

Generating Game Mechanics in a Model Economy: a MoneyMaker Deluxe Case Study

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ABSTRACT

This paper discusses the potential application of procedural content generation to a game about economical crises, intended to teach a large general audience about how banks function within a market-guided economy, and the financial risks and moral dilemmas that are involved. Procedurally generating content for abstract and complex notions such as inflation, market crashes, and market flux is different from generating spatial maps or physical assets in a game, and poses several design challenges. Instead of generating these kinds of phenomena and other macro-economic effects directly, the designers aim to let them emerge from automatically generated game mechanics. The game mechanics we propose include generic business models that can be parameterized to model the behavior of companies in the game, while the player controls the actions of a bank. What makes generating these game mechanics particularly challenging is the interaction between phenomena at different levels of abstraction. Therefore, relevant economic concepts are discussed in terms of design challenges, and how they could be modeled as emergent properties using generative methods.

1. INTRODUCTION

Procedural generation methods for game content have been successfully applied to different aspects of games in which they are embedded, such as maps, levels, quests, characters, vehicles, weapons, stories, and game rules [10]. Although there are some examples of completely automated generated games [1, 11], most of these applications have focused on a specific type of element in relative isolation, without much consideration for how they might interact with other types of elements in the game.

In many applications of procedural content generation, the focus is on physical elements, e.g., the room layout and path connectivity of dungeons, the spatial layout of platforms or planets. Some researchers have argued that it can be useful to consider these kinds of elements together with other,

more narrative elements of the game, such as the contents of a player's mission or quest [4, 7]. However, for some games neither elements in isolation nor the spatial layout of elements is important, especially when the game is centered around more abstract concepts and types of processes other than physical placement or character movement (e.g., flows of resources [12], or negotiation between players).

In this paper we consider the potential application of procedural content generation for a game about banks and companies functioning (and dysfunctioning) within an economy, as well as the issues that arise. We argue that this domain poses several challenges for the design of appropriate generative methods. In section 2, we address these challenges, which include modeling and generating emerging inflation, emerging crashes, evolving business models, and maintaining a healthy economy. In section 3, we discuss issues regarding emergent macro-economic variables, business evolution, and cooperation that arise from procedurally generated game mechanics. Lessons learned in this case study are summarized in section 4.

2. DESIGN CHALLENGES

MoneyMaker Deluxe is a game inspired by the financial crisis of 2008, when a sudden collapse of the financial system brought the worldwide economy to a standstill. The creators of the game aim to teach the inner workings (and inherent dangers) of fractional reserve banking to a large, general audience. In order to better understand how banks work, the player is continuously presented with the type of decisions and moral dilemmas that a real bank would face.

The player is presented a world inhabited by people and companies, where resources are limited and investment opportunities are plentiful (fig. 1). Companies are embedded in a model economy, as they can buy and sell goods from other companies, and transform one product into another (e.g. a baker produces bread from grain). Markets follow the laws of supply and demand: companies in need of resources pick out the cheapest producer, while maximizing revenue by adjusting the prices for their own products. Low prices tend to attract more customers, but inflated prices will yield more income, given that other companies are still willing to buy. A company may decide to decrease its margins, up to the point where the sell price is equal to the buying cost of the resources. Taken together, the local interactions of buyers and sellers cause market prices to be in



Figure 1: Screenshot of MoneyMaker Deluxe.

continual flux.

Playing the role of a bank, the player takes on a central role in this market-guided economy. He or she can issue loans to companies that may increase the company’s productivity or be used to decrease product prices in order to outcompete competitors. For example, the player selects a farm that, like all other businesses, wants to grow further but needs an investment to do so. The game presents the player with several choices on how to lend out money to the farm (e.g. loan duration, return on investment, and interest rate) that determine whether the player is successful in terms of solvency, gaining trust, or creating a healthy financial ecosystem, depending on the player’s goals.

Credit investment by other banks (i.e. the player’s opponents) is guided by the amount of trust a company has earned over time by being creditworthy; a company can become more creditworthy to a bank by paying back loans on time. Of course, even banks cannot borrow out money indefinitely, as their reserves are limited by the amount of savings of the world’s inhabitants. When a bank loses the trust of its savers, its reserves may dry up over a very short timespan. Consequently, several scenarios may unfold during the course of the game, such as the introduction of new types of bank credit, abandoning the gold standard, allowing for fractional reserve banking, or a collapse of the entire financial system.

Allowing these kinds of scenarios, which make the game more interesting and realistic, requires modeling several economic principles. Key economic concepts, such as inflation and market crashes, will have to emerge out of local business interactions, and the game economy should evolve over time. Four major design challenges are listed below; how PCG techniques will be applied in solving these challenges is discussed in the section that follows.

2.1 Inflation

In classical economics, inflation is defined as an increase in money supply causing a general rise in price level. However, inflation does not treat all goods equally: those who buy goods with credit are generally capable of outbidding those who buy the same goods with savings. So, goods that tend to be bought with credit (e.g. real estate) will rise faster

in price than goods that are bought with cash (e.g. food). This type of differentiated inflation needs to arise from the market mechanics (i.e. rather than being determined by an arbitrary price increase over time) for the player to understand inflationary consequences of his credit expanding actions.

2.2 Market Crashes

Although the gold standard (i.e. each currency unit is based on a fixed quantity of gold) is the default monetary system at the start of the game, the player is free to lend out more credit than he has gold to back it up with. This business model (known as leveraging) can be very profitable, as a bank can earn interest on money that it doesn’t have. Conversely, too much leverage can cause a financial crisis, which is typically characterized by a period of sudden deleveraging and a sharp decline of trust in banks. For the player to understand the mechanisms of leveraging and deleveraging, trust levels should not be determined arbitrarily but rather in relation to the underlying market.

2.3 Market Flux

Balancing out the many variables that determine how an economy operates is a laborious task. Moreover, economies tend to be in continuous motion, with companies adapting to times of prosperity and decline. Ideally, as the player makes choices and the game progresses over time, business models would evolve with it.

2.4 Balancing Self-interest

While companies want to increase their own profit, they should not ignore other macro-economic developments that may hurt the economy as a whole in the long run, such as hyperinflation or monopolies. So, as companies try to increase their margins, the market should keep generating interesting investment opportunities from a game-design perspective.

3. PCG APPROACH

Following these design challenges, it is necessary to generate variation in game mechanics while also allowing for the desired macro-economic effects to occur. These effects need to arise out of the local interactions between economic entities, rather than through arbitrary game design or scripted triggering of an event. For example, it is relative straightforward to model inflation as a fixed or stochastic increase of prices over time, or to trigger a market crash at a randomly determined point in time. However, modeling these effects and events as emerging from the market requires a more economically plausible approach.

3.1 A Generic Business Model

We deal with these challenges using procedural generation of game mechanics. More specifically, companies are instantiated with parameterized business models to create a diverse ecosystem of companies in the game. The player may decide to offer a specific type of loan to a company; whether this offer is accepted (and how it affects the company’s production) may depend on different conditions (e.g. interest rate and loan amount) for each company.

Business models need to be generated with respect to two practical constraints: there should be enough variation in

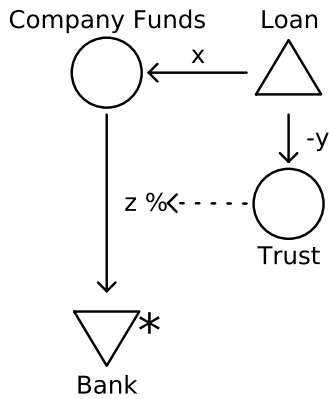


Figure 2: Generic business model that defines the relation between company funds, loan amount x , relative trust decline y , and interest rate z .

the company ecosystem to allow for meaningful competition and choices, and the resulting market should display the desired macro-economic effects. In order to further define the range of possible business mechanics that can be generated with respect to these two constraints, we identify four inter-related factors that, taken together, form a financial model for investment decisions. These factors are: company funds, loan amount, interest rate, and trust.

As a next step, these investment factors are expressed using the Machinations [3] modeling language (fig. 2). As a company generates products from resources, its production capacity is influenced by the amount company funds, i.e. a company can increase resource production if more funds are available. Since revenue is generally not high enough to afford such an investment, a company may instead accept loan amount x from a bank, against an (initial) interest rate z , represented by a stochastic flow of company funds to the bank. However, every time a loan is accepted by a company, its trust rating will decrease by y , which will in turn lead to a higher interest rate.

3.2 Emergent Inflation

As a bank, the player creates loans and thereby distributes credit to companies. Creating loans allows the player to expand his credit beyond his immediate cash paying capability. However, the player is limited in how much credit he can generate by how much trust he has acquired from the companies in the game economy. In other words, trust is not a parameter of company or bank, but rather defines a relationship between two business entities (i.e. company or bank). By virtue of credit expansion being limited by trust, the player can freely create credit within those bounds, and therefore the total credit may increase. More credit means less purchasing power per unit of money, so inflation emerges from this model in a natural way.

3.3 Emergent Market Crashes

The linear gain of increased productivity made possible by borrowing amount x will typically be outperformed by the increase in nonlinear interest rate that occurs due to a loss of trust. It may still be beneficial for a company to accept a loan, for example if trust can be restored by paying back pre-

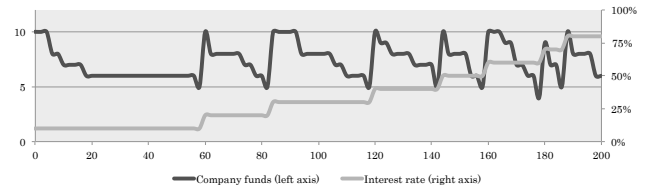


Figure 3: Interest rate and company funds for $t \in [0, 200]$ for a company with 10 initial funds acquired against a 10% initial (stochastic) interest rate z . Following its parameterized business model, the company will borrow money ($x = 5$) each time its funds are down to 5. Repeatedly lending money has an effect y on its trust rating, which is reflected by the increase in interest rate: every time money is borrowed, z goes up 10%. In order to avoid bankruptcy, intervals between loans decrease nonlinearly.

viously borrowed money. Excessive money borrowing clearly is a recipe for disaster: although it may have positive short-term effects (e.g. postponing bankruptcy), it also increases the bank's liability since an increasing amount of money will not be paid back once the company goes bankrupt (fig. 3).

If many companies are instantiated with business models that let them accept any loan, and the player is willing to distribute those loans, it may threaten the economic health of the entire financial system. Although banks can use leveraging, their capacity to distribute loans is still constrained by trust: if the world's inhabitants lose trust in the bank and come to collect their savings, the bank is forced to deleverage and can no longer distribute uncovered loans to companies.

3.4 Adapting Markets

Every so often, the village grows a little. As a new business model is created, its parameters (e.g. input, output, price) are based on the parameters of the most profitable business of that type. In future versions of MoneyMaker, different types of generators to determine these parameters will be experimented with. Companies that are making a loss and can't get a loan will leave the village. This way, companies continuously adapt to the player's style and choices following a logic of random variation and selective retention.

3.5 Cooperation

The macro-economic properties that emerge from local market interactions are good indicators of the state of the economy. For example, high inflation can be a liability for economic entities, as it increases the probability of a financial collapse. Public spirit can emerge from self-interest, as companies benefit from a healthy economy in the long run. The choice between self and society is modeled by limiting company growth (i.e. preventing monopolies), but allowing for cooperation between companies. Extending the generic business model (fig. 2) by allowing companies to be instantiated as business partners for other companies opens up a entirely new generative modeling space.

Cooperation can be realized in multiple ways, for example through buying products against inflated prices, protectionism, risk sharing, cartel formation, or price agreements. In

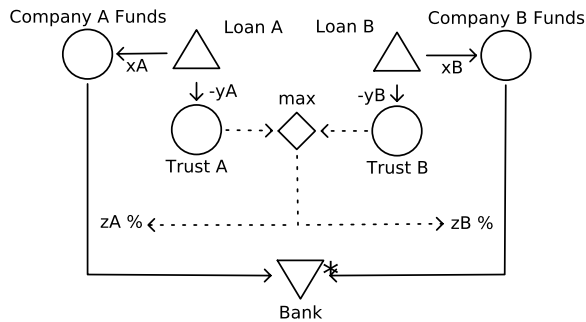


Figure 4: Cooperation through risk sharing.

figure 4, cooperation by means of risk sharing is modeled after a synergetic coupling between emergent processes [2][9], where each process maintains the other's boundary conditions. Companies A and B agree to share the risk of increasing interest rates: whichever company is trusted most by the bank (i.e. has the least amount of loans so far) will vouch for the loan to be repaid. This allows both A and B to borrow money against an interest rate that is based on trust rating $\max(\text{TrustA}, \text{TrustB})$. The downside of this type of cooperation is an increase in liability, i.e. company A borrowing money repeatedly will negatively impact company B, and vice versa.

4. CONCLUSIONS

MoneyMaker Deluxe is currently under development at Firebrush Studios, and is expected to be released in 2016. Several economy modeling issues arose during the game design process, which are dealt with by generating different business models that allow for emergent, macro-economic effects to occur. These models allow for emergent gameplay [6] and can, more generally, be used to create guided unpredictability in games [8].

Adding inflation to a model economy can be as simple as specifying a periodic increase in prices. In our approach, however, inflation follows from the leverage that is created by banks, which is in turn constrained by trust. Therefore, inflation ultimately depends on the trust parameters of the procedurally generated business models in the current economy. Similarly, although a market crash can simply be a scripted event, here we have modeled it as the result of too much lending and leverage; again, the occurrence of a macro-economic event is determined specifically by the generated business mechanics. Then, as players selectively distribute loans to particular companies, the company ecosystem shifts towards the player's choices and preferences. As such, the continuous generation of new business models leads to an adaptive market.

Finally, exchanging unlimited company growth for the possibility of mutual cooperation opens up a new dimension for procedurally generating company-to-company interactions. This gives rise to an interesting observation: as the model economy and the interactions between the economic entities grow more diverse and complex, the player does not necessarily benefit from this complexity if he or she cannot influence it. We therefore plan to allow the player to decide on the constraints within which the economy can grow, for ex-

ample what kinds of cooperations can emerge [5]. Although the case study is currently still underway, the proposed solutions to the design challenges and the preliminary results already indicate that for this type of world-builder game, PCG can support co-creation.

5. ACKNOWLEDGMENTS

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6. REFERENCES

- [1] M. Cook, S. Colton, and J. Gow. Automating game design in three dimensions. In *Proceedings of the AISB Symposium on AI and Games*, 2014.
- [2] T. W. Deacon. *Incomplete Nature: How Mind Emerged from Matter*. W.W. Norton and Company, New York, NY, 2012.
- [3] J. Dormans. *Engineering emergence: Applied theory for game design*. PhD thesis, University of Amsterdam, 2012.
- [4] J. Dormans and S. C. J. Bakkes. Generating missions and spaces for adaptable play experiences. *IEEE Transactions on Computational Intelligence and AI in Games. Special Issue on Procedural Content Generation*, 3(3):216–228, 2011.
- [5] J. Dormans and S. Leijnen. Combinatorial and exploratory creativity in procedural content generation. In *Proceedings of the 4th International Workshop on Procedural Content Generation in Games*, 2013.
- [6] J. Juul. The open and the closed: Games of emergence and games of progression. In F. Mäyrä, editor, *Proceedings of Computer Games and Digital Cultures Conference*, pages 323–329, Tampere, Finland, 2002. Tampere University Press.
- [7] D. Karavolos, A. Bouwer, and R. Bidarra. Mixed-initiative design of game levels: Integrating mission and space into level generation. In *Proceedings of the 10th International Conference on the Foundations of Digital Games*, 2015.
- [8] S. Leijnen. Order of battle: A case study for designing emergent structure in games. In *Proceedings of the 7th Complex Systems Modelling and Simulation workshop at the Artificial Life conference*, 2014.
- [9] S. Leijnen. Artificial self from artificial self-organization. In *Proceedings of the Workshop on AGI, Synthetic Cognitive Development and Integrated-Distributed Agency*, submitted.
- [10] J. Togelius, N. Shaker, and M. J. Nelson. Introduction. In N. Shaker, J. Togelius, and M. J. Nelson, editors, *Procedural Content Generation in Games: A Textbook and an Overview of Current Research*. Springer, 2015.
- [11] M. Treanor, B. Blackford, M. Mateas, and I. Bogost. Game-o-matic: Generating videogames that represent ideas. In *Proceedings of the The third workshop on Procedural Content Generation in Games*, page 11. ACM, 2012.
- [12] R. Van Rozen and J. Dormans. Adapting game mechanics with micromachinations. In *Proceedings of the 9th International Conference on the Foundations of Digital Games, 2014*. ACM, 2014.