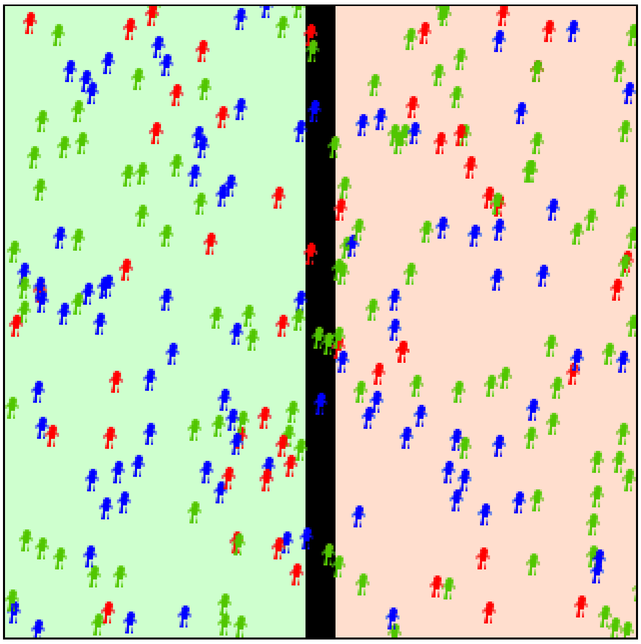
Dynamics of massive multiagent economies: Simulation and analysis of inherent problems

Diploma thesis
by Kai Spitzley



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Abstract

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Massive multiplayer environments are very popular these days. Despite the fun they offer to their players these systems have long been suffering from the same economic problems, inflation being the most prominent one. Some of these problems have real-world equivalents, some do not.
Due to the chaotic nature of complex systems like these several flaws or misconceptions cannot be found during beta testing and surface only when thousands of players already populate the world. (which, obviously, is to be avoided) This work analyzes the cause and effect of typical problems and tries to model a characteristic economy in Netlogo, a multiagent simulation language. Problems found in current systems are expected to arise in the simulation as well.
Agents are supposed to simulate average human player behaviour in an environment which has to be kept very abstract to accommodate a wide range of different games. Several suggestions for economic improvement have been made and, if possible, these will be applied to the simulation to observe their impact.

An online version of the multiagent simulation is available at http://heechee.net/mmorpgsim/

Preface

It all started with a paper on inequality in MMORPGs (Massive Multiplayer Online Role-Playing Games) I happened to read shortly before arriving in Finland. It hinted at system inherent problems and left me with a feeling that there are some interesting things that deserve a closer look.

Since my studies in engineering cybernetics are interdisciplinary by default I ventured into other fields as often as possible. After a rewarding journey into theoretical physics during my student research project I was planning to write my diploma thesis at a different lab than my home university's usual cooperation partner. Fortunately, Prof. Hämäläinen of the Systems Analysis Laboratory allowed me to work under the 'patronage' of his lab. Thus I was able to further dwell on my ideas for my thesis.

I deliberately chose a multiagent approach to simulate this economy since I've modeled plenty of systems in differential equations during my studies so an agent-based approach seemed refreshingly different and more appropriate for the problem at hand. While I've never taken part in any multiplayer environments myself I'm interested in analysing the system and player behaviour which seems to follow certain patterns, independent from the MMORPG being played.

This work should (at least in principle) be comprehensible to most readers, independent from their academic backgrounds. It wants to inspire others to take the risk and peek into different fields of work to learn something new, yes, but also something different.

I hope reading this work will be as much fun for you as writing it was for me.

Espoo, in the summer of 2004 Kai Spitzley

To Ivonne
and my family.
Thank you so very, very much.

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1 Introduction

1.1 MMORPG ?

MMORPGs (aka Massive Multiplayer Online Role-Playing Games) are very popular these days. They are virtual, persistent worlds where people can engage in social interaction, adventuring, trading or any mixture in between. *Persistence* of the environment means that it continues running on a server while players log into and out of the game. Once a player enters the world, they can engage in a variety of activities with others who are accessing the game the same way from all over the world. Players are usually represented by an avatar, that is, graphical representations of the characters they play. MMORPG developers are in charge of supervising the virtual world and offering the users a constantly updated set of new activities and enhancements to ascertain the interest of players. [Mmo04]

Despite the fun they offer to their players these systems have long been suffering from the same economic problems, inflation being the most prominent one. Some of these problems have real-world equivalents, some do not. During modelling we'll get an idea of what makes those virtual worlds go round and at the end of this chapter we'll take a look at a generic MMORPG which combines elements of the most common games available.

Lately MMORPGs have been a center of research although mainly in social sciences and only rarely in economics. However, one prominent example is a paper by Edward Castronova [Cas01], a professor in economics. He examined the virtual world called Norrath, home of the MMORPG *Everquest*, which has a gross national product somewhere between that of Russia and Bulgaria. At SSRN, the web's primary source for academic papers in law, finance, management, and economics, this paper currently ranks third all-time in all subjects and first in economics which proves that this subject promises some interesting fields for research.

1.2 Aims

The first aim is to analyze the cause and effect of typical problems in current MMORPG systems by common sense on one hand (chapters 4 and 5) and by using a simulated environment on the other (chapter 3). Problems found in current systems are expected to arise in the simulation as well.

We'll try to model a characteristic economy in which we can put and observe agents that mimic average human player behaviour. This environment has to be kept very abstract to accommodate a wide range of different games. Several suggestions for economic improvement have been made and, if possible, these will be applied to the simulation to observe their impact. This environment might be used to test future improvements as well although, as we will see, different systems will give rise to different player behaviour which in turn leads to other types of problems.

Another big aim was to get a feel for multiagent simulations and their advantages compared to differential equation systems since I've worked plenty with the latter. A sort of selfish goal but an interesting one nevertheless.

It will also be interesting to analyze problems that do not have any real-world counterparts, i.e. the goal of online games (and their economy) is to keep players happy (and thus keep them paying their monthly fees) - we can safely assume that this is far from the truth in real-world economies.

During the remainder of this chapter I'll give a little introduction on multi-agent systems (MAS) and why they are an appropriate tool for our task. Then we'll examine a generic example of an average MMORPG to get an idea of what usually happens in these worlds. Since we'll develop a player model as well as a world model in chapter two we'll need a working knowledge of an average day in the virtual world. In chapter three we'll learn about the tools used to run and observe our system. Here we'll start implementing our models into the actual simulation in a first rudimentary player economy. The simulation will be refined and extended as we go ahead. The analysis in the next two chapters will be based mostly on common sense and logical deduction instead of the simulation although we will frequently refer to it. Chapter four examines the main problems that arise in those systems. Chief among those are inflation, foraging players, inequality of commodity distribution and several others to be found in real world economies as well. While there are also cheaters in real economies their virtual equivalents take on a different form. Suggested solutions are introduced in chapter five. Here we'll examine improvements that have been suggested or implemented by other game designers, players or critics in official letters, websites/forums or other games. We'll try and assess their economic impact and whether their influence might produce unexpected problems in another aspect of our complex economy. After that, in chapter six, we'll decide whether we can deduce anything useful from the preceding ideas.

1.3 Multi-agent systems

Usually dynamic systems are modelled in systems of differential equations. In our example suitable variables for observation would be (among others) resources, current monetary volume in circulation or player happiness. To increase the latter (and keep it at a high level) is the main goal of MMORPGs after all. Unhappy customers are lost customers.

Conventional simulations start from a set of equations to derive statements about cause-effect relationships. However, finding all relevant relationships in complex dynamic environments like our MMORPG economy is a nontrivial task, hence most of these models often state very strong assumptions which limit their plausibility and usefulness in explaining certain phenomena. Furthermore, it is unlikely that all players follow the same principles of behaviour, as assumed in most such models. To avoid these deficiencies, we base our simulation on the economic behaviour of single agents. We thereby do not need to identify all cause-event relationships in advance, since they are expected to arise from the interplay of the individual actors. [Grimm] To simulate different types of players we can assign random values to certain character traits, this will be explained in detail in the next chapter. Modelling as a multi-agent system is also very suitable since the crucial events that have the highest impact on the overall economy consist of interactions between the players themselves.

A distinguishing mark of multiagent systems is emergent behaviour. Through the interaction of its parts the system exhibits a behaviour that one part in itself is not capable of and is not working towards. Although there is no leader, patterns emerge due to the behaviour of individuals and the interactions that occur among them.

An example of emergence is the synchronized flashing of fireflies (which has a NetLogo model as well - see [NetFF]). It is a fine example of how a distributed system (i.e. a system with many interacting elements, but no 'leader') can coordinate itself without any central coordinator using only the interactions between the individual fireflies. At first people were puzzled how thousands and thousands of fireflies, which are not very intelligent creatures, manage to coordinate their flashings on such a vast scale. In the 1960s the biologist James Buck caught several fireflies and through observation discovered that they could not only emit a flash but also adjust their own rhythm, depending on flashes in their surroundings. By using a flashlight he was able to speed up or slow down the cycles of single fireflies. By influencing each other huge flocks of fireflies will eventually light up in sync with each other. No single firefly is aware of this emergent phenomena. It is the result of hundreds of thousands of interactions.

An interesting analogy are the numerous pacemaker cells in the human heart that synchronize using each other. If they go out of sync, life-threatening fibrillation would be the result and instead of a flashlight, an electric shock (using a heart defibrillator) is used to make them beat synchronously again. In this case biological evolution had a reason for choosing this multiagent mechanism: since there is no leader the death of one cell doesn't threaten the survival of the whole system. On the other hand, synchronisation is not always desired. When people suffer from epileptic attacks their brain cells fire in unison although none of the cells is 'epileptic' by itself. To put it another way, one brain cell has no idea about the thought it carries - these are emergent patterns.

We can (before getting too metaphysical about the mind) take a new look at our system now - players follow their own agenda and do not have the whole system in mind. No individual is solely responsible for inflation or overproduction and no single agent can counter it. (this leads to an interesting view on trade laws) The behaviour of the system as a whole, including all its members, exhibits these patterns. This reminds us of the classic "Tragedy of the Commons" example. It deals with grazing sheep on a common pasture (as was typical of town commons in 19th century England). If each shepherd follows his or her own best interest, that shepherd will use as much of the common grazing land as possible, regardless of what other shepherds do. If all shepherds follow this assumption, however, all of the grass will be depleted and none of them will prosper. While these thoughts could lead us to the prisoner's dilemma and deeper into game theory it will suffice to say that the global effects and their repercussions that interest us are consequences that arise from the interactions of numerous agents.

"Artificial life is concerned with generating lifelike behaviour. Thus, it focuses on the problem of creating behaviour generators." [Lan89]

And thus our focus is on the agents, our artificial players. Instead of cause-effect relationships we need to understand player behaviour. (I didn't say it would be any easier.)

1.4 A generic example

Before we start modelling our players and their world we need to know what everyday life in an average MMORPG looks like. Some technical details (players logging into and out of the game, people playing more than one character, disconnection issues) will resurface later on so we can safely skip them for now as we're only interested in the game's economic mechanics.

Usually players start out in towns which are mainly used for social interaction and trade. These can be a medieval village, a modern megalopolis or a futuristic megacity. Here players meet and socialize, decide to (team up and) go on quests, buy necessary equipment or status symbols or train their character. Since most people (at least this is the game designer's assumption) have their own ideas on character development we end up with lots of different player characters with varying abilities and skills (which range from stealing or begging to tailoring and alchemy). This leads to players bargaining for items or services that other players can provide. A warrior might need a new sword from a blacksmith. This blacksmith struck his finger this morning and needs a healing spell from a cleric. This very cleric has run out of spell ingredients and needs to visit the shop run by a forest ranger.

Outside of town (where the ranger ventures to find the necessary ingredients) the world is different. While in the safety of guarded towns crime and murder are rare, there is no guaranteed security in the wilderness. Monsters and malicious players (roleplaying *is* a central point in these games after all) roam these areas. Players may form a party in town to head out together and destroy an orc hideout since people who accomplish noble deeds like these are rewarded experience points (which raise attributes like strength, dexterity or magical ability) or money which can be used to further develop the character, i.e. buying stronger weapons, training at a famous swordsman's school or buying a little pet dragon to show off. (these status symbols are important money sinks as we will later see)

Of course players can be 'killed' but if death was as frustrating as it is in the real world the MMORPG creators would soon run out of customers. Usually players have to roam the world as ghosts for some time until they find a priest or shrine where they can be resurrected, then return to their place of death to find their belongings. Some games have introduced insurances in case of death - for a moderate price players can have their items insured which prevents other players from looting their corpses; an interesting aspect that lacks a real world counterpart and another effort from the game designers to introduce yet another money sink.

Since players have limited capacity to carry the treasures they've earned on quests or bartered they need a place to stow them away. One option are banks that provide safe deposit boxes, another option is buying a place to live in and to put one's items. Equipment that is dropped outside of player owned areas is removed from the game after some time. This so-called 'garbage-collection' prevents server congestion but is also another money/commodity sink which is not to be underestimated. We'll return to this when we talk about the problem of hoarding.

In addition to monsters, there are also benign computer controlled characters, so called NPCs (non-player-characters). They are scripts run by the game designers and thus another way to influence the economy. Most NPCs exist in the form of shopkeepers that sell and buy items. This ensures that a) items not produced by players (due to economic reasons) are readily available and that b) players can sell their items to somebody in case no player is interested. This touches on the subject of non-market incentives which we will return to later on. We'll get there.

2 Modelling

In our modelling process we need to stay as abstract as possible since the simulation is supposed to accommodate medieval environments as well as sci-fi worlds. This of course implies that there is a general (obviously very abstract) structure inherent in those types of games that varies only slightly between systems. Whether that is the case we hope to establish during the course of this work. There will necessarily be numerous parameters that will have to be tweaked to accommodate different game models.

After developing a model in this chapter we'll implement a rudimentary economy in the next chapter and will shape it to a certain game's aspect's needs, staying as versatile and abstract as possible.

In our case a good simulation consists of an appropriate player model and a suitable world model. The player model is a bit tricky since player behaviour changes during the course of a game or between different games and there are no certain rules to begin with. After all, people are free to choose their character and act in a way they might not be allowed to in the real world. Player model parameters need to be identified through beta testing (which is still far from the conditions we have shortly after launch) or plain old experience. The world model gives us full control over the parameters that affect the environment - whether (to be explained later) the economic flow is open or closed, items decay or how general probabilities of encountering other players or non-player characters (NPCs) affect exchange among them.

2.1 Agents

One of the first questions is how many types of agents (called *breeds* in Netlogo) do we need ? At least one type of agent, the player, is mandatory. Since one representative player is unlikely to sufficiently mirror all aspects of gameplay we could either use several breeds (adventurers, socializers, etc.) or one player with various attributes that are randomized at initialization. Normal distribution will lead to fairly balanced (in terms of predictability) player behaviour with only few exceptions. Depending on the requirements we could also employ uniform distribution which in turn will produce a wild mix of player types with all sorts of extremes. Other characters in the game like NPCs and monsters do not need to be modelled as agents since they only represent an interface between the player and the system and do not exhibit complex behaviour themselves. In our simulation we'll let players interact with the server resources directly. That means instead of fighting a monster (which basically is a moving container created by the game mechanics) and taking it's belongings as a reward we'll let our players take the monster's belongings straight from the game's resource pool. Whether he encounters a monster and is successful (i.e. wins the fight) or not depends on numerous simulation parameters like monster strength and -density in the current area, player stats, interaction probabilities and more. Non aggressive entities that present resources for harvesting (i.e. animals consisting of meat and fur, robots consisting of metal and oil) belong to the same category and are not explicitly implemented. Another sort of actors are town guards that attack criminals (players who arbitrarily attack other players) to keep law and order. They and similar environmental scripts serve no other purpose than support and establish rules in the game world without actively taking part in it (although the criminals might disagree).

Now we'll start carving out our player model.

2.2 *Player Model*

While decisions of a single person may be incredibly complex in itself (at least we boldly assume them to be) it is our hope that thousands of players become a pretty predictable lot and behave according to certain rules which we try to incorporate into our player model. We assume that player behaviour doesn't change drastically during the course of a game and people stick to the character they choose. If that proves to be wrong we can implement some sort of adaptive behaviour to simulate behaviour change or learning. (payoff vectors are an interesting option, see [Grimm])

There are several parameters that affect a player's actions, we'll divide them into traits and properties.

2.2.1 Traits

Traits refer to the simulation itself and don't have any technical equivalent in the game's code. They represent parameters that affect player decisions during the course of a game which we can manipulate to create certain player characters. They pertain to the human behind the avatar. These player traits will be randomized upon initialization and stay constant throughout the rest of the simulation. We may change the type of randomization (uniform or normal distribution, variance) to produce homogeneous or heterogeneous player populations but we'll restrict our intervention to the startup phase.

One player attribute that has a huge impact on the economy is the tendency to hoard things. Foraging players will severely hurt a closed system (more on that later on), thus this is an aspect that needs to be incorporated into our player model. Greed, apart from leading to stockpiling, will also influence player trades since pack rats are more reluctant to part with their belongings than average players. Whether a player decides to leave the safety of town and accomplish a quest instead of socializing with the locals depends on whether he is adventurous or prefers to play the game for social interaction. Whether he is of a risky nature or not determines the actions he takes while on a quest. A reserved player might choose a safer quest with little to win while the reckless swashbuckler might risk losing most of his wealth for fame and glory or precious treasures.

Richard A. Bartle, an MMORPG designer, suggests four types of players: "Four approaches to playing MUDs (Multi-User-

Dungeons) are identified and described. These approaches may arise from the inter-relationship of two dimensions of playing style: action versus interaction, and world-oriented versus player-oriented." [Bartle] Figure 2.1 shows his approach. We will examine this model with economic aspects in mind. The achiever (having certain adventurous traits we mentioned before) is interested in quests and acquiring experience points to further strengthen his character and achieve everything there is to achieve, he is the prime example of a consumer who needs the latest weapons, best skills and flashiest items. That's why especially this type of player depends on a working economy. If he can't reach his goals because the economy is not working he will grow frustrated. Examples are stale game worlds because of hoarding or too many rich players because of vast amounts of money which is easily obtainable (which makes achieving a certain status very easy and therefore less attractive). Seemingly arbitrary price fluctuations will also keep him from reaching his goals and pose another source of frustration.

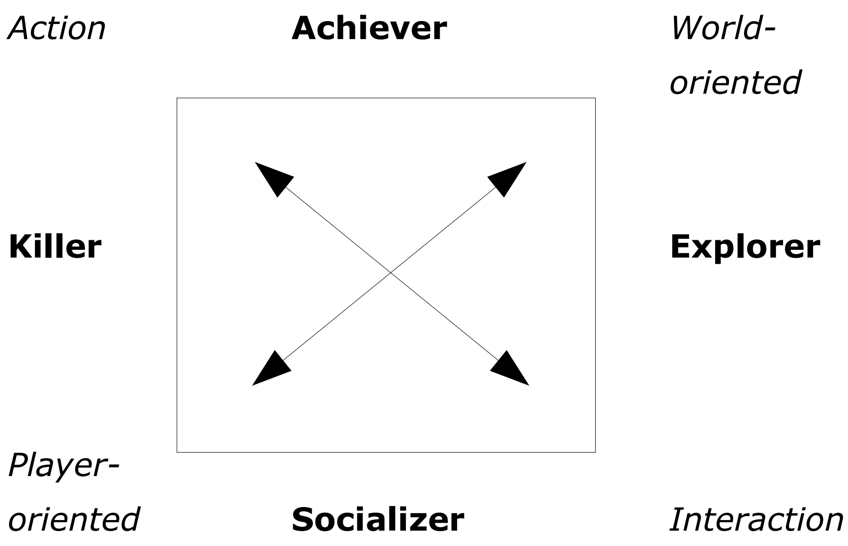

Figure 2.1 Bartle's player types

The socializer is to be found in cities where lots of players mingle and interact. Chatting and socializing is the main reason why those types of people join games. Concerning economic aspects, this player type regards trade as a means to communicate. These players usually take on a producer role and set up a shop, a bar or similar gathering places. Haggling about prices is part of their player-to-player relationships and they will of course prefer prices that are determined by supply and demand. Die-hard traders might be regarded as a mixture of achievers and socializers since they have the rare ability to obtain money in towns. Basically the wilderness is a money source and cities are drains so successful traders help to redistribute wealth among the players (to their own advantage, of course). Achievers might settle for a worse deal to get the weapon they need to go on their next quest and bring even more wealth back to town.

We'll mainly concentrate on the action vs interaction axis since those two types exert most of the economic influence. Explorers are like adventurers is many ways and concerning economic impact there is not a huge difference. Player killers are important when player happiness is concerned, we'll talk about that next. While this used to be a big problem in the early days player killing or PKing, as it is often written (and often in conjunction with various curses) is better under control in current systems. Most environments have safety zones (cities) where PKing is not permitted and severely punished. One has to differentiate between PKing (which is the bad aspect of it: so called *grief players* attacking other players to annoy them and ruin their gaming experience) and intended combat (Player vs Player - PvP). Most game designers have acknowledged PvP as an important part of an MMORPG and set up special areas/servers where PvP is permitted. This way grief playing can be avoided, not altogether, but at least to a certain extent. The grief playing problem leads us to another factor: player happiness. This is actually the most important indicator in our economy and, unfortunately, the most difficult to measure and model. Unlike real world markets, having pleased participants is the prime aspect around which our economy revolves. We'll assume that player happiness decreases gradually over time since people will get bored if nothing happens. Their interest in the virtual world gets a boost from accomplishing quests and gaining from it, be it treasure, experience or prestige. Even taking part in a quest (successful or not) or engaging in a fight will keep players interested (a victorious one obviously even more so). It is crucial to note that positive experiences aren't the only things that make a game enjoyable. Being robbed by another player or losing an epic battle is also part of the experience, the sheer process of interacting is the spice in the MMORPG soup. Keeping players occupied is one thing, rewarding them is another. Naturally people will stick to a game that throws valuable (albeit virtual) items at their feet. Gaining wealth, interesting things for their inventories and status symbols are an important part of today's online games. The same goes for interaction between players. While some people's main goals are to develop their characters, most gamers like to brag about it. If you weren't into exchanging experiences with others you most probably wouldn't choose an MMORPG to spend your time with, would you ? We'll talk about game world size later since interaction is not properly possible if the environment is too huge and players start to miss the 'multi' in MMORPG.

Prestige, just like in everyday life, is a thing many people strive for. The same applies to virtual life. Players form groups to accomplish tasks together and gain recognition among other players. The act of forming a group is another common action in MMORPGs. Depending on the setting they are called parties, factions, guilds, clans, squads and range from a couple of players to huge organizations that consist of thousands of players. These are the main factors that increase player happiness: interaction, achievement and entertainment (in terms of keeping gamers occupied).

On the other hand, people get frustrated by monotonous gameplay. Vast areas with few players or other things to interact with will turn off potential subscribers so the world needs to be permanently adjusted and reconfigured.

Interestingly, death isn't as much of a nuisance as one would think. Most players have died several times but keep playing anyway since a) death is not the end, just an inconvenience and b) without death the combats would be pretty meaningless so it indirectly helps participants to enjoy the game by means of excitement and a feeling of accomplishment after having won a difficult battle. Bad economy is by far the greatest problem affecting player satisfaction. Here bad economy has to be read in terms of *bad for the player*. If players cannot properly exercise their desired economic actions like producing or trading they will grow tired of it and look for more promising lands (i.e. a different MMORPG). To sum it up, virtually every interaction has to include some sort of happiness modifier which we will quantify during the simulation phase. Of course, an adventurer will look for different things than the socializer. This list of player types and their traits is probably not complete and it remains to be seen whether our simulation encompasses enough traits to properly represent the pool of different player types.

Our model depends on one hand on company's player models and what they think what players expect from a game and on the other hand on what people really do intent to do in these virtual worlds.

2.2.2 Properties

Properties refer to the game itself and mirror aspects that are incorporated into the game, so called players stats. They pertain to the player's ingame persona, their avatar. While they don't influence player decisions they might influence the result of such decisions. An example would be a player deciding to attack a monster since he/she is an adventurous person. The outcome of the resulting battle is determined by his/her properties, i.e. strength (depending on the difficulty of the quest at hand). Power/strength combines all combat abilities like dexterity and similar physical attributes, including numerous skills ranging from archery to melee combat. This is important in PvP combat and quest success and corresponds to player experience. The longer a player has been inside the game world the stronger he usually is. Mental abilities like intelligence and magic proficiency influence so many aspects that there's no need to implement them separately. Crucial skills that involve bartering or stealing, however, need to be implemented since they directly influence interaction between players and can be included as a transaction modifier. Thieves and excellent traders will be better off in any 'transaction' (be it theft or barter). We can use experience as an indicator for that. It is important to note that this experience (called XP from now on - experience points) is of a technical nature, a player parameter measured in plain numbers. It is not the experience of the human playing the game but a simple scale unit to measure the advancement of his avatar. This is a property. The trait would be that experienced players (humans) are usually more knowledgeable about the game's environment and have spent much time exchanging goods or information with other players. We'll stick to properties in this section.

Players with many XP's get bonuses on several skills that make it easier or faster to accomplish certain actions. I was tempted to measure experience points in percent since usually there is a limit as to how many experience points one can acquire. This is a dilemma for the game designers since they have to introduce some kind of boundary so the players have something to strive for. If the scale is not limited achievers will have nothing to aim for. Usually the designers introduce more challenges as soon as the first players start reaching the highest levels. Either new, more difficult worlds to explore or ten more levels to reach. This leads to a competition between the designers raising the bars and the players reaching for them. There have been suggestions that this XP scheme and levelling system is the sole reason for economic problems and will always lead to the same disastrous results. We'll return to that in chapter four. For now we'll measure XP in points and will then scale the population from the most experienced player (100%) down to the beginners. This way we can observe how the scale stretches and makes it harder for new players to advance in the game, another common problem in most MMORPGs.

Wealth on players obviously is another important number to be measured and interpreted. Since their carrying capacity cannot and should not be unlimited we either have to limit the amount of money players can have on them (a very difficult and unpopular decision in MMORPGs) or include bank accounts when we measure their wealth. Such accounting systems where players can store their wealth were introduced by the designers to counteract their unpopular decision to cut capacity. This is not the case with items for which players actually need to buy storage space in forms of houses. Inventory will be identified by a number which simply represents the value of the inventory's contents.

Most MMORPGs include a reputation/karma/fame system and if they don't we'll model it anyway since it is a helpful tool to assess relationships between players. This system will be called karma system from now on since that definition represents most aspects of these systems. As an example, the reputation system in Ultima Online (UO) is represented by a matrix described by fame on one axis and karma on the other. While fame describes how well known a player is among other inhabitants of Britannia (the world Ultima Online is taking place in) karma is a measure of spiritual balance, whether a character is 'good' or 'evil'. The main reason to introduce this system was to regulate combat between players. In UO the character's names are color coded according to their karma so people can recognize a despicable murderer as soon as they see one. On one hand this is for their own safety but on the other hand they know that they can attack this character (for a bounty even) without fear of reprisal. Karma is gained or lost on a sliding scale: "At the top of the scale, it requires many more noble deeds to raise it further, while only murder is a horrid enough act to take you lower when you're near the bottom of the scale." [UOG04] Fame is not that important for economic decisions but we can always include it in the experience measurement.

For us karma is mainly an interaction modifier and is a trait and a property at the same time. Ingame it represents a character attribute which affects the player's surroundings in numerous ways. Shopkeepers might be reluctant to deal with murderers and call the guards (who won't even let you into town as soon as you have reached a certain degree of vileness) or other server controlled entities might make your life more miserable. Most players prefer to trade with trustworthy characters so bad karma can be a huge disadvantage. Since karma also represents the playing style of our (human) player it can affect party forming. While honorable players might avoid an evil warrior other low karma character might band together and form a party ("Birds of a feather flock together").

Independent of whether current karma is positive or negative, it tends to return to zero over time since you have to earn (and defend) your reputation and in a virtual world with thousands of inhabitants you can basically start anew by venturing into another town. The fading factor can be adjusted in the simulation. Of course, karma does not always influence interaction between players. A player might have been travelling for some time and is just entering a new area as a dark horse since the locals haven't heard of his glorious (or horrible) deeds yet. This leads us to the question how karma propagates or to be more specific, how we can model the influence of karma. Let p(k) be the probability that karma affects a certain action like trade. The karma fading factor usually is a constant although we can argue that karma fades faster in the barren wilderness. Then again, when a player returns to town his karma is still known among his peers. That's why we vary the probability of karma intervention, not karma fading itself. P(k) depends on the size of the virtual world, the number of players, communication between players and several other factors.

P(k) is subject to local variation - although the gameworld might be huge, p(k) may be considerably higher in confined spaces with high player density like towns. Bars and markets are karma islands where p(k) approaches one. A shopkeeper that has been cheated on will make sure that everyone in the vicinity knows about the crook and thus penalizes him (so to speak) with a negative transaction modifier. While karma itself is determined by the player and his actions, p(k) depends on the surrounding gameworld, that's why we'll return to that during world modelling.

Karma is raised by killing evil NPCs or PCs (= low karma characters), killing monsters and doing noble deeds which includes giving gold and items to good NPCs or casting helpful spells on characters with positive karma. Accordingly, players suffer from karma loss when they kill good NPCs, players with positive karma (the higher the victim's karma, the higher the penalty) or useful animals. Karma is also decreased by casting healing spells on monsters or evil NPCs. Of course, the latter might offer a precious reward in exchange for a little karma loss. Stealing from other players and exerting similar skills has a negative effect as well so players are supposed to think whether it is really worth pestering other players. Game designers obviously had grief players in mind and try to promote a more social style of playing.

2.2.3 Actions

Player actions need to be kept as abstract as possible due to portability requirements since the simulation should be applicable to a wide range of game types. We'll assume that actions available to a player do not vary a great deal in current games. Every action will be assigned an adjustable probability that will be checked every turn and can be modified by a characters nature (socializers are less likely to venture into the wild).

In general, we're only interested in actions that either have a direct economic effect or indirectly affect economic decisions or skills. This encompasses change in player wealth, karma, health, XP, happiness and interrelations between them. The first thing that comes to mind is of course commodity exchange. Players trading will transfer a certain amount of wealth from one player to another. In rare cases players will exchange the exact amount of value but most of the time one of the two partners will be better off so we can model trade as one player grabbing some wealth from another character nearby (if there is one to be found). The exact amount of money to be taken is a randomized percentage of the trading partner's wealth, the maximum percentage is set in the simulation. The same applies to the general probability of a trade occurring.

Players can buy interesting or necessary items for their inventories which in our simulation is essentially the same as getting money. We won't model the fact that player inventory is limited since a person can carry (or store) more items if he/she is more experienced. High level players can plainly carry more weight (due to added strength bonuses) and usually own some sort of premises where they can store commodities. If players buy a status symbol it basically means losing money since it is an exchange for a very expensive but otherwise useless item. The reason players spend money for it is because it is a happiness modifier. Doing some sort of challenging task in the virtual environment ('questing') will also keep the game exciting and players happy. Additionally, rewards in forms of wealth and/or experience are given to successful adventurers. Most quests take place in the wilderness so players have to leave the safe city to earn their fame. Depending on the game's setting a quest can encompass delivering a certain item to someone, protecting an NPC from harm, disarming the bomb on a spaceship and similar heroic feats. We will model the aspects that are independent from the setting. The probabilities of going on a quest and succeeding (which is the case with most quests due to the all-dominating rule "Do not frustrate the player.") can be changed at all times. Most activities can be summarized as questing, the difference lies in reward, requirements and costs. Costs can be plain health if a player enrolls as a mercenary in a war but also money or karma. The aforementioned example of a malicious lord offering a player a reward for assassinating a rival represents this type of cost. While murder (of innocents) will greatly decrease a character's karma, smaller penalties can be issued for trivial deeds which are done in service of evil NPCs. It might be a different matter if an evil corporation pays a player to spy on the (corrupt) government. As we can see, all sorts of varying quests exist.

For now we will not include party forming. Grouping occurs when several like-minded players (in terms of karma, be it positive or negative) decide to band together if (just like in the real world) each participant will gain an advantage from it. While this can have tremendous social impact, it doesn't make any huge difference to the economy whether a group of players act independently or as one. For the players themselves and their gaming experience it is an important option. Forming a party is usually exciting but when the happiness of the whole group drops below a certain level it disbands and each of the members has their own agenda to follow again.

Of course, players might also decide to fight each other which is fine if both combatants agree. Involuntary combat cannot and should not be prevented since (if not done excessively by PKs) it represents an important part in most games. We'll assume that the higher the karma difference between the two players the higher the probability of an ensuing fight. Combat is only possible in the wilderness and outlaws with negative karma have an even higher chance of being attacked since there might be a bounty on their heads and lawful players can hone their combat skills without fear of karma loss. Most fights result in the death (or unconsciousness) of one player and the other player taking some of the other's belongings (yes, in this case, technically speaking, death results in a 'trade' in our simulation). The beaten opponent will either regain consciousness or be resurrected soon after. Death doesn't affect happiness that much since losing a fight rarely frustrates the players but most of them then try to improve their characters to win the next one instead.

2.3 World model

Our virtual world is divided into two types of areas. Cities or towns are safe places where trade and general socializing is common. Usually some type of authority maintains law and order in those areas, enforcing it when necessary. As an example, Neocron, an MMORPG with a dark futuristic setting has several areas in a massive city. The expensive, upper-class district is guarded heavily by the local police (NCPD) and weapons are not allowed. The further you get from this area though, the less likely it is to encounter a patrol.

Cities have a high player density since those are the places every character has to return to sooner or later. As a result, the karma propagation probability p(k) is much higher than in the wilderness. The wild is dangerous, much larger and therefore has a much smaller player density. This is the area where monsters lurk, quests (and heroes) are made and where exploration is done. Other common names (depending on the game's genre) include dungeons, wastelands or similar lonely and lawless imageries. While we could introduce several cities on our world map, we'll take a different route to make sure about half of the player population is in cities. We'll designate half of the world patches (this is how one unit of area is called in Netlogo, our simulation tool) to cities and the other half is wilderness. At one point I had three types of patches, with cities (no fighting, much trade) on one end, dungeons (no trade, much fighting) on the other and the wilderness (less trade, more fighting) in between. There's wasn't any noticeable economic difference, it only slowed the simulation down so we'll stick to two types of patches. We settled for half wilderness half city although in (virtual) reality the wilderness area is a multiple of the city area but since player density in cities is much higher we can let our agents run around freely (i.e. randomized) and about half of them will be in town areas at all times. A convenient side effect is that we don't have to implement an attraction to city areas in our agents. Despite a different average player per area ratio, using this approach we have an equal overall city to wilderness population ratio. Our simulation map will look as if the city area has been magnified since its apparent size is the same as that of the wilderness.

The trade probability is considerably higher in cities which the model has to account for. Due to the magnification of the city area the range of the trading algorithm (choosing a nearby player) has to be extended, the city/wilderness trade ranges can also be adjusted through the simulation interface. The same applies to p(k) which has a larger influence in heavily populated player areas like taverns.

Now our world model needs a proper system for the economic flow of money and commodities. There are two ways to implement it. At the beginning many game designers created a closed loop: There is a reservoir of virtual resources and whenever a monster with loot is created, a miner extracts ore from a mountain or a player receives money from an NPC shopkeeper this is taken from the virtual resources. When money is spent or swords are destroyed, their value is returned to the VR pool. As Zachary Simpson put it: "The impetus for this design was to prevent resource inflation; the theory being that a fixed quantity of resources would simply circulate from abstract to concrete and back again thus preventing the inflation that had plagued many similar on-line worlds." [Sim99] While this worked at the beginning it pretty soon became a failure due to the deflationary effects of hoarding. We'll examine this closely in chapter four.

The alternative is an open system with a source and several drains. In the previous version the source was fed through the virtual resource pool and the drain pointed back into this pool. This connection has been separated, currency and commodities just flow out of the system, never to be seen again, while resources are created from thin air and flow into the virtual world. In this open system the input/output should be equal. There may be peaks in both of them but over time those inequalities should cancel each other out except in cases where the overall amount of resources in the world needs to be (permanently) changed, i.e. in case of sudden player influx. We'll take a closer look at how this economy and its sources and drains work when we talk about their problems. The simulation will include a switch to choose between an open and closed economy flow.

Another interesting aspect is the size of our game world and how it can be modeled. World size can only be properly appraised if set in relation to population size. If the ratio is unbalanced players rarely get a chance to interact or, in the opposite case, people will feel alienated in a place crowded with others that feel just as lost. Is there an optimal player/area ratio ? Can it be kept constant while a steady stream of players keeps pouring into the game world ?

3 Simulation

3.1 Tools

There are several free/open source multiagent modelling environments available. While complex systems like Swarm [Swarm] or Repast [RePas] are very versatile languages, Netlogo can be learned in a shorter time and is sufficient for our simulation needs. It is a "programmable modeling environment for simulating natural and social phenomena. It is particularly well suited for modeling complex systems developing over time. Modelers can give instructions to hundreds or thousands of independent agents all operating concurrently. This makes it possible to explore the connection between the micro−level behavior of individuals and the macro−level patterns that emerge from the interaction of many individuals." [Net99]

Additionally, a visual simulation control center of some sort can be created fairly quickly in Netlogo. Controls, switches, sliders, monitors and more can be arbitrarily arranged on the workspace. Netlogo features a powerful and flexible plotting system which we will use extensively to observe numerous parameters.

3.2 Surveillance

To keep an eye on some crucial indicators we'll monitor their values on our control panel. Several per player data like the current average amount of money per player will be displayed. More average values can be shown for the other player stats as well. This way we can keep an eye on the parameters and watch out for specifics (i.e. peaks) during simulation. Good numbers to monitor might be the current total amount of money/resources in the system or the money on players/NPCs. The latter is shown in the so-called money-per-player graph. It plots the player's wealths from poorest to richest. Since in this simulation run we initialize each player with the same amount of money, this plot shows a horizontal bar in the beginning. As soon as monetary exchange starts the graph takes on the form of a hysteresis curve. The more people are in the middle class (which is equal to a fairer wealth distribution), the flatter the curve:

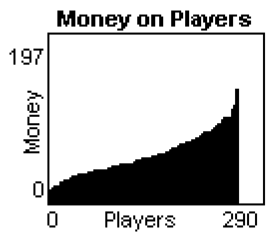

Figure 3.1 Money On Players Plot

To observe the development of wealth accumulation / distribution in the player community players are colored according to their monetary wealth. The richest player's money is taken into account and every player who owns a third of this sum is shown in red, players who own between a third and two thirds of this sum are marked green and the remaining richest players are colored blue. That means (taking the above plot as an example) we divide the population via the y-axis, not the x-axis, thus the current amount of players in a third can (and does) vary over time: The Class Histogram shows the class distribution in our player population and is updated in real-time. During the simulation the bars (representing the thirds we used for division) reflect change in player classes and grow or shrink.

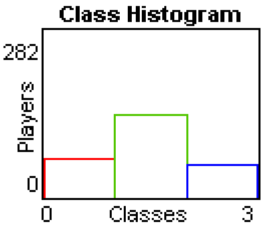

Figure 3.2 Class Histogram

While the Class Histogram delivers glimpses of the present state, the Class Plot visualizes class development over time which is necessary to observe the effects that changes in game parameters can have.

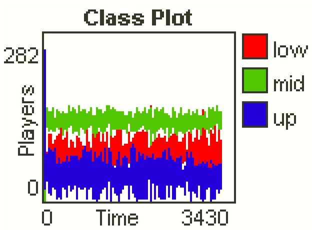

Figure 3.3 Class Plot

As we can see from the thin blue line at the left, all players started out as the richest class. Since in this example we gave each of them the same amount of starting money, they all had the highest amount of wealth. This changes almost instantly as soon as the simulation starts. In real environments this change obviously doesn't happen that fast since rich players tend to stick to their treasures - a big problem known as 'herding' or 'foraging' which we'll get to in the next chapter.

Of course it would be interesting to color the players and put them into classes according to their experience or their happiness. Therefore a switch is added which can be used to choose which criteria is taken into account when recoloring the players and sorting them. This way we can take a look at global characteristics like happiness distribution in the player population.

In order to examine a single player we'll add a plot that shows how one of the attributes of a random player develops over time. This can be money, happiness, or one of the other interesting qualities. Using a button the observer can switch to another random player and view how he compares to the previous one.

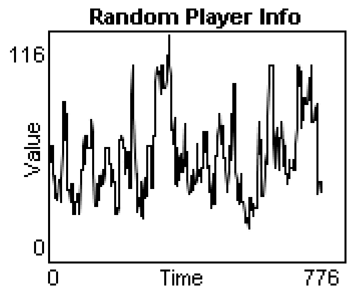

Figure 3.4 Random Player Information Plot

Two widely used economic methods for measuring equality (or inequity) of income distribution (used in [Net98] for instance) are the Lorenz Curve and its numerical representation, the Gini Coefficient (or Gini Index). A balanced distribution of income is desired in our economy. The fairer people feel treated the more satisfied they are. Since we like to keep as many paying customers as possible lots of people that are 80% content are preferred to a couple of players that are 100% content. This means we have to try to keep the Gini Coefficient low:

To plot the Lorenz Curve we sort the player population by their wealth and then plot the percentage of the population that owns each percentage of the wealth (e.g. 30% of the wealth is owned by 50% of the players). Hence the ranges on both axes are from 0% to 100%. While in the "Money on Players" plot equality corresponds to a horizontal line (everyone has the same amount of money), in the Lorenz Curve it manifests itself as a straight line with a 45 degree incline at the origin (everyone holds an equal part of the available wealth). On the other hand, should only one player hold all of the wealth in the population (i.e. perfect inequity), both plots would show a backwards "L" where 100% of the wealth is owned by the last percentage proportion of the population.

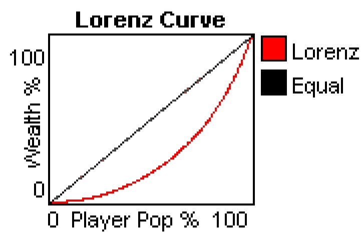

Figure 3.5 Lorenz Curve

The corresponding Money on Players-Plot looks like this:

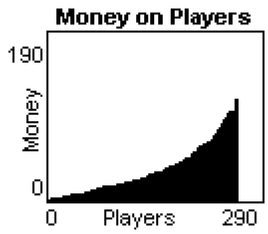

Figure 3.6 Money on Players showing a degree of inequity

For a numerical measurement of the inequity in the distribution of wealth, the Gini Coefficient is derived from the Lorenz curve. To calculate the Gini Coefficient, find the area between the 45 degree line of perfect equality and the Lorenz curve. Divide this quantity by the total area under the 45 degree line of perfect equality - this number is always 0.5. If the Lorenz curve is the 45 degree line then the Gini Index would be 0; there is no area between the Lorenz curve and the 45 degree line. If, however, the Lorenz curve is a backwards "L", then the Gini Index would be 1. Hence, equality in the distribution of wealth is measured on a scale of 0 to 1 - more inequity as one travels up the scale.

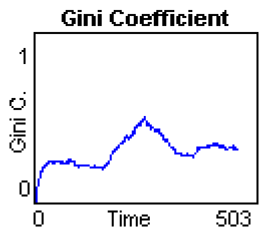

Figure 3.7 Gini Coefficient

To get a better feel for this number, here are some Gini coefficients for the United States :

Years	1970	1980	1990	1994
Gini Coeff.	0.394	0.403	0.428	0.456

Table 1 Gini Coefficients for the US

In reality, as most people are aware, the Lorenz curve is far from the perfect equality curve. Pareto's Law, aka the 80/20 rule, states that 20% of the population earns 80% of the income. This rule has been valid since its formulation by Vilfredo Pareto in the late 18th century and can be applied to various fields, i.e. 80% of decisions come from 20% of meeting time; only 20% time and effort will get your room 80% clean. Juran [Jur37], the 'father' of quality management, called this the separation of the vital few from the trivial many. Roughly 20% of your advertising will produce 80% of your campaign's results. The problem is to determine which 20% are the vital few.

3.3 The first iteration

3.3.1 Setup

In our first rudimentary environment we'll start out with a very basic model. Player types, traits and properties aren't implemented yet since we're mainly concerned with the monetary flow using a virtual resource pool. Figure 3.8 shows how money circulates in this simulation:

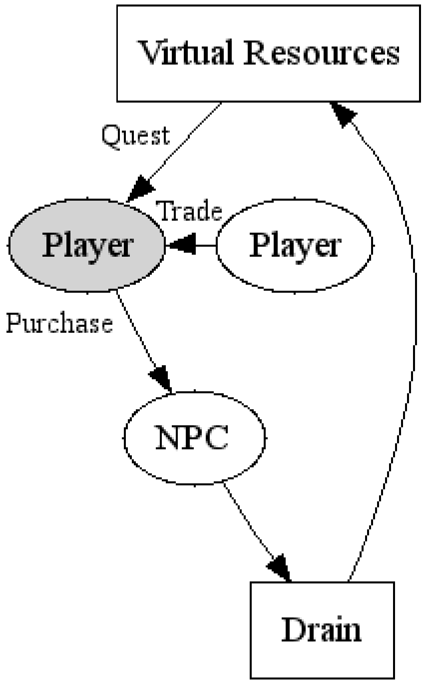

Figure 3.8 Economic flow of the first iteration

Our agents, the MMORPG players, can increase their wealth by doing a quest, this will draw currency from the virtual resource pool (as long as there is something left) into the economy. They can either trade with other players or decide to buy something from an NPC shopkeeper. We modeled player to player trade as a simple commodity transfer from one player to another. The amount to be taken from a random nearby player can be adjusted in the simulation. The player that is worse off in this deal will lose this fraction, which can range from 0% to 100% of his wealth, to the initiating player. A deal with an NPC is almost always a loss for the player since they represent important money sinks to reduce the money in circulation and put it back into the resource pool. NPCs usually sell items for more than their real value and buy for less. An (intentional) side effect is that this type of NPC shopkeeper behaviour encourages player-to-player business because there's plenty of possibilities for bartering and making a good deal with other humans instead of inflexible computer controlled scripts. The world already consists of wilderness (left half) and city area (right half) where players move randomly.

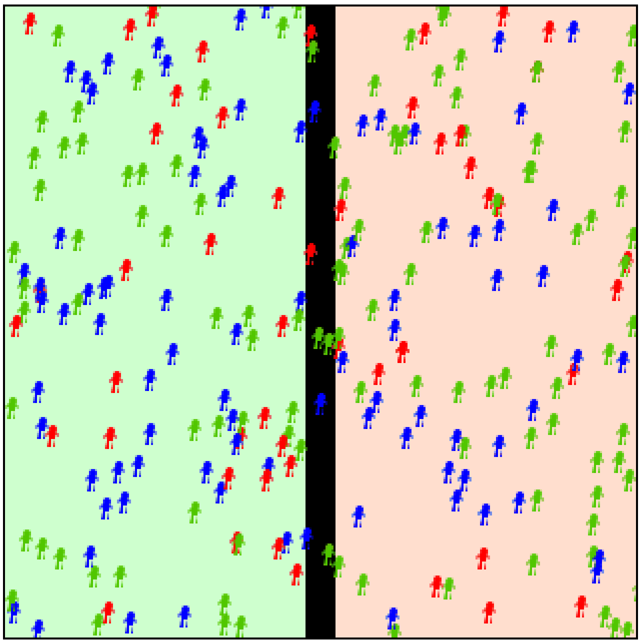

Figure 3.9 Wilderness and city areas

Although the right half is a magnified version of the town area, our agents move with the same speed as in the left half since people tend to linger in town more and about half of the game time is indeed spent in civilized hot spots. Player speed can be changed during the simulation using a slider. Slower players correspond to a larger game world and longer periods between wilderness and city visits. When players stay longer in one of the two areas, there will be less exchange between traders and adventurers and demographic characteristics between the two areas will start to drift apart. Towns will get poorer since riches cease to pour in at a constant rate.

This is all players do in this stripped-down simulation - move around, quest and trade. At initialization we'll equip them with 50 currency units and distribute them randomly in the virtual world. A switch changes startup wealth from the constant 50 units to a random amount between 0 and 50. The virtual resources are initialized with 200 units times the number of players - this is an arbitrary number and can be changed anytime.

We'll dive deeper into the mechanics now. A quest is won with the probability <p-quest> if there are still virtual resources available and if the player is in the wilderness. The reward amount is a constant fraction of the players wealth. If a player is in town he will trade with another player with the probability <p-trade>. He will choose a nearby player and take an amount between 0 and (<trading-ratio> * partners total money). If the resulting wealth is higher than a set constant - <max-money-on-player> which corresponds to inventory capacity or carrying limits - the excess money is put back into the virtual resource pool. When a player trades with an NPC (if in town and with probability <p-npc-trade>) an amount between 0 and (<trading-ratio-npc> * players money) is taken from the player and added to the virtual resources.

As we can see, for now the quest is the only source and NPCs are the only designated drains we have in this system while player-to-player trades distribute income between agents. We have to remember that if money acquired during a trade or a quest exceeds player capacity some money is also 'drained' back to the virtual resources. While testing and tweaking our parameter space we'll observe whether this system has any equilibria.

3.3.2 First observations

The parameters for the first iteration are

Max money on players	200
Player Trade Probability	0.2
Player Trade Ratio	0.3
NPC Trade Probability	0.2
NPC Trade Ratio	0.05
Quest Probability	0.15
Quest Ratio	0.1

Table 2 Parameters for the first iteration

Due to the nature of the trade implementation most players are green (middle class) and a few are red or blue after reaching a steady state in this scenario. Despite frequently fluctuating player wealth the ratios between the three classes stay approximately the same since it's harder for rich players to stay rich (less rich people to take from, lots of poorer people to 'trade' with) and for poorer people to stay poor (many wealthier players to take from). This inherent control will suffice for now. In real MMORPG environments players usually stay in one class and move up now and then while new players join the fray to repopulate the lower class but the class ratios are very similar. Players do not fluctuate as much between classes as they do in our simulation and if this poses a problem later on we will refine the player model's implementation to suit our needs.

In this first model steady states arise after the player's money carrying limit has been reached or the virtual resource pool has been depleted. These steady states vary depending on certain parameter combinations. We'll take some representative looks at these states to learn about our systems' behaviour and sensitiveness.

In this and the following simulations we'll use 250 players unless stated otherwise. As mentioned before, we put 200 * 250 = 50.000 currency units in the virtual resource pool. In case the pool empties too early and intervention becomes necessary we can add money with the touch of a button. Simulations run with a thousand players yielded virtually the same results while taking a lot longer to calculate so we'll stick to 250 agents for now. Most runs reach a steady state after no longer than approximately 1000 turns so our simulation length for most of our experiments is 1200 iterations. While observing the virtual resources in Figure 3.10 we can plainly see when players start reaching their money capacity. While money still leaves the system (which in this case is out of the economy and into the virtual resource pool) at the same rate, players receive only as much quest rewards as they are still able to carry.

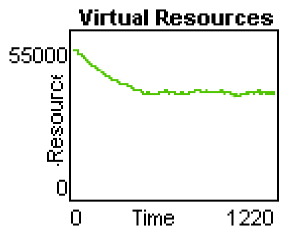

Figure 3.10 Resource pool development with player cap at 200

While the number of players in the middle class remains relatively constant, a population exchange between the lower and upper class takes place, as can be seen in Figure 3.11.

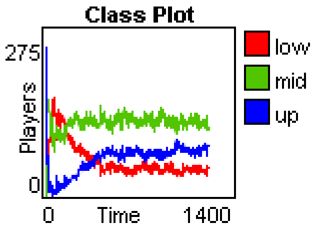

Figure 3.11 Class development in the first run

This behaviour changes when we adjust the player's money capacity. By raising it we can prolong the seemingly instable fluctuations in the beginning, if we raise it too high the virtual resource pool will be depleted but another interesting thing will happen as well. We established a "The rich get richer and the poor get poorer" scenario as can be seen in Figure 3.12.

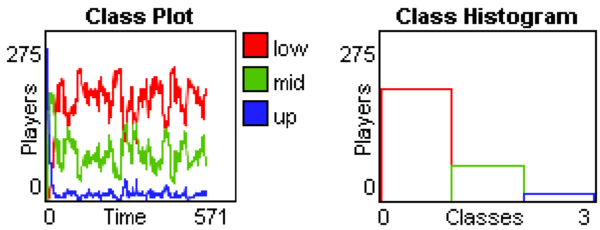

Figure 3.12 No limit on player's money capacity

As long as players have a relatively low money capacity and reach it the middle class will encompass most of the players. But as soon as they are allowed to accumulate as many riches as they want the biggest fraction of the population will belong to the lower class, a few are in the middle class and even less players constitute the upper class. Capitalism at its best it seems. Figure 3.13 shows the money on players graph:

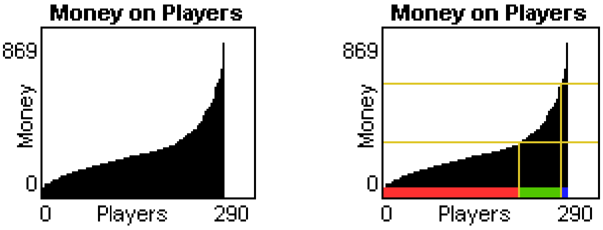

Figure 3.13 Money on players (no money cap)

The graph on the right has been divided into horizontal thirds to help identify the three classes. The difference in ratio can be seen as the classes are marked on the horizontal axis. The same is shown for a more balanced distribution in Figure 3.14.

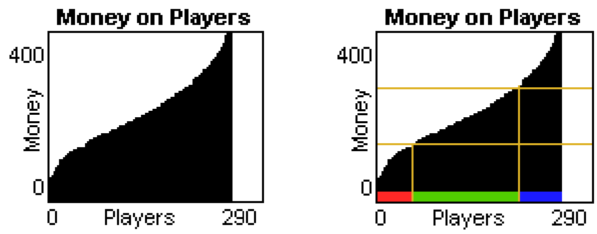

Figure 3.14 Money on players, a fairer distribution

After the system has reached a steady state due to money carrying limits the average money per player is approximately half the player's money carrying capacity and keeps this value.

An empty virtual resource pool on the other hand does not have as much of an impact on the rest of the system, the unfair scenario has already firmly taken its place by then since players still seem to have money capacities left. Without any resources left to acquire players will be stuck in an unfair economy. Should they reach their limits after some time in the unfair system (which, for example, could happen after we insert more money into the economy) they will still be able to convert to a fairer system after all. In Figure 3.15 we see that the system starts to convert to a fairer state but the pool is depleted too early to allow full conversion and we revert to the previous system.

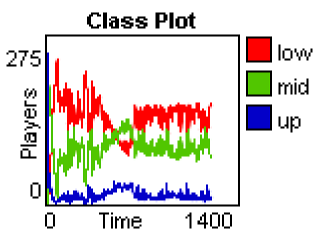

Figure 3.15 Capitalism overrules

Instead of initializing every player with 50 currency units we can randomize their starting wealth. Each agent is given an amount between 0 and 50 units which leads to an 'unfair' start at the beginning of the simulation. This is reflected in class development. The player's money capacity is set to 100 in the first row and to 200 in the second. On the left hand side we initialize the players with 50 units each and on the right hand side the starting assets are random.

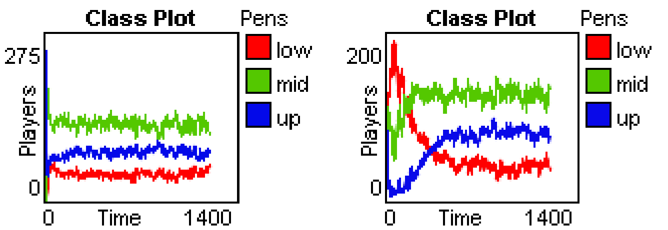

Figure 3.16 Different initialisation with capacity at 100

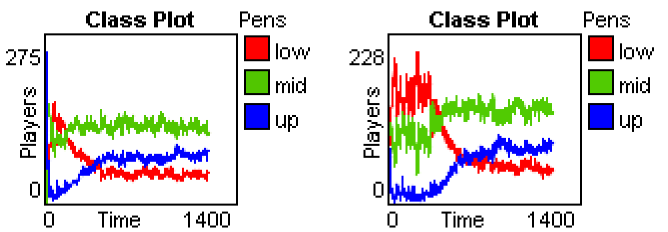

Figure 3.17 Different initialisation with capacity at 200

When starting equally with 100 units capacity limit (which is reached almost immediately) there's no time for the capitalist economy to surface while with 200 units capacity the system moves to a fairer economy right away. A random start establishes the unequal economy and pushes conversion to a fair system further ahead along the time axis but cannot prevent it.

The difference in starting wealth can also be seen in the development of the Gini Index which we have neglected up to now. If all players start with the same amount, the Index starts at 0, perfect equality:

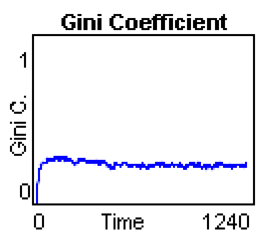

Figure 3.18 A fair start for the Gini Index

A random distribution of wealth corresponds to a Gini index somewhere between 0.31 and 0.36. How does a change in parameters affect the Gini Index ? Even big changes in class distribution only marginally affect the Index. A simulation run with a cap at 100 currency units leads to a Gini Index that fluctuates between 0.23 and 0.24. A cap of 800 units produces a Gini Index between 0.26 and 0.29. Using a random initialisation and a 100-unit-capacity the Gini Index only slowly 'recovers' (after about 400 turns) as can be seen when we compare the two graphs in Figure 3.19.

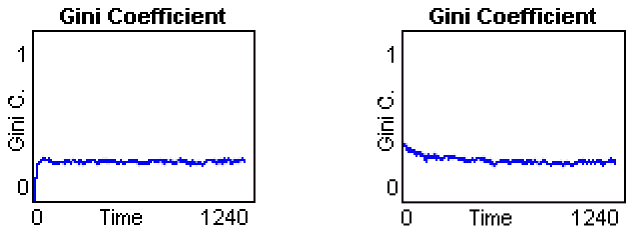

Figure 3.19 Gini Index with different initialisations

Why is the difference so small ? When do big changes in the Gini Index occur during simulation ? The Gini Index is a numerical representation of the scale of the Lorenz curve. Very high values hardly surface with our parameters since the curve doesn't vary much if we change starting conditions and player capacity. The curve will always look similar to the the one in Figure 3.20.

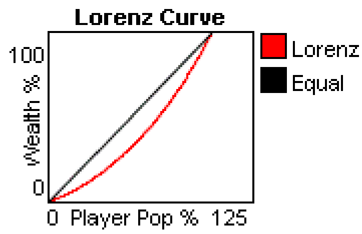

Figure 3.20 Lorenz Curve for the first runs

If we raise either the quest probability or the quest payoff there is a significant change in the Gini index. Since money pours into the system at a much higher rate but players are stilled capped at 300 a higher percentage of players does in fact reach their capacity. This is easily seen in the money on players graph in Figure 3.21. The corresponding Lorenz Curve is shown below in Figure 3.22 on the left. After raising the money influx the Gini Index falls from about 0.24 to 0.14. To the right is the Lorenz Curve that represents one of the highest Gini Indices (0.7-0.75) we can achieve by suddenly draining money from the system. Our economy will be located somewhere between those two extremes.

While the p-quest and p-npc-trade parameters control the

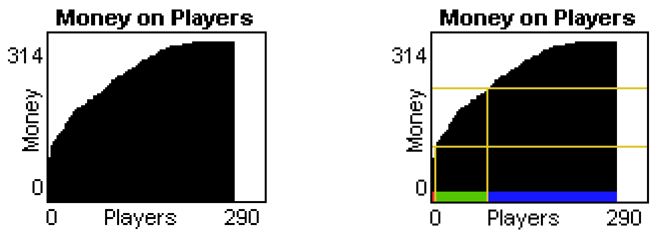

Figure 3.21 Player wealth with higher money influx

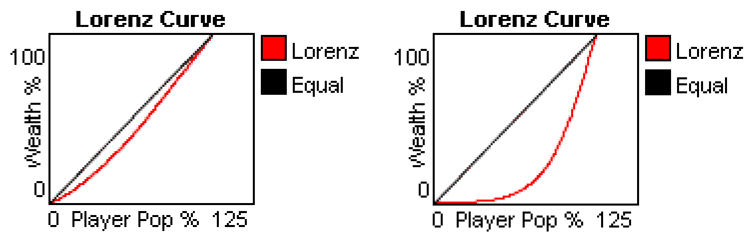

Figure 3.22 Two extremes of the Lorenz Curve

frequency of money exchange with the virtual resource pool, the actual amount that is taken into or out of the economy can be set through the exchange ratios. By having a high frequency of exchange of very small amounts we can smoothen the graphs and prevent high amplitudes that could trigger other, unwanted effects.

While combinations of those four variables lead to numerous interesting results, exploring every corner of our parameter space is beyond the scope of this thesis. We just want to take a look at some representative simulation runs.

Up to now we haven't looked at the influence of player to player trade. The aforementioned simulations were run with a trade probability of 20% and the amount to be traded was between zero and a third of the trading partner's wealth. To get an idea of its effect we'll run the previous simulation with player to player trade disabled. The results are shown in Figure 3.23.

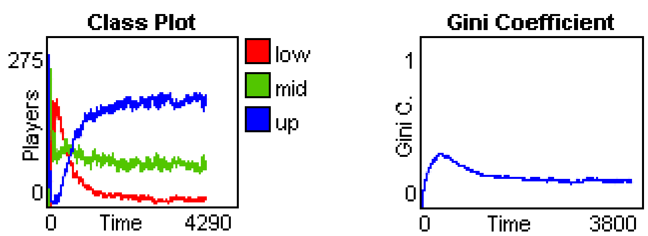

Figure 3.23 Trade prohibited in this run

As we can see, we have lots of rich players this time. Since nobody is grabbing money from them and richer players naturally earn more during their quests (reward is based on their wealth) players have better chances to accumulate riches. Since alle players do that at the same time the classes only represent who is behind on his way to become part of the upper class. As a result, average wealth in steady states is higher than in the previous runs and the money on players graph looks like Fig. 3.21.

By using a very high trade probability and a very small trade ratio be can provide for fast and fair income distribution since everybody gives the same percentage of his money to many people and in turn receives from many players at the same time, this quickly diminishes any significant differences in player wealth.

3.4 *Extending the simulation*

We'll now start adding features to our simulation while checking how they change our results and taking care that our changes do make sense.

3.4.1 Economic flow

The most common sources for money and commodities are loot on monsters, raw materials that can be acquired through work (mining ore or chopping wood) and shopkeepers that produce many items out of thin air, especially those that do not have player-production paths (e.g. reagents).

Drains for example are botched items through inexperienced manufacturing (in Ultima Online), decay of items, dropped items that are removed from the game after a certain time (garbage collection), consumable items that are used (potions, reagents) and selling things to NPC shopkeepers who can remove items from the world if they (i.e. the game designers) choose to, depending on the economic situation. Apart from items, those shopkeepers are also gold sinks, they charge items for more than they (in game mechanic terms, not in game world terms) are worth. Players can also own shopkeepers that sell wares for them but they charge a recurring rent.

Right now we have a virtual resource pool where every economic unit is taken from and put back into. This doesn't pose any problems until the pool runs empty. We'll add a switch to toggle between an open and closed economic flow. All it does is allow resources to become negative. Since the virtual resource graph isn't meaningful anymore we'll plot the economic flow as well - two graphs will plot the money that flows into and out of the system in each iteration:

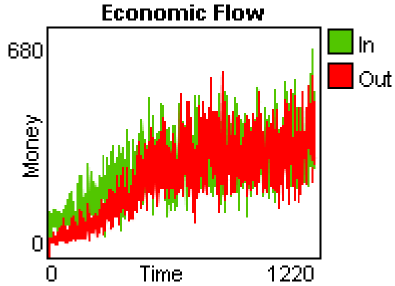

Figure 3.24 Economic Flow plot

Figure 3.24 shows the economic flow of a simulation where players reach their capacities after approximately 500 turns.

Now we can eliminate the risk of running out of virtual resources but this introduces a host of other problems. More on that later.

3.4.2 Inventory and consumption

Player inventory will be implemented as money. Thus it can easily be integrated into our current player wealth model. Player wealth represents the value of items in inventory. There are many types of inventory items, most of them can be compared to money but some need to be handled in a special way. We'll divide items into non-decaying items and slow- or fast decaying items but decay will not be implemented until the next chapter. Items like armor, weapons or tools decay at a fairly slow rate and do not have to be replaced very often. Items like food, reagents or ammunition on the other hand are very short-lived and decay very fast. We'll later think of how to implement it in a smart way.

So far prices were always dependant on the buyer's wealth. Pricey status symbols were introduced to give the ultra rich players another money sink. While it was much too expensive for new players to even think about acquiring such an item, rich player parted with a big chunk of their money to obtain that prestigious item. (After running out of ideas the creators of Ultima Online offered hair dye to the player, at ridiculous prices. This way people had another option to spend their money on and have other players admire their green hair at the same time.)

In our current system every player, regardless of their wealth, can buy any item so we will have to determine status symbol's prices by comparing it to the average player's wealth, this makes them too pricey for poor (or new) player to buy. To prevent the simulation from slowing down and for the sake of keeping track we'll stick to normal (i.e. through NPC trade) money sinks. Test environments with separate status symbols didn't have any significant impact, it only raised the amount of money taken from the system by a barely noticeable bit so we'll include status symbols in the already implemented NPC trade.

3.4.3 Player types

How will player types change the way our little economy works right now ? Currently every player ventures into the wild with the same frequency but in reality some player types prefer to go on quests and only return to the safety of town to replenish their supplies and cash in their treasures. We will characterize players whether they are adventurous or not by giving them a value at initialisation which is distributed normally and between 0 and 1. Players wo are adventurous will spend more time in the wild. A value of 0.75 would correspond to 75% probability that a player (if he is in the city) turns towards the wilderness. 0.25 would correspond to a 75% probability that he will head for the city in case he is on wilderness patches. This means we will run a test on a players locality preference. If it succeeds (the random number is lower than the preference value) and the player is on city patches we will turn him towards the wilderness. If the test fails and he is in the wild we will set his heading towards the city area. Figure 3.25 shows the world with locality indifferent players and on the right is the simulation run where players exhibit normally distributed locality preference.

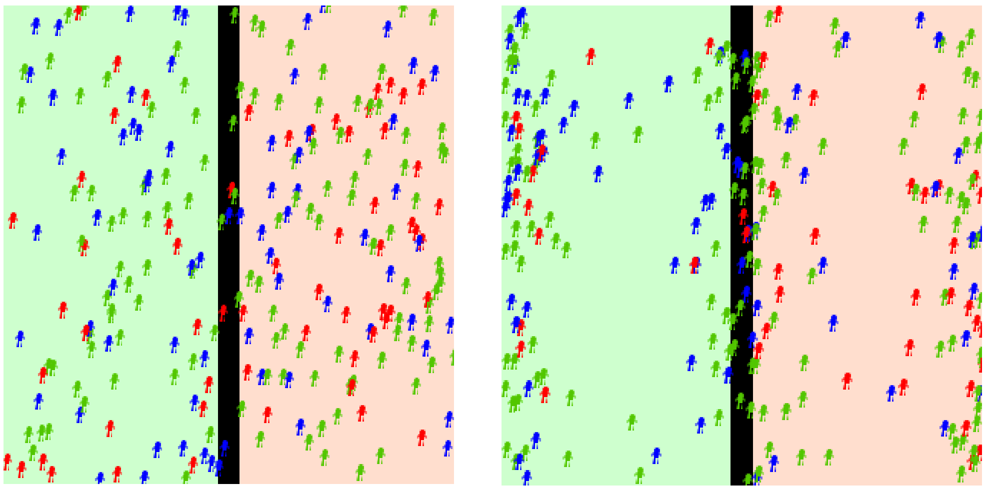

Figure 3.25 Locality preference in action

Due to our implementation the player density at the border is higher since players tend to turn towards it as soon as they feel they have to go to their desired patches. The world wraps around in our virtual world, that's why players linger at the outer edges as well.

With locality preference enabled the Gini Index rises to a higher value after initialisation but drops down to normal level (i.e. without locality preference) after 200-300 turns. Another interesting thing to notice is that money leaves the system at a slightly faster rate than before. This in turn leads to the turnaround time (conversion to the fairer system) occurring earlier. Figure 3.26 shows how money

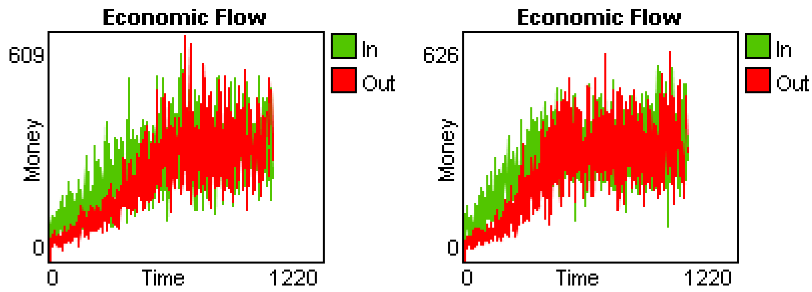

Figure 3.26 Economic flow using local preferences

flows out of and into the economy in the two situations.

So far the change we introduced is not drastic but we'll add a switch to turn locality preference on or off anytime since it might have a larger impact later on.

Greed is another factor that influences economic behaviour. Greedy people refuse to part with their belongings and are more reluctant to trade with other players. As with wilderness affinity, greed will be a probability that affects transaction with other players and NPCs. The greedier a player the harder it is to take money from him and the more he tries to earn in any deal. Lots of greedy player will make it very hard for the game designers to pull money out of the economy.

Having greed modify player to player transaction has the same result as lowering the player to player trade probability. NPC deals on the other hand are more interesting. This is an important point where money leaves the system and here foraging players will hurt the most. Depending on the player's greediness we will decide whether money leaves the system or not. A 100% greedy person will never allow an NPC trade while a 0% greedy person will accept the usual NPC-trade-probability. Greediness is normally distributed but we put the mean at zero and map the negative part onto the positive axis. Figure 3.27 shows the difference between players with (right) and without (left) normally distributed greediness.

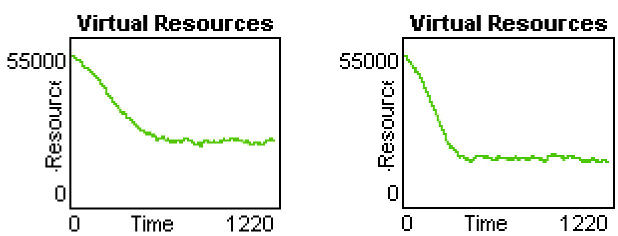

Figure 3.27 Resources and greed

The impact on class distribution is shown below.

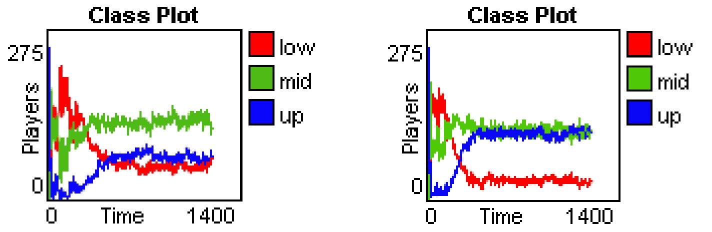

Figure 3.28 Classes without and with greed enabled

Greedier players obviously put more strain on the resource pool and make sure that more money stays in the economy since they refuse to part with it. The result is that part of the population shifts from the lower class into the upper class, leading to a slightly higher Gini Index. Greed, like locality preference can be toggled on or off.

3.4.4 Karma and propagation

Karma defines the player's alignment and thus his attitude towards others. It ranges from 0 (evil) to 1 (good). We'll initialize players with a certain karma which will only vary slightly during the simulation. Since players usually stick to their chosen karma range (whether they play a good, neutral or evil character) we will change it only slowly to simulate some karma penalties or rewards during their journey in the MMORPG world. Just like locality preference, karma is normally distributed around 0.5. Figure 3.29

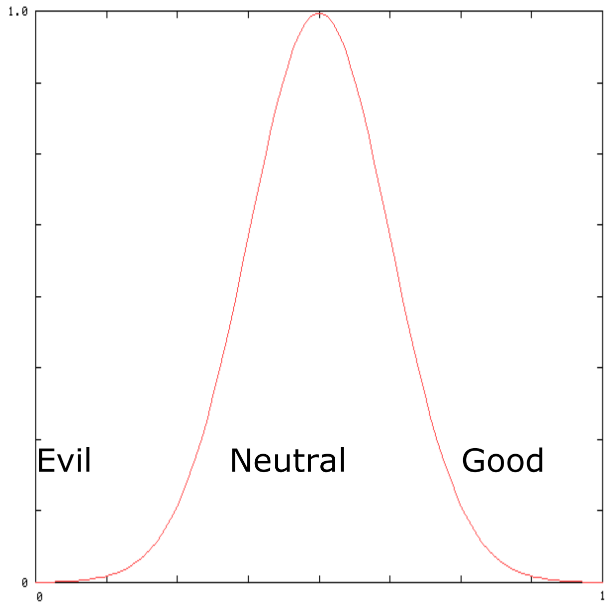

Figure 3.29 Karma distribution in the population

illustrates the distribution. If the karma difference between a player and his trading partner is too big the trade will fail. This threshold can be adjusted and is somewhere between 0.05 (very selective trading) and 1 (karma independent trade). Additionally, karma propagates much faster in cities so we'll cut the threshold in half in these areas. This means karma has more influence on trades on city patches. While greedy players inhibit the currency flow out of the economy, karma differences result in less exchange between players. This leads to a higher Gini Index at the beginning of the simulation but after about 800 turns it drops below the level of the karma-independent run. This is because lots of players move from the lower class to the upper class, similar to the effect greed had on the simulation. Only this time it affects a different part of the economy. The Gini Coefficients are shown in Figure 3.30.

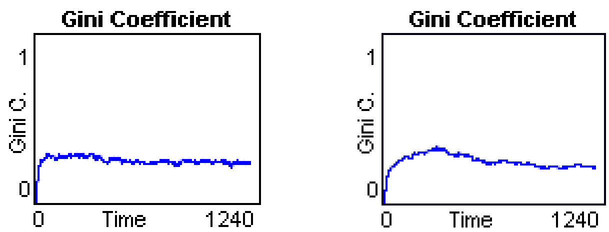

Figure 3.30 Gini Index without and with karma influence

One is lead to believe that the same results are achieved by simply reducing the player-to-player trade probability but this affects every player in the population simultaneously. We want to affect only parts of the population and observe differences in player grouping or whether high greed and karma correspond to upper class affiliation.

One option would be to log all output into a file and feed it to a data mining program to find statistical correlations between certain parameters, this might prove to be interesting material for another thesis.

3.4.5 Experience

Obviously all players start out as beginners without experience. Everybody advances at different rates and after a while the world is a melting pot of newbies, intermediate players and high-level adventurers. 20% with low XP, 20% high-levels and the remaining average players in between is a common ratio. Experience is crucial when combat occurs, the more experienced player usually wins. (as we mentioned before, combat loss results in a trade)

To mirror the experience ratios in MMORPGs we allocate experience points in a normal distribution to our agents. After that they receive one XP per trade and one XP per quest, sometimes even two. If needed we can add an option to pump 10-20% new players into the game in case our population gets too experienced. Those newbies cannot receive the same starting money since inflation would make it impossible for them to advance, that's why startup wealth usually depends on several factors like current population size and average wealth.

3.4.6 Happiness

Happiness is a very important part of information but it is also very difficult to measure. Every action has to include a happiness modifier. Every player starts with approximately the same happiness. It decreases gradually and this decreasing rate varies from player to player. Happiness points are given for engaging in any type of activity. Achieving an equilibrium or, even better, steadily increasing happiness seems to be just a matter of keeping the player occupied but of course it isn't that easy in real multiplayer economies. Players have different interests and aims and as always it is hard to please everyone. Adventurers gain more from doing quests while socializers have fun playing when they can exchange commodities through interacting with likeminded players. The more our players tend to be in the wilderness (using the locality preference value) the more they earn from quests and vice versa with city dwellers. Trades with NPCs also raise the happiness a little bit since players are usually left with the impression that they are the ones better off in the deal. The implementation of happiness is pretty straightforward but its impact and dynamics are more complicated.

3.4.7 Combat

Since we established that combat basically results in a trade this is how we will implement it. But when do players engage in combat ? We'll suppose that if their karma difference transcends a certain level players will decide to fight. There are obviously many exceptions to the rule but in general this is a good guesstimation. The difference between our usual trade is that players with many XPs will be able to succeed in more and higher trades than others. We'll let more experienced players grab a higher percentage (called fight_prey) from players with less experience. The new 'trading ratio' and the karma difference threshold can be adjusted during the simulation run.

The result is less money in the economy, a third to be precise. With combat enabled rich players grab even more money when they are close to reaching their money capacity and thus more excess money is returned to the resource pool. Players that still have plenty of space to accumulate money lose it to players that do not have enough free space left to keep it in the economy. Figure 3.31 shows the class distribution with combat disabled and enabled.

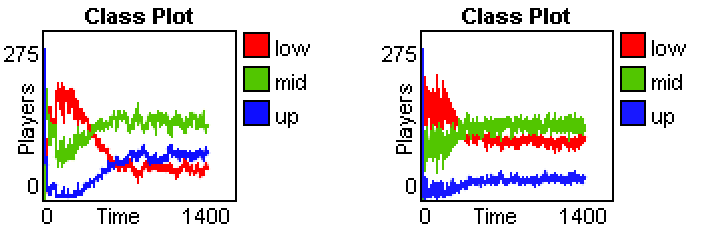

Figure 3.31 Economic impact of combat

As we can see, the amount of people in the lower class does not drop below those in the upper class although a similar tendency can be seen in the development of the two classes. Enabling combat leads to a slightly higher but much more stable Gini Index in the steady state, namely 0.275 compared to about 0.24. It shows less fluctuations than in the previous simulation so combat seems to have a stabilizing effect. See Figure 3.32.

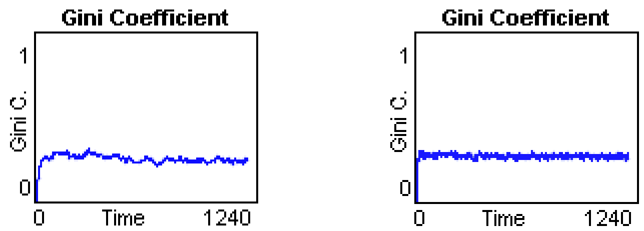

Figure 3.32 Stabilizing effect of combat

3.4.8 Influence of inflation

To better mirror inflation effects, we will calculate prices directly from the economy as a whole; to be more specific, from the average money per player.

We'll add a switch to turn on market prices. Usually the amount that players pay to an NPC is determined by the NPC-trade-ratio from their own wealth. With market prices enabled the NPC-trade-ratio is applied to the average player wealth instead of the current players wealth and this is the price the player has to pay. If it is too high the simulation automatically switches to the old fashioned NPC trade costs. This means while average players will not experience any changes, poor players pay higher NPC rates and rich players pay only a tiny fraction of what they used to.

Rewards still remain a fraction of a player's current assets. Being dependent on only the active player's wealth (instead of average values) one is led to believe that rewards aren't influenced by inflation. However, players can usually choose their preferred type of quest/mission themselves. Depending on the setting the game might contain some high-tech terminal for viewing and applying for mercenary missions or the landlord's servant offers tasks to gallant knights at the weekly market. According to the quests' difficulty the MMORPG system determines the offered rewards while taking the current state of economy into account. Hence there's no need to simulate reward fluctuations since players can choose their quests and will do so according to their economic status. Thus simply making the reward dependent on the quester's wealth appropriately mirrors current practices. If inflation is high and players have lots of money on them, rewards will be high as well. If money is sparse the opposite is the case. One might argue that this is an excellent tool to combat inflation. In the real world anti-cyclical economic policy has similar problems as in our game but due to the special constraints put on the game designers this is an especially precarious matter in our virtual worlds. Nobody will object to higher rewards in times of deflation but reducing hard-earned treasures is (even when inflation occurs) politically not viable.

4 Common problems

..and how they manifest in our little virtual world. MMORPG systems are very chaotic and sensitive to external intervention: "Every tiny change sent massive tremors though the entire game." - Raphael Koster, Ultima Online Designer while talking about the UO economy. All problems are strongly interconnected and heavily influence one another. Trying to rectify one inconvenience may trigger havoc in several other areas but this also implies that a minor (but smart) change could solve several problems at once. A truly cybernetic system.

A simple fact is that the economy cannot be planned by the game designers although that certainly doesn't stop them from trying. Quickly changing (seemingly) non-crucial game parameters has become known as nerfing in the online gaming world. At some point in Ultima Online, the creators, in an attempt to balance the game, reduced the power of swords in melee combat which resulted in players complaining that they were hitting each other with *nerf* swords, the foam weapons popular with kids.

Why is there need for quick and dirty changes after the game has launched ? Despite extensive testing there are aspects of the game that simply cannot be explored in a closed testing environment. One of the UO designers neatly summed this up:

"Because something small changes that has big results that could not be tested in a closed environment, but which needed thousands of players to find.

Because players change their behavior over time, and that results in completely new behaviors being discovered.

Because players give the game more "testing" on the first *hour* of launch (in terms of plain old man-hours) than ANY testing we could do over the course of months.

Because (sad to say) many players don't tell us when things are exploitable. This is especially noticeable during beta testing, when people will actually hide bugs "so we can cash in when the game goes live."

Because, frankly, these games are chaotic systems, and it's not mathematically possible to predict exact outcomes of things."

We'll now take look at why there is need for change and which problems need rectification. Many aspects more or less pertain to one major headache, namely inflation.

4.1 Inflation

As with every inflation, no single player can be blamed since each of them acts on their own rationale. Inflation results from the system inherent interdependencies and it is our (or the game designers) task to keep inflation and the rate at which money pours into the system as low as possible. New players who enter later on in the game wouldn't have any chance of advancing. This would be reason enough but there's more. Why is inflation such a preeminent problem in MMORPGs ?

Why is money simply hemorrhaging out of monsters; why do shops simply create endless amounts of money for worthless items which players continually bring in and sell at fixed prices ? This leads to money essentially being a secondary experience point system rather than a useful unit of trade. In real world economies the continual printing of money results in hyperinflation and other economic inconveniences. The same applies to virtual economies - most of these systems currently use a fixed pricing system to try and control problems. As a result money isn't a useful representation of effort among players. Basically the total pool of money continually increases while the same stock is available at the same price. Effectively the price of items is continually decreasing as a percentage of the total wealth available.

Much of this is due to game designers having single player games in mind:

- There's no supply and demand so why should there be the need to implement it ?

- The player has to beat the economy 'subgame'. (at the end of most games he's obscenely rich)

- The whole 'economy' is tailored to one player.

According to Michael Moore, Ultima Online designer, this is one of the reasons that lead to the aforementioned problems: "Unfortunately, the same approach is almost universally used in multiplayer games as well. Better equipment costs more money and higher-level monsters drop more. In the early game, a player might have to play for an hour to collect up a few hundred units of currency, but in the late game the money might be rolling in ten or a hundred times as fast. The only problem is, in a multiplayer game you have "lowbies" and "übers" mixing it up together. One veteran player giving away the loot from one short hunting trip to a new player will totally blow the curve for the new player. One thousand gold coins might mean five minutes of play to a veteran, but five hours to a newbie. This illuminates a basic flaw of the multiplayer game's economy. It's true that in the real world, one hour of an all-star basketball player's time might be worth thousands of hours of an average Joe's. The only difference is, in a multiplayer game, all players can reach that all-star level of virtual income just by progressing through the game. If everybody in the world got multimillion dollar contracts to do their jobs, then the dollar would be next to worthless."

As mentioned above, inflation is responsible for the gap between player generations.

4.2 Experienced/new player dilemma

This is an inherent problem in multiplayer systems. Advancement is one of the main motivators for MMORPG players and this makes it very hard to appeal to newcomers during a later time period in the game. Inflation wouldn't be as bad in a closed game where nobody is able to join after an initial recruitment period but in an environment where new players enter the game at all times it seems unfair to beginners. If they start out with the same wealth as their predecessors did, they will have a hard time getting on in the game.

If you, as more players joined, kept the amount of wealth in the game equal everyone would get poorer. This would discourage players and lead to people leaving. If you let the amount of wealth grow the gap between richer, older players and the poor new players will also grow. In case you hadn't noticed, this is a problem in the real world economy too, and no one thinks it's particularly fun there.

Things that balance the game but which were not planned this way are events like advanced players giving newbies high-powered items because they have more than they need or even discarding items that a beginning player would love because it isn't worth their time to find someone to give it to. If events like these occur it is a sign that the economy is failing.

To my knowledge there aren't any games that do not accept new players after the game has been running for some time, simply because the publishers do not want to miss subscription fees. To quote another designer: "The turnover rate of subscribers in Ultima Online is fairly high. At any given time a significant fraction of the online population is new and therefore at a significant disadvantage." [Sim99]

It seems like this is a problem we have to live with if we want to stick to an all-growth, experience and advancement - based system. But how could it be designed better?

The casual gamer probably doesn't want to spend much time shopping. Being on a limited time budget, this type of player wants to equip and go. Many players would probably prefer fixed prices, considering that prices are generally stable in the real world and they're used to fixed prices in single-player games. Merchants would prefer to see real supply and demand determine prices, finding the dynamics of a reality-based economy enjoyable. Virtual craftsmen want to be guaranteed a demand for their services. With so many different playing styles to accommodate, a perfect solution will indeed be difficult to find.

Attempts have been made to create separate worlds for more experienced players to prevent beginners from having a hard time getting ahead in the economy while experienced/rich players tend to become bored. Those separate areas contain a mixture of more difficult quests and even more powerful items with extraordinary prices. Beginning players wouldn't stand a chance in those places. Notice the frequency of the word 'more'. The stronger the players the more needs to be thrown at them, to ridiculous extremes in some cases.

4.3 Shopkeepers

There have been lots of discussions on whether these NPCs are necessary or not. There are two types of shopkeepers, NPCs that are controlled by the server (i.e. the game designers) and those that are controlled by players.

Player controlled shopkeepers are supposed to relieve players of tedious duties. When players have something to sell they usually find a crowded area or a commonly known marketplace and try to offer their wares to players that happen to be in the vicinity. If a player, for example, has taken on the role of a blacksmith and has a large amount of items for sale he will spend a significant fraction of his online time selling those weapons. If he was able to setup a shop with an automated shopkeeper he could use the time saved to create more weapons or to engage in one of the endless possibilities a virtual world offers. And thus shopkeepers were introduced. For a monthly rent they sell and buy items which the player assigns to them. The price range can be set as well so the NPC shopkeeper helps the player run his business.

The server controlled NPC helps provide players with necessary items which might not be found elsewhere. These shopkeepers were an integral part of the economy even before player controlled shopkeepers were just a thought. While player run shopkeepers only support player to player trade, autonomous NPCs pose independent market entities. They play an important role because they are permanent. Real players disconnect now and then and are therefore not online the majority of the time. NPCs provide stability since an NPC shopkeeper will tend his store 24 hours a day and thus provide players with a constant source of critical goods and services. This consistency role has become less important after player-run shopkeepers have been introduced. Afterwards the NPC economy was mainly intended to augment the player-to-player economy by supplying those things which it didn't make sense for the players to produce.

Since server-run NPCs have always sold for fixed prices, a fundamental flaw surfaces: While prices in the player to player economy rise, prices in the NPC to player economy stay fixed and thus lose value. This severely disturbs the player to player economy since people will not even start looking for a human trading partner if they know the price is fixed at the NPC's shop next door. Another problem was that server-side shopkeepers bought everything to circumvent player frustration. If players produced a hundred torches and sold them to a shop they produced a thousand torches during the next night, knowing that they can sell them the next day. Absurd decisions like these lead to economic problems that are hard to counteract and support economically irrational player (or NPC) behaviour.

Some time after the beginning of Ultima Online shopkeepers were given a couple of new rules (which weren't implemented before but which seemed pretty obvious once they were established) to battle the economic problems that arose:

- Shopkeepers always sell for more than they buy. This encourages player to player trade.

- They raise prices if they sell much and lower their prices if they buy much. This prevents people from selling useless items in thousands to shopkeepers.

After a while people suggested removing server-side shopkeepers altogether or at least gradually from the game since the player to player economy should pose the primary market. Without shopkeepers run by the game designers they have to make sure that newbies retain sufficient access to the goods they need to get started in the game. For some commodities which cannot be created by players or be found in the wild new production paths would have to be created and this leads to a new economy altogether. Up to this day server-side shops have always existed and it is likely that game designers do not want to give up this tool which gives them a little (but not to be underestimated) ingame control over the economy.

4.4 Overproduction

Overproduction was a specific problem of the MMORPG Ultima Online. [UOG04] To understand this we need to look at the game mechanics that facilitate this behaviour. In UO Players can have numerous skills. Specializing in one area automatically creates weaknesses in others so one player can't master all skills at once. Player can improve their skills by training (for a fee) with a master but the most prominent way to improve is through use. Frequently employed skills become better and better while unused skills degrade as time passes. With player manufacturing this is a major economic problem - players who produce shirts out of wool get better by producing shirts. Players have a non-demand incentive to (over-)produce – they plainly improve by doing. That means a tailor may choose to produce clothing not because there is a demand for clothing but because their abilities to produce clothing cheaply and efficiently tomorrow depend on producing superfluous shirts today. This oversupply problem becomes even more complicated because players expect to make profit from their labour regardless of whether there is a market for it or not. A tailor may create a large number of shirts and then take them to an NPC shopkeeper to sell. This happened at a time when NPC storekeepers still had a carefully implemented AI algorithm to properly include supply and demand. The shopkeeper who already has a pile of identical shirts which he cannot sell refuses to buy more. Many players reported this as a bug since they expect something for their labour in return.

The overproduction problem became critical when many players started using macros exactly for this reason. Macros are helper programs that repeat sequences of mouse moves and clicks and can be used to script certain parts or even the full tedious process of production. Players enter a mine, start one of the macros, go to bed and wake up to a ton of mineral ore and their character a master miner. This creates more junk that cannot be sold to human players (nobody needs more pliers than they can carry) and even more demand for the NPC shopkeepers to buy the produced goods. At the same time players who do not use macros complain bitterly about those players that get ahead of them through cheating and then justify their own cheating on these grounds.

Oversupply is a typical "Tragedy of the commons" - situation. Low prices (little grass on the commons) are bad but players keep on producing (eating grass) anyway until nobody can really profit from their wares anymore. Asian DRAM chip factories had a similar problem a couple of years ago. Decreasing their output would have led to higher profit margins but the companies continued producing anyway which then resulted in huge losses to everybody.

Eventually, the game designers were forced to partially give in to these demands. The shopkeeper code was changed to buy goods such as the aforementioned shirts which were in massive oversupply regardless of the demand. To prevent abuse and the shopkeepers from permanently going broke, however, they will only buy in limited quantities, restricted to about a dozen per hour. This way writing a macro which produces endless shirts will not allow players to sell them for endless amounts of gold. As we can see, trying to implement supply and demand with shopkeepers was a useless task. They had piles of things no one wanted and no cash on hand.

To facilitate these shopkeeper changes, the AI which required them to keep a positive cash flow had to be abandoned. Shopkeepers now effectively create currency in order to buy the useless goods which are being created by the player manufacturers. As a result the improve-by-doing system inflates the money supply and this still is the current status quo.

In real-life economies non-market incentives like subventions and trade penalties are mainly used for market control and support the economy. In our case it perturbs the intended market development although it could be used to our advantage. Changing player incentives and not encouraging overproduction seems to be the only way out of this. In the next chapter we will think about how to modify incentives.

Last but not least, overproduction causes servers to slow down and the game's backups to become bigger and possibly less frequent - more on this in the next section.

4.5 Hoarding

Players have the tendency to hoard things. There might be several reasons for this behaviour, here's a speculative list taken from [Sim99]:

Decoration	People will line their houses with such things as helmets or cloth to make their space interesting and special
Laziness	Why bother throwing things out if there is plenty of space and it doesn’t cost anything to warehouse
Speculation	If players think that the price will go up on an item, they will hold it in hopes of selling it for more later.
Pack-rat syndrome	"I might need this someday."
Mementos	Objects can serve as reminders of old adventures. "Remember when I got that from the dragon during…"
Status symbols	Huge piles of wealth show how experienced the player is and can be used for bragging rights.
Achievement	Many games are filled with arbitrary goals, some players will create them even when they don’t exist. "I have a million gold, I win!"

Table 3 Reasons for Hoarding

Whatever the reason may be, it is a fact that foraging is prominent in most MMORPGs. Commodities which entered the system from a virtual resource pool always ended up in players' inventories and didn't leave the system.

For the game designers this is a server-side problem. More and more items in the economy lead to larger server load. While technical problems due to server congestion are more likely the size of the daily backups increases continuously as well. These server limits create a requirement that the economic and social design of the game discourages hoarding. This is an interesting problem – one which lacks precise real-world analogies.

On the player side (and thus the game designers' problem as well) hoarding is an economical problem. Foraging players will severely hurt a closed system. If liquidity of commodities cannot be maintained, the gameworld becomes static and stale. If nothing flows back into the virtual resource pool there aren't any resources from which to create new treasures or monsters and the players that inhabit this empty and boring world will quickly start to complain. This hoarding problem takes currency out of our carefully balanced in-game economy resulting in a barren market, stripped clean of bargaining goods. The management issues with this (closed) economic model are with the drain and how to make sure players effectively spend money rather than hoarding (which has to be discouraged).

An interesting economic phenomenon (taken from [Won00]) occurred concerning the rent charged by (player owned) shopkeepers. When they were first implemented, vendors charged a rent based on the *resource* price of their inventory regardless of their sales. With this in mind clever players realized that they could set the price for the goods to be extraordinarily high and thus prevent anyone from buying them. This, as it turned out, was a very effective way of creating a safety-deposit box since the shopkeepers cannot be robbed. Players started buying them for the sole purpose of increasing their hoarding space. This exacerbated the hoarding problem and also resulted in a form of suburban sprawl where people built tents and attached vendors consuming valuable land. The designers ultimately fixed these problems with an elegant economic solution: the vendors now charge a fee based on the *player-assigned* value of the goods. This way players can still set the values too high but they will be charged rent proportionately thus deterring this practice dramatically.

Another indirect hoarding effect results from rich players logging on and off. If a rich character doesn't play the game for a month or longer, how is the economy affected by the loss of their money ? What if that player decides to leave the game and never logs on again ? At which point can you reclaim that wealth and add it back into the system ? Of course this depends on how many players actually log off for a long time and how wealthy they are. A small percentage doesn't make any difference but in times of school holidays a significant fraction of the players (and their wealth) might be missing. The same can happen if a new MMORPG is published and lots of players temporarily leave their current game to give it a try and a part of those return (this can lead to a sudden money influx) and another part does not.

Hoarding was the main reason why the open system was abandoned. Supply becomes unpredictable since availability is heavily reduced due to foraging players. A favourite anecdote among the UO designers is of a character who had over ten thousand identical shirts in his house [Sim99] - just because they were easy to produce or cheap to buy. And after having found something new to collect they claim their right to sell all of their hoardings to a shopkeeper.

Houses are of course a problem since they pose storage areas for pack-rats and promote hoarding and server congestion. Another reason why the supply of housing has to be controlled is that unused land is limited and wilderness is required for adventuring. Why not remove houses altogether from the game ? As it is, houses are one of the most important money sinks. They are very expensive and can help counter inflation. To sum it up - it's all about balancing. In the shopkeeper example inflation has been accepted to combat overproduction and player frustration while hoarding must be endured in exchange for a little less inflation.

4.5.1 Deflation

Deflation results from currency hoarding players who take money out of the system. Besides accumulating all sorts of commodities people always try to amass as much money as they can. As we mentioned before, inflation is a prominent problem in MMORPGs - what is the effect of deflation and inflation at the same time ?

As we've seen in the previous sections, money is permanently flowing into the system on purpose due to measures that prevent other problems like overproduction. As a result the players in this virtual environment become richer and average wealth rises. This leads to new players having a hard time getting ahead in the game since prices rise and thus the rich-poor player gap widens.

At the same time players hoard as much items and money as they can squeeze into their storage spaces and/or bank accounts. Money becomes scarce, especially in a closed economy or when game designers react too slowly and do not adjust the money input in time.

These two antagonistic effects lead to player wealth rising quickly while people are not spending anything (or at least as little as they can). This will, sooner or later, most certainly bring about the collapse of a closed system. One could be led to believe that the effects might cancel itself out but the system is in a highly unstable state and the slightest perturbation will lead to one of the two extremes or, at best, heavy oscillations.

5 Improvements

The main problem is that most improvements are a trade-off between different disadvantages. Game designers try to balance these things as good as they can, sort of like trying to minimize the average error. Unfortunately many solutions have a negative impact on player happiness and there are few game designers who dare risk the (virtual) well-being of their customers.

Decisions that might annoy players are a very precarious matter. While a little inflation is ok in exchange for pleased players there are of course limits to everything. Worthless gold pieces will also upset our valued players. This means we are basically trying to find the happiness maximum but happiness is the one parameter which is the most difficult to measure. Players have suggested many solutions and those have been taken seriously. After all, concerning happiness, the players themselves are the ones who should know. Some suggestions are egoistic while some try to understand the game designers' point of view.

Opinions have been voiced to make the economy more dynamic, with prices rising and falling based upon laws of supply and demand. Additionally, the sources and sinks for resources within the environment should have adjustable rates such that the economy can be kept in a stable state even as shifts in player population and activity occur. While we have seen several examples for sinks none of them can be changed arbitrarily. We may be able to adjust the amplitude and frequency of the money output function in our simulation but we do this to mirror output in a real MMORPG. Usually money sinks are beyond our control, as much as we would like to be able to manipulate these important parts in our economy.

Some players, obviously with an economic playing style, demand that controls on the markets exist in order to prevent irrational events violating laws of market behavior from occurring - such as markets (player or non-player) purchasing items when it would not logically be in their interest to do so. External interventions, as with all interruptions on behalf of the game designers, disturb the ingame development and upset lots of people. They will complain about the designers' unfair behaviour toward their customers, harming the players to rectify economic problems they caused themselves. A better solution would be to design the economy in such a way as to prevent players and their markets from doing illogical purchases in the first place. Some solutions were already hinted at in the last chapter but let us elaborate a bit more on given suggestions in this chapter and how they might help, or, to be more precise, where they help and in which area they lead to disadvantages.

5.1 *Fighting the inflation beast*

Inflation is by far the most prominent problem in most current MMORPGs. To dampen other harmful effects inflation has been allowed to a certain extent and thus game designers are perpetually looking for ways to remove money from the economy. In effect, inflation has to be prevented but not at all costs, especially happiness, which is the reason it has to be prevented in the first place.

5.1.1 Balancing

Drains can be categorized into voluntary and involuntary drains. Involuntary drains are of course those that might lead to player frustration so great care has to be taken when implementing those.

A game designer's favourite is one of the voluntary drains - creating desirable things that cost obscene amounts of money. When the Ultima Online designers offered different hair dyes that cost a fortune players took the bait. Inflation had done its work and on average people were very wealthy and actually looking for things on which to spend their fortunes. Dyeing their hair blue seemed like a good investment to show off their wealth. Additionally, the designers offered lots of titles that could be bought and even upgraded when the players had money to spare again. These huge money sinks were a success since people gladly payed for them because they had the feeling that they had a choice in the first place instead of feeling as if a new rule was imposed on them.

Unfortunately, the very fact that these highly priced objects are desirable means that players simply go harvesting until they can afford them - effectively they encourage an unwanted behavior pattern. That is, people start mining ore like maniacs, they produce as much as they can and continue hoarding money instead of exploring the world and interacting with other adventurers. One way to prevent this harvesting mentality has been suggested, namely limiting the players' bank accounts. While this might help against players hoarding money in the long run, they will certainly start complaining vehemently about these sorts of artificial restrictions. We need to find ways to prevent harvesting without making it appear obvious to players. A slightly better suggestion is making harvesting more difficult. This can be done by reducing the loot on monsters. When orcs carry less money people will have a harder time trying to hoard currency. Unfortunately this only postpones the inevitable and players will only try harder to keep up their harvesting odyssey. This way the attempt to discourage harvesting fails and players, especially new ones, become frustrated since they notice that they have to work harder (or play longer) to advance in the game.

5.1.2 Open vs closed economy

We already established that a closed economy is doomed to fail. To my knowledge, most of the popular MMORPGs employ an open economy using a source/drain model. Designers try and strive for an equilibrium. Ideally they are able to limit the amount of money created per time unit and can then let a percentage of that wealth drain out of the system per time unit. Decay seems to be the perfect tool for this task - more on that in the next section. This would lead to an equilibrium point where currency enters and exits the system at more or less the same rate. This point would vary depending on many factors like how many people quest and loot on average or how many people utilize the wealth - draining features of the game. If this data is known parameters can be adjusted accordingly to lead the system along the desired paths - in theory.

Although closed economies have some advantages they still pale next to open systems. Although they have the aforementioned problems they do exhibit much less inflation (albeit in exchange for highly valued player satisfaction). An example would be natural resources and how they are handled. In closed economies they are very limited, that means players (or mines) could run out of ore or gems. While this would prevent the amount of money in the system from spiralling upwards it would annoy the aspiring miner who just joined the game hoping to play an ore miner. To his surprise, all the mines were mined out months ago. Since this is unacceptable especially for new players the alternative is to make the mines continually produce ore but then we're back to the problem of more and more money pouring into the economy.

5.1.3 Decay

There are several options that we'll file under 'decay'. They encompass more or less reasonable and small recurring costs. One of the aims is to make the profit margin from harvesting drop severely and make it no longer worth the time spent.

One of the first suggestions was introducing certain taxations. With more money coming into the system (by the NPC shopkeepers for example) we need to keep the influx of new money into the economy at a stable level. While taking into account that there is an average amount of money that comes into circulation in a certain time period, this exact amount can be taken out of the the economy using taxes. Specific taxes/rents could be charged for the land/area/space station in which players live but this quickly comes across as forced payments which aren't really part of the game experience. Players work in real life to pay their monthly bills and it is a safe bet to say that they are not keen on doing the same thing in their free time as well.

Either those costs have to be kept very low or they have to be justified so that they are understood by players. A carefully balanced cost of living might absorb most of the income that players would normally hoard. The negative impact on happiness is obvious here. Players *like* to hoard. The remainder of the excess income could be mopped up by desirables - those things that players want (but don't need) and that ideally are either temporary and have to be replaced or cause more ongoing expenses. An example was given in an MMORPG forum: "For example, a player that wants a horse to ride around upon needs to pay for stabling, food and services of a groom in addition to the cost of purchasing the animal." This sounds reasonable from an economic point of view but it's hard to make players understand this point. All they see is lots and lots of costs that dampen the MMORPG experience.

There's another problem with ongoing costs like rent for a certain living area. These costs have to remain in effect while players are offline. Having ongoing costs for the exact time spent online will take away a lot of the fun in adventuring ("No time to chat, must find treasures to cover my rent.") - that's why these recurring costs are calculated in real-time. But if there are offline costs, casual players who can't spend much time online are at a severe disadvantage.

Most suggestions try to implement new services for players which they have to pay for. Contrary to red hair dye, these service are actually supposed to be valuable. Players could recruit mercenaries or bodyguards who join their party and fight at their side - for a salary of course. While all these services would have to be carefully evaluated and checked whether players would take the bait, there is one sort of decay that is widely accepted: wear and tear. Weapons, armour, clothes, etc all get damaged and wear out and must, sooner or later, be replaced or repaired. This decay factor (or possibly several decay factors - one for houses, one for weapons...) might only need to be changed a little, with thousands of players it will have a large impact on overall economy without players noticing any change. It might occur to them that the latest weapon wore out faster than the old one or that the current sword is much more durable than that rusty battle axe they used to wield. That means this money drain can (to a certain extent) be controlled. This is one of the very few drains so far which can be controlled without players complaining about unfair intervention like house rent or taxes. The items decay itself does not decrease inflation but the money spent for repair takes money out of the system and fortunately it's pretty obvious to players that weapons wear out with use.

Additionally, this is the only solution which we can try and run in our little simulation since the others are just additional sources or rely too much on the human factor and player acceptance to properly model it.

There are two ways to implement decay. Either a certain

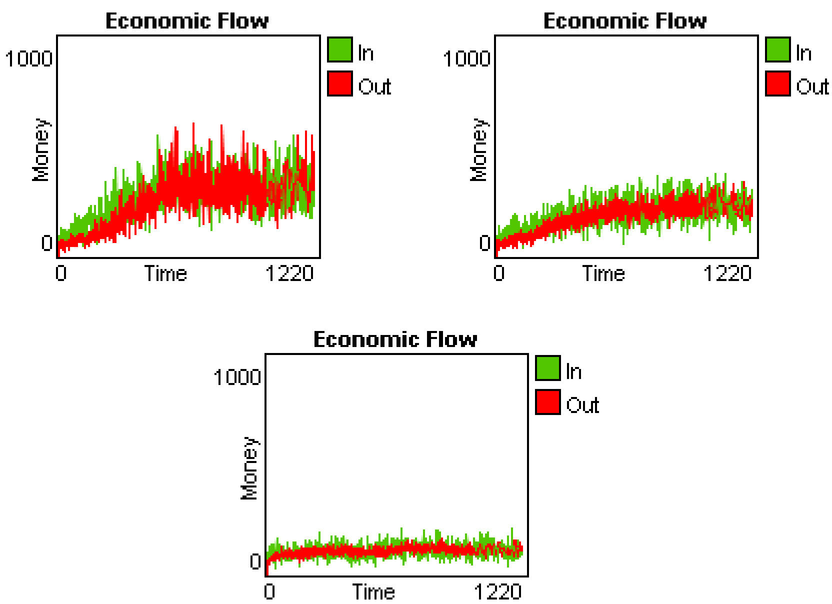

Figure 5.1 Economic flow with wealth decay

percentage of player wealth decays or the same percentage is taken from the average player wealth and every player loses the same amount of money. Using the first implementation we decrease the overall economic flow. At the end of each turn our player wealth decays and more money leaves the system. As a result, less money enters the system since money input depends on the questing player's wealth. Figure 5.1 shows the economic flow without decay, with 0.7% decay and with 1.2% decay.

If we apply the decay factor to the whole economy and use average player wealth to determine the amount of money that decays then poor player have to pay more and rich players pay less. In this case every player loses the same amount of money and after the system has reached its steady state this amount remains constant. As a result the player capacity is effectively decreased by this constant sum. As can be seen in Figure 5.2 the constant output is already apparent on the left (0.7% decay) and very obvious on the right hand side (1.2% decay). The variable part 'on top' results from our familiar stochastic NPC trades.

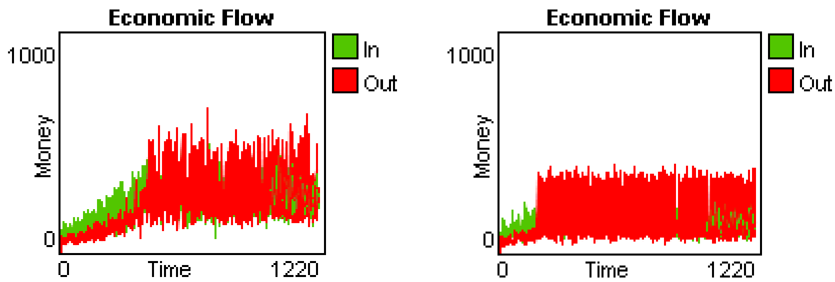

Figure 5.2 Decay determined by market

Inflation might be the most prominent problem but fortunately it is also the one which players are prepared to endure best since the money supply simply has to increase due to every player trying to amass riches through adventuring. Only very few people will complain about too much money in the economy as long as they aren't on the receiving end. (which is the case for new players)

5.2 Paradigm change

There have been thoughts (and demands) to abandon the whole levelling concept that everybody is used to. If people weren't always trying so hard to earn experience points and reach higher levels a whole group of problems would be taken care of. As a substitute we need a different reward system with different metrics to measure 'progress', however that will be defined. Instead of the XP hierarchy we could use currency and reputation/fame. It is important to note that currency should not be allowed to be amassed by harvesting or similarly monotonous activities that are harmful to the economy. Additionally, the improve-by-doing system has to be replaced with a pay-to-improve structure, this will reduce inflation as well as overproduction.

Players in current MMORPGs exhibit their economic behaviour because they believe to get the most out of the system this way. If the world was designed differently, people will exhibit different behaviour patterns. This means what we need to work with and change is *player incentive*. Players will not appreciate being forced to do something. Our aim should be changing (or creating from scratch) the environment and economic parameters and thus player incentives to achieve a desired economy and at the same time have players keep (and exercise) their free will.

An interesting take on incentives (and inflation responsibility in our case) can be found in an article on game theory from the Stanford Encyclopedia of Philosophy [Ros03]: "Plato, in his book *The Republic*, at one point has Socrates worry about the following situation. Consider a soldier at the front, waiting with his comrades to repulse an enemy attack. It may occur to him that if the defense is likely to be successful, then it isn't very probable that his own personal contribution will be essential. But if he stays, he runs the risk of being killed or wounded -- apparently for no point. On the other hand, if the enemy is going to win the battle, then his chances of death or injury are higher still, and now quite clearly to no point, since the line will be overwhelmed anyway. Based on this reasoning, it would appear that the soldier is better off running away regardless of who is going to win the battle. Of course, if all of the soldiers reason this way -- as they all apparently should, since they're all in identical situations -- then this will certainly bring about the outcome in which the battle is lost. Of course, this point, since it has occurred to us as analysts, can occur to the soldiers too. Does this give them a reason for staying at their posts? Just the contrary: the greater the soldiers' fear that the battle will be lost, the greater their incentive to get themselves out of harm's way. And the greater the soldiers' belief that the battle will be won, without the need of any particular individual's contributions, the less reason they have to stay and fight. If each soldier anticipates this sort of reasoning on the part of the others, all will quickly reason themselves into a panic, and their horrified commander will have a rout on his hands before the enemy has even fired a shot!"

It is virtually the same with inflation in our MMORPG world. While no player wants to inflate the money supply, they, by choosing the best of their individual options available to them as a collective, bring about the inflation which we have observed in most virtual worlds. It is in these options where we find a lever to make players behave differently without them feeling patronized. With incentives in mind we'll continue with the quote from [Ros03].

"This situation has a deep and interesting logic. Notice that the soldiers are not motivated to retreat just, or even mainly, by their rational assessment of the dangers of battle and by their self-interest. Rather, they discover a sound reason to run away by realizing that what it makes sense for them to do depends on what it will make sense for others to do, and that all of the others can notice this too. Even a quite brave soldier may prefer to run rather than heroically, but pointlessly, die trying to stem the oncoming tide all by himself. Thus we could imagine, without contradiction, a circumstance in which an army, all of whose members are brave, flees at top speed before the enemy makes a move. If the soldiers really are brave, then this surely isn't the outcome any of them wanted; each would have preferred that all stand and fight. What we have here, then, is a case in which the interaction of many individually rational decision-making processes -- one process per soldier -- produces an outcome intended by no one. (Most armies try to avoid this problem just as Cortez (who burned his own ship on the enemy's shore) did. Since they can't usually make retreat physically impossible, they make it economically impossible: they shoot deserters. Then standing and fighting is each soldier's individually rational course of action after all, because the cost of running is sure to be at least as high as the cost of staying.)"

The interactions of many produce an outcome no one really intended. That means we need to change player incentives (although not as drastic as Cortez did) so their own reasoning will lead to the desired behaviour or, since that might prove to be impossible, at least to a desired range of actions which is beneficial to our economy and, ultimately, to the player.

It seems as if one of the latest MMORPGs is taking a brave step in the right direction. A Tale In The Desert [eGe04] takes place in Egypt and features no combat: "Players strive to build the perfect society." This is a departure from most other virtual worlds where combat was at least an alternative to interaction. A Tale In The Desert is not a competitive game but a cooperative civilization-building one that depends upon the players to forward the story. The publishers are obviously aware of this fact and use it in their marketing campaigns: "The entire game is about building your character and building relationships with other players. The game is about solving social puzzles, not puzzles to discover more loot or gold."

Advancement in this game happens through 49 different tests in seven disciplines, or virtues. They run the gamut from building a pyramid, to breeding and exhibiting a scarab beetle, to winning a dueling tournament, to searching for hidden altars, to winning an election. They only have one thing in common: they all require players to strategize amongst each other, not wander off into the wilderness to find the best weapon.

People win (yes, win - the game is not open-ended) by smart management and sharp-witted negotiation instead of better and better weapons. The game has a plot that unfolds in response to player actions and when the story is over the game ends - this raises the eyebrows of avid MMORPG players. Many economic problems are solved in a closed game. There's no advancement by numbers, new players will not feel left behind and can still join later on. A 'telling', as defined in ATITD, is the completion of building a society – intended to be 6 months. The first telling ran significantly longer but gave the developers time to learn much from the players. The second telling is starting at the time of this writing, in September 2004.

An interesting element of gameplay is the unique process of 'lawmaking' since players develop the rules that govern the game. They first propose them and after voting and ratifying the law the developers create the code to modify the game, this results in interesting situations unseen in other environments. In the first telling players managed to create a dominant currency within this system. When the game was initially started there wasn't any currency to begin with. Everyone had to work with each other to trade for necessary items or learn new skills to create the items they need. But a few select groups of individuals created a way to assign value to a currency they created. After a few weeks or months, there was only one dominant currency within the game. All of this was created and voted upon by the players.

It remains to be seen whether new MMORPGs will be inspired by A Tale In The Desert or whether established worlds might include some of the innovative ideas exhibited in this game. So far players from other games welcome the fresh changes and the new economy which is so different from what they are used to. It will be interesting to observe what kind of economic disturbances might surface here.

6 Conclusions

After getting to know the mechanics of MMORPGs and seeing some effects in our simulation in action we can safely say that virtual economies are indeed complex systems that are hard to control.

The extensions of our simulation had many interesting effects but we still have to keep in mind that those are the results in the simulation. It would be interesting to compare these results (after some statistical analysis using a data mining program) with the economics in real MMORPGs. Unfortunately (but understandably) it is very hard to come by this data. Nevertheless, the simulation environment can be modified in several ways and is available online.

Some problems are very similar to the real world and in our simulation we observed patterns that simply arose from the interactions of our agents which are worth mentioning. Limiting the wealth a player can have will lead to a fairer income distribution. To put it the other way round, as long as people are allowed to hoard as much as they please, there will always be inequity, an interesting result from an economists point of view.

While hoarding commodities is also prevalent in day-to-day life there are some things that are exclusive to virtual worlds. In most cases the game designer is to blame since their system encourages behaviour that is harmful to the economy. Overproduction would not be such a pain if other options of playing style were more attractive. But why is it so hard to design a system that makes players behave as we'd like them to ? The answer is simple but disillusioning - in a system as complex as a virtual economy there are bound to be behaviour patterns that no designer could foresee or intend to happen. Players simply find other things to do and other ways to interpret rules. Because of this unpredictability small things need fixing all the time and because of this unpredictability small fixes can change a lot and lead to a whole new family of new problems.

MMORPG creators weren't able to completely let go of single player games that dominated the industry for so long. They started out with fixed prices, lots of treasures and loot on monsters and as a consequence, extraordinarily rich players. It was already too late when new players entered this game in progress and saw what was happening - basically every player in this environment was in effect trying to play a single player game. Not because they wanted to but because the system was designed that way and rewarded players that played by the rules.

Shopkeepers were the ones to go broke in this strange economy. To keep players happy (and, as a side effect, producing more and more commodities) they bought and bought in order to combat overproduction while at the same time inflating the economy and going bankrupt. As we have seen, every solution had an unpredictable chance of wreaking havoc in another area of the virtual world, they were just tradeoffs between several disadvantages. This is so difficult because a working economy is not supposed to reflect any real, existing economy but one that benefits all players and allows them to profit from whatever they like doing best. This premise obviously requires compromises to be made again and again to battle the symptoms that the last change summoned while at the same time trying to prevent any imposition on the player.

Once these inconsistent goals are identified as such, one can see why new multiplayer systems try to take a different approach. A new paradigm to put emphasis on interaction between players instead of having people advance through solo campaigns takes care of many economic problems. The economy just fades into the background since it is not the primary tool to achieve fame and glory anymore. These new virtual worlds will exhibit completely different dynamics which, however, will certainly be just as fascinating as the old-fashioned economies we're used to.

7 Source Code

This is the main part of the Netlogo source code from the simulation. Lots of lines that were used for testing, bugfixing and similar things have been removed for clarity purposes. Most of the code should be comprehensible if the reader knows at least one programming language in general.

```
globals         ; variables not assigned through the command center
[
in                  ; money going into the system per turn
intotal             ; in total
out                 ; money leaving the system per turn
outtotal            ; in total
avgmoney            ; average money per player
resources           ; virtual resources not in ciculation
                    ; (if economy is a closed system)
randomplayer        ; a random player to plot info on
]

breeds [players]    ; only players for now
players-own [
        money       ; money can be exchanged 1:1 in resources
        xp
        happ        ; happiness
        karma       ; (in %)
        wild        ; preference for wilderness
        greed       ; (in %)
        ]


to setup
ca
  set-default-shape players "person"
  set intotal 0
  set outtotal 0
  setup-patches
  setup-players
  setup-variables
  do-plots
end
```

```
to go
  set in 0
  set out 0
; happiness decay
  ask players [if (happ > 0) [set happ happ - 1] ]

  ask players [move]
  ask players [quest]
  set avgmoney (sum values-from players [money]) / num-players
  ask players [trade]
; quest and trade are being called separately and not in
; one [] block to synchronize agents - without synchronization
; several agents might arrive at the trade block while others are
; still questing. This leads to money disappearing from the
; economy.

  if combat [ ask players [fight] ]
  if decayfactor > 0 [ ask players [decay] ]
  set intotal intotal + in
  set outtotal outtotal + out
  recolor-players
  do-plots
end

to setup-patches
  ask patches [
    ifelse (pxcor > 0)
      [set pcolor 29]          ; town       (light orange)
      [set pcolor 69]          ; wilderness (light green)
    if pxcor = 0 [set pcolor 0]
  ]
end

to setup-players
;  locals [luckyguy]
  create-players num-players      ; depending on the num-players
                                  ; slider
;  set luckyguy random (num-players + 1)

  ask players                     ; position players and initialize
    [
    setxy (random-float screen-size-x) (random-float screen-size-y)
    ifelse players-wealth-init = "50"
      [set money 50]
      [set money random 50]

    set happ 100
    set xp random-normal 500 100
    set xp abs xp
```

```
    set wild random-normal 0.5 0.18
    set wild abs wild
    if wild > 1 [set wild (1 - (1 - wild))]

    set greed random-normal 0.5 0.2
    set greed abs greed
    if greed > 1 [set greed (1 - (1 - greed))]

    set karma random-normal 0.5 0.2
    set karma abs karma
    if karma > 1 [set karma (1 - (1 - karma))]

    ]

; ask turtle luckyguy [set money 1000]
  recolor-players
  set randomplayer random-one-of players
end

to setup-variables
  set resources 200 * num-players
end

to move
  if locality_preference
    [
    ifelse (random-float 1 < wild)
      [if (xcor > 0)
        [                                ; if in city go into wild
        ifelse (xcor > 5)
          [set heading 90]
          [set heading 270]
        ]
      ]
      [if (xcor < 0)                     ; if in wild go into city
        [
        ifelse (xcor < -5)
          [set heading 270]
          [set heading 90]
        ]
      ]
    ]                                    ; end locality preference
  rt 30 - (random 60)
  fd player-speed
end
```

```
; Win a quest (with probability p-quest) to get money from
; virtual resources (if any left). Quest reward is always proportional
; to the player's wealth and only possible in wilderness.
to quest
  locals [amount]
  if (resources > 0 or not closed_economy) and (xcor < 0) and
  ((random-float 1) <  p-quest)
  [
    set happ happ + (10 * wild)    ; wilderness people like to quest
    set xp xp + 1
    if (random-float 1 < 0.2) [set xp xp + 1]
    set amount int (money * quest-wealth-ratio)
    set resources (resources - amount)
    set in (in + amount)
    set money (money + amount)
    if money > max-money-on-player
                ; put excess money back into virtual resources
                ; (i.e. drop older items when receiving new ones)
      [
        set resources (resources + (money - max-money-on-player))
        set out out + (money - max-money-on-player)
        set money max-money-on-player
      ]
                ; karma fluctuations
    set karma karma + (0.01 - random-float 0.02)
  ]
end

; grab no more than (trading-ratio * money) from a nearby player
; (put excess money in V-Resources ?) This corresponds to a trade
; (money moves from one player to another) where the initiating
; player is better off
to trade
  locals [partner amount k_thresh]
  if (random-float 1 <  p-trade)
  [
    set partner random-one-of players-on neighbors
    ifelse (xcor > 0)          ; if in city (due to higher karma influence)
      [set k_thresh karma_threshold / 2]
      [set k_thresh karma_threshold]
                               ; if partner is found and karma difference
                               ; isn't too big - initiate trade
    if (partner != nobody) and (not karma_influence or (abs(karma -
    value-from partner [karma]) < k_thresh) )
    [
      set xp xp + 1
      set happ happ + (10 * (1 - wild))    ; city people like to trade
      ask partner
```

```
      [
        set amount int random (money * trading-ratio)
        set money (money - amount)
      ]
      set money (money + amount)
      if money > max-money-on-player
          ; put excess money back into virtual resources
          ; (i.e. drop older items when receiving new ones)
      [
        set resources (resources + (money - max-money-on-player))
        set out out + (money - max-money-on-player)
        set money max-money-on-player
      ]
    ]
  ]
  if (xcor > 0) and ((random-float 1) <  p-npc-trade)
  [
          ; if in town and if greed test fails, trade with probability
          ; p-npc-trade with an NPC
    if not greedy_players or (greedy_players and not (random-float 1
< greed))
    [
      ifelse market_prices
        [ set amount int (avgmoney * trading-ratio-npc)
          if amount > money [set amount int (money *
          trading-ratio-npc)]
                    ; if player too poor use 'fair' method
        ]
        [ set amount int (money * trading-ratio-npc) ]
      set money (money - amount)
      set resources (resources + amount)
      set out out + amount
      set happ happ + 1
    ]
  ]
end

to fight
  locals [partner amount]
    set partner random-one-of players-on neighbors
                ; if combatant found, karma difference high enough
                ; and XP higher than opponent's - win!
    if (partner != nobody) and (abs(karma - value-from partner
    [karma]) < combat_threshold) and (xp > value-from partner [xp])
    [
      set xp xp + 1
      set happ happ + (5 * (wild))
      ask partner
```

```
    [
      set amount int random (money * fight_prey)
      set money (money - amount)
    ]
    set money (money + amount)
    if money > max-money-on-player
              ; put excess money back into virtual resources
              ; (i.e. drop older items when receiving new ones)
    [
      set resources (resources + (money - max-money-on-player))
      set out out + (money - max-money-on-player)
      set money max-money-on-player
    ]
  ]
end

to decay
  locals [amount]
  ifelse decay_by_market
   [
   set amount int (avgmoney * decayfactor)
   if amount > money [set amount int (money * decayfactor)]
              ; if player too poor use 'fair' method
   ]
   [ set amount int (money * decayfactor) ]
  set money (money - amount)
  set resources (resources + amount)
  set out out + amount
  set happ happ - 1
end

to recolor-players
  locals [max-value]
  ifelse plotvalue = "money"
  [
   set max-value max values-from players [money]
   ask players
    [ ifelse (money <= max-value / 3)
       [ set color red ]
       [ ifelse (money <= (max-value * 2 / 3))
          [ set color green ]
          [ set color blue   ]
       ]
    ]
  ]
  [
   ifelse plotvalue = "xp"
   [
   set max-value max values-from players [xp]
   ask players
```

```
     [ ifelse (xp <= max-value / 3)
         [ set color red ]
         [ ifelse (xp <= (max-value * 2 / 3))
             [ set color green ]
             [ set color blue   ]
         ]
     ]
   ]
   [              ; not money, not xp, so let's plot happiness
   set max-value max values-from players [happ]
   ask players
     [ ifelse (happ <= max-value / 3)
         [ set color red ]
         [ ifelse (happ <= (max-value * 2 / 3))
             [ set color green ]
             [ set color blue   ]
         ]
     ]
   ]
 ]
end

to do-plots
  set-current-plot "Virtual Resources"
  plot resources
  update-randomplayer-plot
  update-class-plot
  update-class-histogram
  update-money-on-players
  update-lorenz-and-gini-plots
  update-flow
end

          ; this does a line plot of a certain value of a random
          ; (but fixed) player
to update-randomplayer-plot
  set-current-plot "Random Player Info"
  if singleplotvalue = "money"
          [ plot value-from randomplayer [money] ]
  if singleplotvalue = "xp"
          [ plot value-from randomplayer [xp]    ]
  if singleplotvalue = "happ"
          [ plot value-from randomplayer [happ]  ]
  if singleplotvalue = "karma"
          [ plot value-from randomplayer [karma] ]
end
```

```
        ; this does a line plot of the number of people of each class
to update-class-plot
  set-current-plot "Class Plot"
  set-current-plot-pen "low"
  plot count players with [color = red]
  set-current-plot-pen "mid"
  plot count players with [color = green]
  set-current-plot-pen "up"
  plot count players with [color = blue]
end

        ; this does a histogram of the number of people of each class
to update-class-histogram
  set-current-plot "Class Histogram"
  plot-pen-reset
  set-plot-pen-color red
  plot count players with [color = red]
  set-plot-pen-color green
  plot count players with [color = green]
  set-plot-pen-color blue
  plot count players with [color = blue]
end

to update-money-on-players
  locals [sorted-wealths index]
  set-current-plot "Blabla on Players"
  plot-pen-reset
  if blabla = "money"
        [ set sorted-wealths sort values-from players [money] ]
  if blabla = "xp"
        [ set sorted-wealths sort values-from players [xp]    ]
  if blabla = "happ"
        [ set sorted-wealths sort values-from players [happ]  ]
  if blabla = "karma"
        [ set sorted-wealths sort values-from players [karma] ]
  set index 0
  foreach sorted-wealths [
    plot ?
    set index (index + 1)
  ]
end

to update-lorenz-and-gini-plots
  locals [total-wealth sorted-wealths wealth-sum-so-far
        index gini-index-reserve gini]

  set-current-plot "Lorenz Curve"
  clear-plot
```

```
  ; draw a straight line from lower left to upper right
  set-current-plot-pen "equal"
  plot 0
  plot 100

  set-current-plot-pen "lorenz"
  set-plot-pen-interval 100 / num-players
  plot 0

  set sorted-wealths sort values-from turtles [money]
  set total-wealth sum sorted-wealths
  set wealth-sum-so-far 0
  set index 0
  set gini-index-reserve 0

  ; plot the Lorenz Curve and calculate the Gini Coefficient
  repeat num-players [
    set wealth-sum-so-far (wealth-sum-so-far + item index sorted-
wealths)
    plot (wealth-sum-so-far / total-wealth) * 100
    set index (index + 1)
    set gini-index-reserve
      gini-index-reserve +
      (index / num-players) -
      (wealth-sum-so-far / total-wealth)
  ]

  ; plot Gini
  set-current-plot "Gini Coefficient"
  set gini (gini-index-reserve / num-players) /area-of-equality-
triangle
  plot gini
end

to-report area-of-equality-triangle
  report (num-players * (num-players - 1) / 2) / (num-players ^ 2)
end

to update-flow
  set-current-plot "Economic Flow"
  set-current-plot-pen "in"
  plot in
  set-current-plot-pen "out"
  plot out
end
```

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