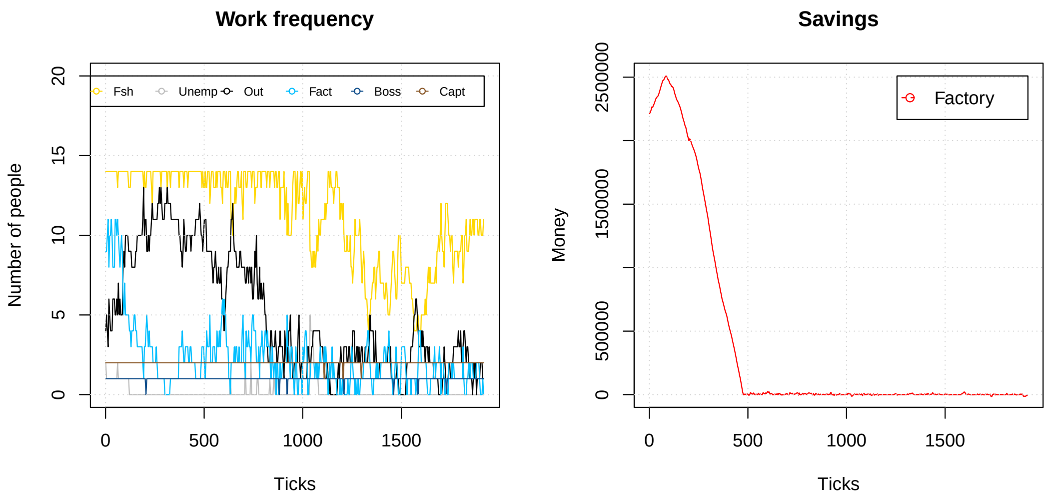


Figure 8.15: The number of agents per type of job (some jobs are left out for clarity sake), the right graph shows the decline of the factory

As mentioned previously a power and tradition population, does not migrate more when donation is removed. This can be explained by looking at the donation value trees, as there is a negative influence on power by donating and on tradition by not donating. When agents choose to donate they also have to select between a decrease of power or a decrease of tradition, which is not beneficial for tradition or power oriented village. The most important values are less likely to be decreased. This shows how important the value perspectives are, when donation would be bad for self-direction and universalism instead of power and tradition maybe the results could be flipped.

No donation and no event hall

Donation and the event hall both play an important role in value satisfaction. Removing donation lead to an increase in migration, but removing the event hall lead to a decrease in migration. By removing both, it is expected that most agents cannot satisfy their values anymore and migrate out of the village.

Figure 8.17 shows that many agents migrate immediately after the simulation starts. The elderly seems to migrate the fastest, as of the first six agents that migrate five of them are elderly. They have no possibility of satisfying their values with donation and the event hall removed. The adults can still satisfy their values with work but this is also limited, as not all types of work allow for multiple value satisfaction.

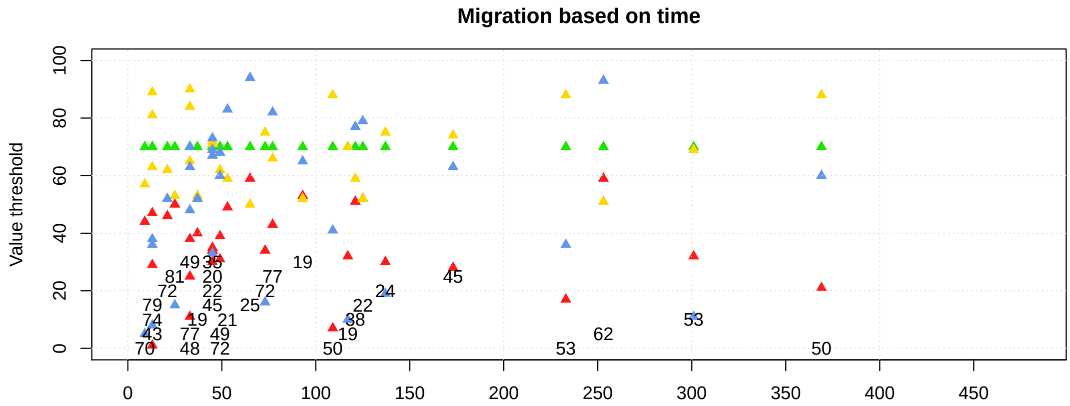


Figure 8.16: Global migration values of self-direction 70 with no donation, age is indicated at the bottom.

Figure 8.17 shows an agent that manages to stay somewhat longer, until tick 233. The agent can satisfy most values with the fisher job except for self-direction. Self-direction reaches the minimum but as long as the agent is happy, at least 2 values satisfied and social status > 0.25, and gets paid it will stay at its current job.

Around tick 75 tradition is below the threshold and here it changes its job, probably because power or universalism was also below the threshold but this is not visible on the graph since it is not fine grained enough. The agent changes its job to worker outside, but quickly gets a better opportunity as factory boss. This is its job for a couple of years but its universalism is slowly drained, the rest of values are satisfied by this job. Then it becomes mayor also satisfying the same values, but universalism is still low until it decides to become a fisher. This increases universalism but decreases self-direction, the next step is to become elderly caretaker for the universalism and tradition values. However the other values have drained so much, thus the agent decides to migrate.

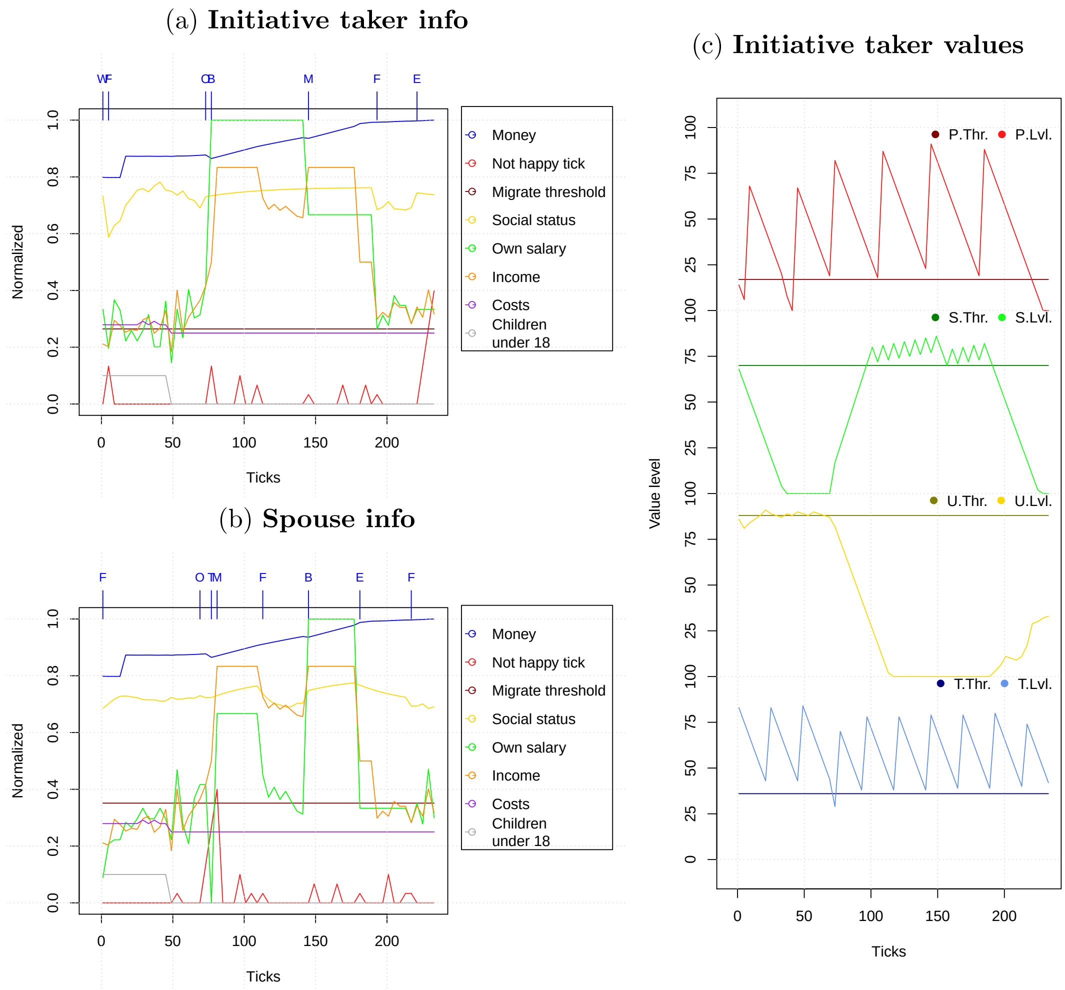


Figure 8.17: Information and values of last 5 years of migrated agents. The status of the agents is indicated with a character F: Fisher, O: Work out of town, W: Factory worker, T: Teacher, E: Elderly caretaker, B: Factory Boss, M: Mayor

Chapter 9

Discussion

In the previous chapter, we have presented the results of a value based simulation. This chapter forms the discussion around the used methods and interpretation of the results. It describes the weaknesses and strengths of our approach and discusses possibilities of further research.

9.1 General discussion

Most of the results supported the hypotheses, those that do not support the hypotheses, can also provide us with interesting insights in the model's strength and weaknesses. When testing the hypotheses we did not only look at the interacting systems, i.e. social, ecological and economical, but also at the definitions of those system. Especially the value framework that allows for different interpretation of the real world, by adjusting the perspectives. This change in perspective can create agents that have different personalities. The original value tree has a positive influence on power for the action *fish a lot*, even if the fish population is in danger. This models a short term perspective, where an agent cares about its short term wealth gain. It tries to get as many fish for itself, before the fish is completely depleted. The fish value tree has a changed perspective for the action *fish a lot*, when the fish population is in danger. In that case it has a negative influence on power instead of a positive. This models a long term view, where an agent sees its long term loss of income, when it keeps overfishing. The results show that this micro level change, has an effect on macro level. The fish population, with higher power values, does not deplete anymore.

The agents in the simulation use the value system as motivator for their decisions. The water tank system creates the need for value satisfaction over time, with more important values needing more frequent satisfaction. This system does not use long term planning, but responds on the values that have to be satisfied, at that point in time. Assume we have an agent that has a higher importance for power than for universalism. At a specific point in time, it can be the case that this agents tries to satisfy its universalism, but in the long term the agent will try to satisfy its power more frequently. This behavior is visible in the analyses of captains actions (see section results 1), where e.g. power oriented captains perform power satisfying actions.

The simulation contains value based decisions, not based on norms or goals. This is justified since the decisions that agents have to make are mostly long term, where values play an important role Schwartz [20]. According to Dechesne et al. [4], values form culture. Norms are dervied from culture and values. Where culture is the aggregate of values of all the agents. Norms can be seen as shortcuts for achieving important values. A norm guides behavior, by accompanying expectations on how to behave. This may be of less influence on long term behavior, such as choosing a job. However in donation actions, norms can play a larger role. In a society it can be the case that donating is the norm, when enough agents value universalism and tradition. The moment the society shifts to a power oriented society, for example through migration, it could be that the norm changes to not donating. It can be expected that such a norm would lead to a more strict form of donation, where either most agents donate or most agents do not donate. Only having values would show a gradual change in donation. It would be very interesting to add norms to the simulation and see, how the interplay of both the value framework for more long term decisions, and norms for the shorter term decisions.

Although the long term behavior complies with the values, there is no explicit notion of goals. This is a problem in some cases, for example when there is no school in the village. The goal of an agent should be to satisfy its values, thus it should prevent a state where this is not possible, i.e. a state where it does not have enough money. We can see that an agent's costs exceed its income, because it is getting more children (section 8.4 No school). This prevents it from participating in social events and donation, in the long run. If the agent would have a long term goal of satisfying its values, i.e. making sure its costs are not higher than its income, this *out-of-money problem* could be prevented. Implementing this would also require to connect the children get action to the goals. In this implementation getting children is not bound to values, but this of course possible to do. Some agents would not get many children out of money concern, and some would get many children as this is the traditional behavior of agents in their community.

Comparing the model with the original implementation of Heidari and Dignum [10], the effect of a more comprehensive value framework is noticeable. In the paper the fish catch was directly connected to the universalism and power values. An agent valuing power more would always try to get a bigger catch, while an agent valuing universalism mostly would go for the ecologically acceptable amount. However in this simulation the behavior is not necessarily the same throughout the run. In the results section it becomes clear that with the perspectives an agent can change its behavior. For example when the fish population is in danger, the fishers change their behavior. It also enables agents to perform actions that satisfy different values, which is more in line with real human behavior. A CEO of a company would be able to satisfy self-direction and power with its job, by respectively making its own decisions and having authority over others. However its other values have to be satisfied as well, and these could be satisfied in leisure time activities, like volunteering (for universalism) or visiting its grandmother (for tradition). This multitude of types of actions in a single agent is another merit of the applied value framework.

9.2 Future work

There are still many aspects in the simulation to discover. We changed perspectives, value distributions and saw how the village interacts when elements are removed. But other interesting things to look at can be for example the definition of happiness. Making changes here propagates to both job switching and migration. The definition states that an agent is happy, when two out of four values are satisfied and the social status is above 0.25. However it can be changed such that three of the four values have to be satisfied or agents are only happy when having a higher social status than the average.

Another interesting definition that could be changed is the definition of migration. It is now dependent on the time an agent is not happy; and an agent tradition and self-direction values. It could also be expanded by making it also dependent on whether an agent works outside of the village or has children in the school outside. This could lead specific groups to migrate earlier or even later, creating new patterns. Looking at the no school run, one could expect agents to migrate even faster.

The value trees are global in the simulation, meaning that each resident shares the same perspectives. Giving each resident an individual tree would be one of the next steps. Perspectives can then be formed by the social connections an agent has and the affiliations with for example its parents, friends and classmates or colleagues. Further more an agent's personality can create perspectives within a tree. For example an agent that generally has a short term or long term view on the world.

To relate to the work of van der Weide [25] once more, the leaf nodes of value trees, that are now actions in our implementation, can be changed to *outcomes of actions* as is described in his work. He describes how fuzzy logic can be used to create those expected outcomes of actions. This can give the actions even more dimensions, allowing for a finer distinction between for example, the wealth influence of jobs. The current framework allows for a positive, negative or neutral perspective. Applying fuzzy logic can give gradations like: very much, much, medium, low, lower, with either a positive, neutral or negative perspective.

Chapter 10

Conclusion

This thesis shows how a value framework can be implemented in an ABM to provide the agents with value based decision. The ABM models an Icelandic fishery village to give insights in contemporary problems regarding sustainability of the village and migration.

Based on the results with a more power oriented fishing society the fish population will deplete in more cases. However with an adaptation in the perspective on fishing, a long term perspective on power, could stop the depletion of the fish population, even in extremely power oriented villages. This shows part of the capability of a value based simulation, as it allows to create both short and long term behavior.

The other results show the importance of elements within the village. Removing the school leads to more migration among adults who have many children. The factory is only important in a very traditional village, as agents of other populations can work outside the village. Removing the event hall decreases migration in power and tradition oriented villages, as the fish population depletes, the absence of the event hall prevents agents to spend money. Due to these interesting and intuitive results, we can say that the value framework is an appropriate method for modeling values in agents.

Though much has been discussed in this thesis, the work regarding values in agents is far from over. The future possibilities of value trees, and the combination of values and norms open up enough new challenges.

Appendix A

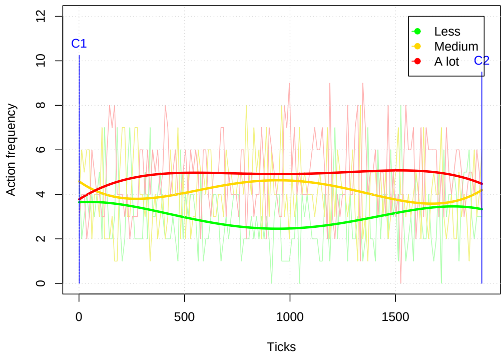
Captain behavior

This appendix chapter shows the behavior of captains on both boats. The results section only shows the captains at one boat.

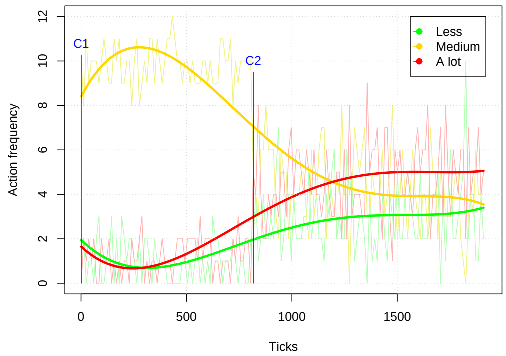
A.1 Captain behavior power at 60 - Standard tree

The full data of captains behavior showing both boats.

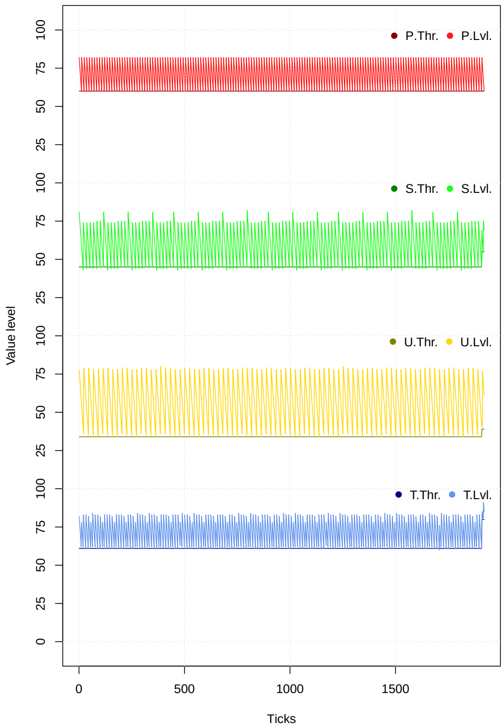
(a) **Catch actions - boat 1**



(c) **Catch actions - boat 2**



(b) **Values - boat 1**



(d) **Values - boat 2**

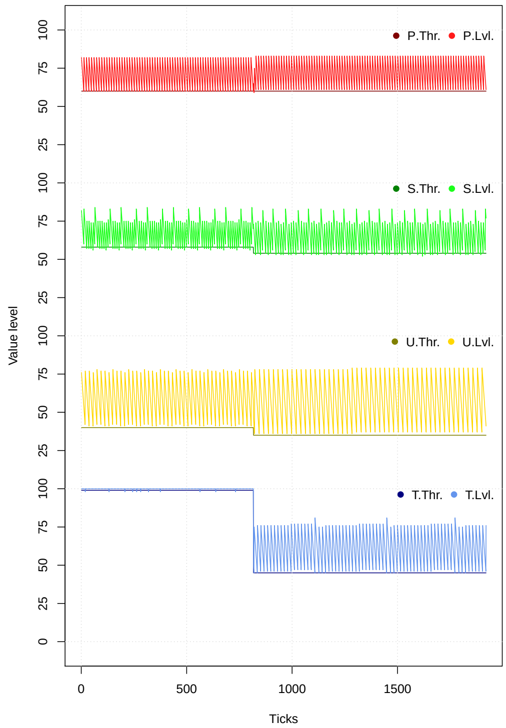
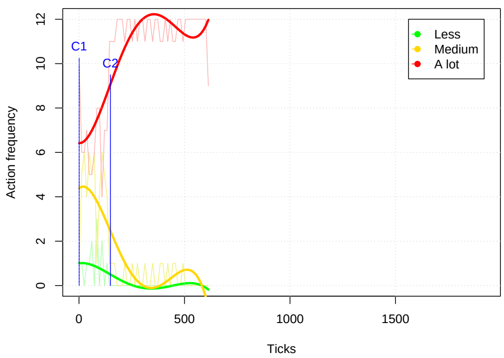


Figure A.1: Behavior and values of captain - power: 60 and value tree: *Standard tree*

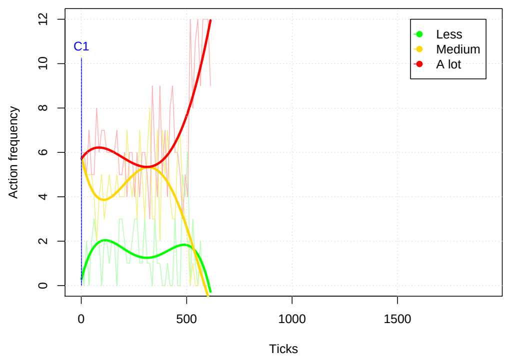
A.2 Captain behavior power at 80 - Standard tree

The full data of captains behavior showing both boats.

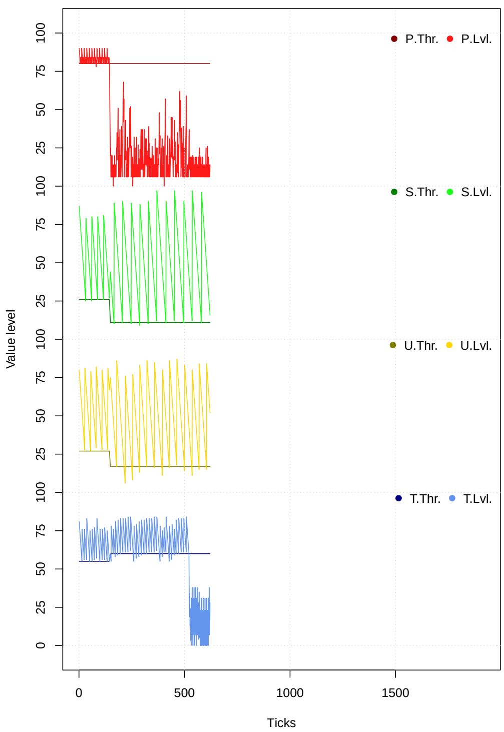
(a) **Catch actions - boat 1**



(c) **Catch actions - boat 2**



(b) **Values - boat 1**



(d) **Values - boat 2**

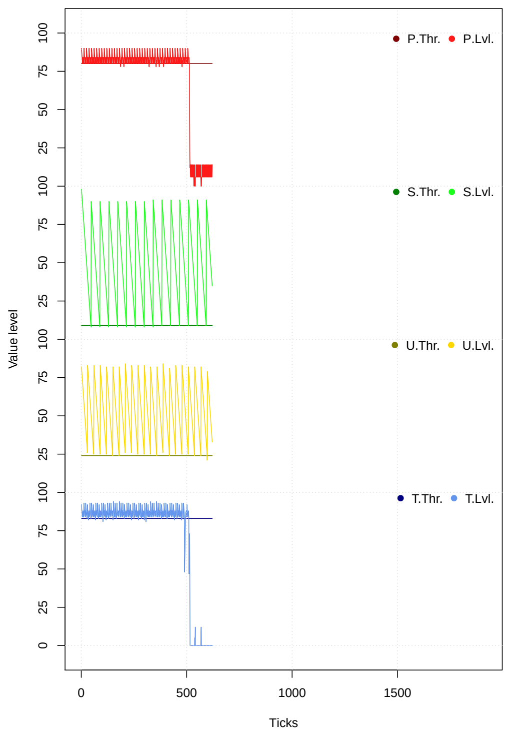
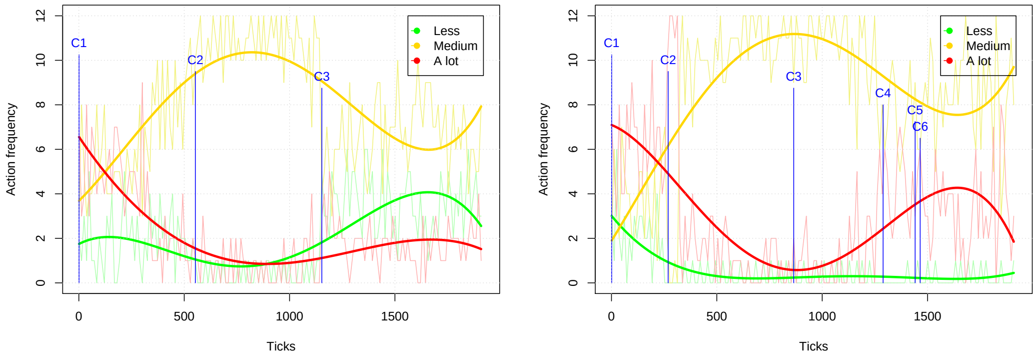


Figure A.2: Behavior and values of captain - power: 80 and value tree: *Standard tree*

A.3 Captain behavior power at 80 - Fish tree

The full data of captain behavior showing both boats.

(a) **Catch actions - boat 1** (c) **Catch actions - boat 2**



(b) **Values - boat 1** (d) **Values - boat 2**

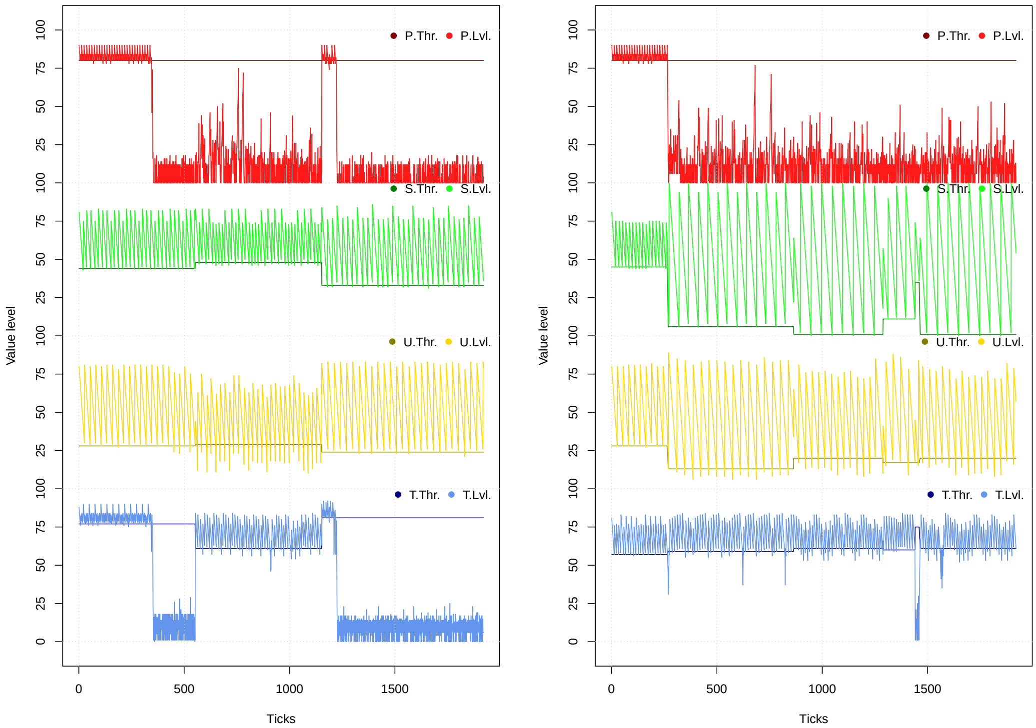


Figure A.3: Behavior and values of captain - power: 80 and value tree: *Fish tree*

Appendix B

Migration agent information

This appendix chapter shows the information and values of both the migration initiative taker and the spouse. The results section only shows the information of both agents, but not the values of both agents.

B.1 Migration information - u70 no school

(a) **Initiative taker info** (c) **Spouse info**

(b) **Initiative taker values** (d) **Spouse values**

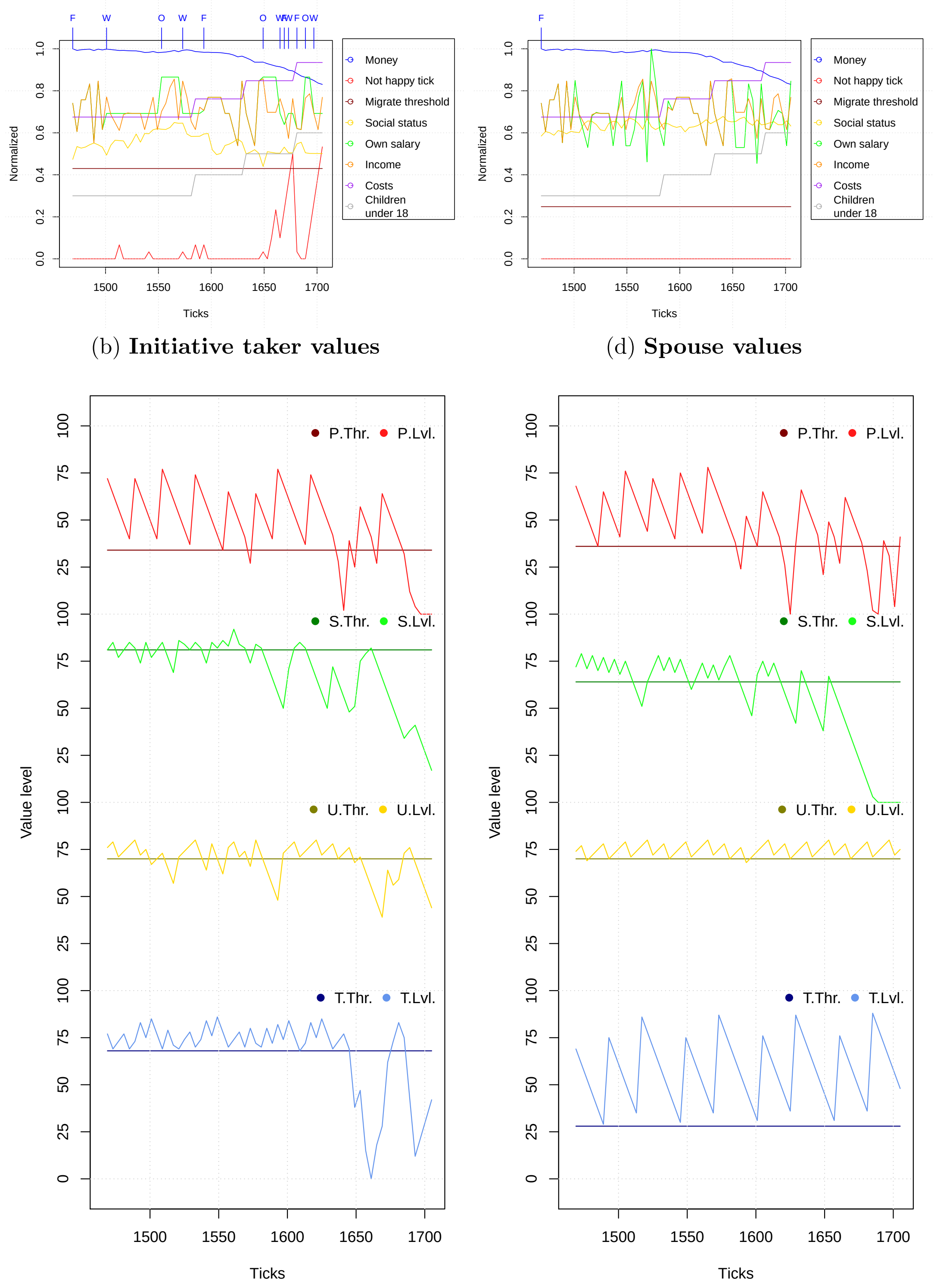
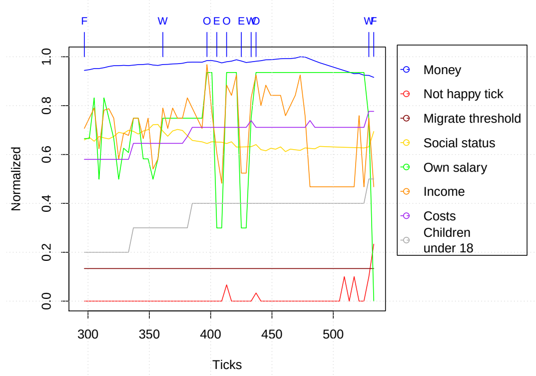


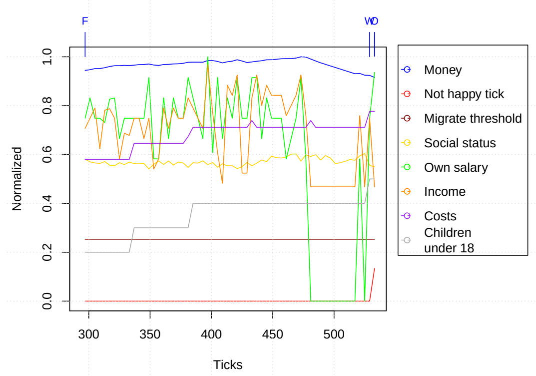
Figure B.1: Information and values of last 5 years of migrated agents. The status of the agents is indicated with a character F: Fisher, O: Work out of town, W: Factory worker

B.2 Migration information - s70 no donation

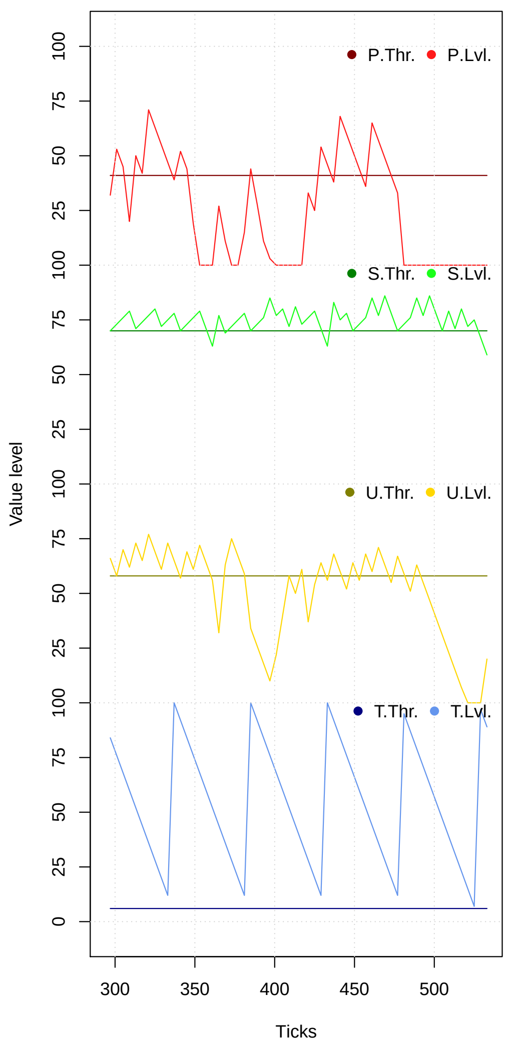
(a) **Initiative taker info**



(c) **Spouse info**



(b) **Initiative taker values**



(d) **Spouse values**

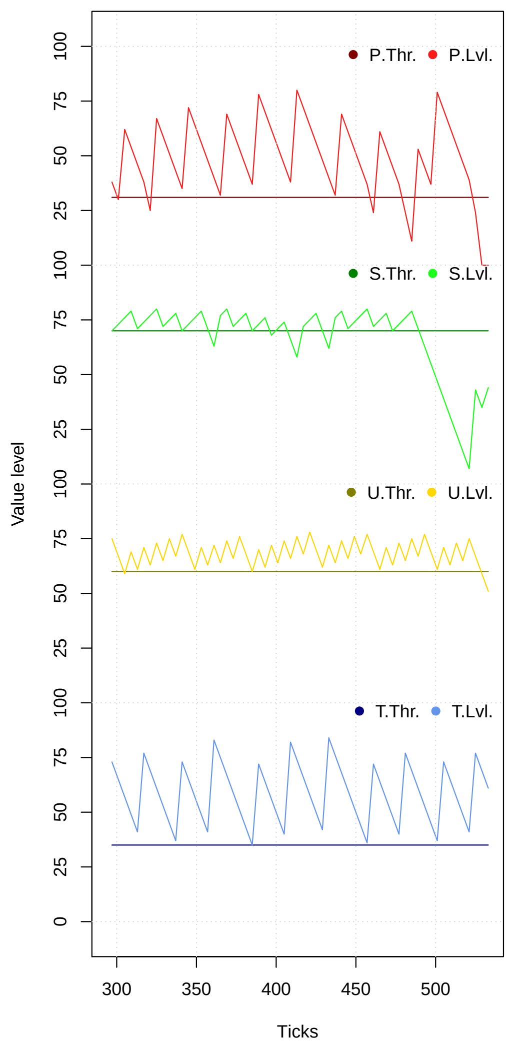


Figure B.2: Information and values of last 5 years of migrated agents. The status of the agents is indicated with a character F: Fisher, O: Work out of town, W: Factory worker, E: Elderly caretaker

B.3 Migration information - s70 no donation

(a) **Initiative taker info** (c) **Spouse info**

(b) **Initiative taker values** (d) **Spouse values**

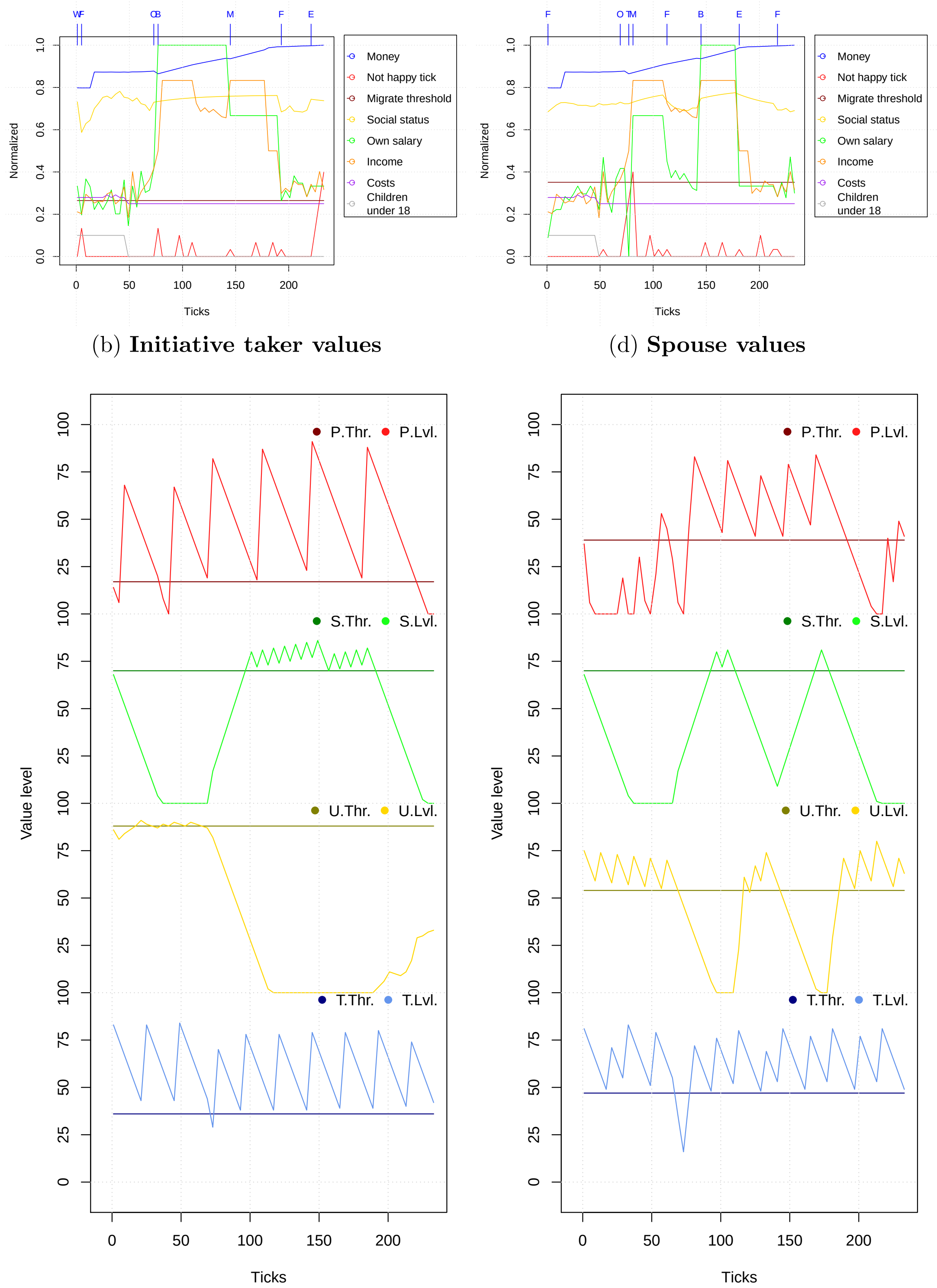


Figure B.3: Information and values of last 5 years of migrated agents. The status of the agents is indicated with a character F: Fisher, O: Work out of town, W: Factory worker, T: Teacher, E: Elderly caretaker, B: Factory Boss, M: Mayor

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