Diegetically Grounded Evolution of Gameworld Languages

James Ryan
Expressive Intelligence Studio
University of California, Santa Cruz
jor@soe.ucsc.edu

ABSTRACT

We present perhaps the first exploration of the procedural generation of gameworld languages, meaning fictional languages spoken by characters in a game's diegesis. This preliminary work takes a simulation-based approach in which languages are represented abstractly, using a vectorial scheme, and evolve over simulated game time as the emergent byproduct of diegetic agent interactions. While this method does not produce concrete languages with surface representations and rules, the abstract vectors that it does produce still provide interesting authorial affordances, which we discuss. Moreover, as an operationalization of linguistic theories, particularly Labov's *incrementation model*, we position our work as a potential contribution to the computational modeling of linguistic phenomena.

Keywords

generative methods, simulation-based approaches, computational modeling of language

INTRODUCTION

Many games feature fictional *gameworld languages* that are spoken by characters in the games' diegeses. These languages are typically represented using constructed sound systems or orthographies, often runic-looking ones, that are intentionally opaque to the player. This design move has been employed for light worldbuilding that is nonessential to gameplay, like the variant of Hylian used in *The Legend of Zelda: The Wind Waker* (2003), as well as in support of abstract procedural dialogue (thereby skirting the cost of full natural language generation), a purpose served by the Simlish language of the *Sims* series (Portnow, 2011). Other games, however, use gameworld languages in their core gameplay. In the *Myst* series, for example, the fictional D'ni language is central to certain puzzles (Portnow, 2011). Chris Crawford's innovative *Trust & Betrayel: The Legacy of Siboot* (1987) utilizes an early version of the designer's modular iconic language, Deikto, as an important player interface (Crawford, 2007). Differently still, *World of Warcraft* hinders communication between players whose characters are not in the same factions, using the narrative conceit that the factions are associated with mutually unintelligible languages (Lowood, 2006).

While generative methods have been employed to produce a huge variety of videogame content (Shaker et al., 2015), including content representing other sociocultural concerns (Johnson, 2015; in het Veld et al., 2015), we are not aware of any project that has procedurally generated gameworld languages. Even *Dwarf Fortress* (Adams, 2015), whose range of content generation is famously vast, does not generate or alter its languages at runtime.

In this paper, we present preliminary work that constitutes, to our knowledge, the first exploration of the procedural generation of gameworld languages. Our project, housed in

Proceedings of 1st International Joint Conference of DiGRA and FDG

a currently unreleased game called *Islanders*, takes a simulation-based approach (Smith, 2015) in which languages are represented abstractly, using a vectorial scheme, and evolve over simulated game time as the emergent byproduct of agent interactions occurring in the game's diegesis, or fictional storyworld. While this method does not produce concrete languages with surface representations and rules, the abstract vectors that it does produce still provide interesting authorial affordances. For instance, as we discuss more deeply below, communication with non-player characters (NPCs) could be dynamically inhibited, in the style of *World of Warcraft*, by comparing character language vectors. Further, the vectors themselves could be used to generate fully specified *conlangs*, or constructed languages, for instance by serving as genetic sequences that, by a mapping scheme, yield phenotypic traits that express in the surface representation of a language or in its rules. Beyond its novel contribution to procedural content generation in games, we position our project as a potential contribution to the computational modeling of linguistic phenomena, an area we outline briefly in the next section. As we note throughout the paper, our approach operationalizes linguistic theories surrounding language change; in particular, we have devised our method as a broad computational account of William Labov's *incrementation model* (Labov, 2007), which we introduce shortly. We hope that our project will spark interest and subsequent work in the underexplored area of procedural generation of gameworld languages.

RELATED WORK

While we are not aware of examples of the procedural generation of gameworld languages, we more broadly situate our work in the application area that computationally models language phenomena using agent-based simulations. In this body of work (Steels, 2011; Gong and Shuai, 2013), there is a particular focus on *operationalizing* theories about the origins of language and about specific attested linguistic phenomena (*e.g.*, the emergence of a particular permissible word order in a language), where the simulation outcomes serve as empirical results for the operational theory. Relative to this craft, our method is quite simplified in its modeled evolutionary processes and linguistic representations, but it does appear that our project might be novel in its simulation of diachronic (across centuries) macroscale (the phylogenetic level) language change in a massive discrete physical space (whereas other work typically models a single abstract agent environment). Without a more rigorous review of this literature, however, we are not comfortable making any formal claims. The biggest differences between this work and ours is that we seek primarily to produce a specific set of authorial affordances, as discussed below, and have targeted a fidelity of simulation that allows for use of our method as part of a larger videogame framework; obviously, these are not goals that would frame (or constrain) system design in the community we have profiled.

BACKGROUND: LABOV'S INCREMENTATION MODEL

Broadly, and at times specifically, our approach is an operationalization of William Labov's *incrementation model*, which is a theory of real-world language change as a bottom-up evolutionary process that is driven by the speech activity of individuals (Labov, 2007). While we periodically explain more details below, the thrust of the model is that the individuals of each new generation of speakers begin life by inheriting the speech tendencies of their parents, which they proceed to adapt and modify during adolescence, before eventually transmitting their innovative tendencies to their children, the next generation of speakers.

ISLANDERS

Islanders is a currently unreleased *dwarflike* (a game in the mold of *Dwarf Fortress*; Adams, 2015) that is roughly inspired by the Polynesian settlement of the south Pacific. Briefly, gameplay is preceded by a *world generation* procedure that begins with a large sea containing scattered island archipelagos and proceeds as follows: the world is uninhabited, save for a single ship holding several dozen agents, which is guided to land at a randomly chosen island on which they establish a settlement. From here, the general simulation proceeds at regular timesteps that each represent one year of game time. During a year, each agent carries out a life in a low-fidelity simulation, and thereby the small initial agent community grows and eventually disperses across the gameworld. As we explain below, this diffusion of agents across the simulated space allows us to model the largescale linguistic phenomena that is the basis of this paper. While we do not have room to explain *Islanders* in depth, for our purposes here we must explain a few things before continuing. First, islands are modeled as abstract rectangles with agent settlements that take up discrete area, and the remainder of the island's extent is modeled as a wilderness. Agents move between settlements (and campsites in wildernesses) on foot, and move between islands by ship; travel is constrained such that agents may only voyage so far on foot or by ship in a year, which means agents tend to keep relatively close to their birthplaces. Since the unit of timestep is one game year, each year in an agent's life is spent in a single place (either a settlement, a campsite in a wilderness, or a ship). Finally, there is some basic modeling of personality, and agents form friendships according to a method described elsewhere (Ryan et al., 2016). During gameplay, the player controls the actions of a randomly selected agent.

EVOLVING GAMEWORLD LANGUAGES IN *ISLANDERS*

In this section, we outline our method for evolving computable representations of gameworld languages in a way that is diegetically grounded.

Vectorial Representation

Our approach is made possible by the utilization of a vectorial scheme by which a language is represented as a sparse *bit array* with 1,000 entries—*i.e.*, an array composed primarily of zeros but with a small number of ones. In this representation, bits stand for abstract linguistic features—as such, we model evolution that in the real world occurs largely in a *discrete possibility space* (intuitively consider syntactic and semantic change) in an approximately *continuous possibility space* (*i.e.*, a vector space). This allows us to nearly altogether skirt issues surrounding the complexity and nuance of natural language. We specifically target a bit-array abstraction because it supports the efficient simulation of bottom-up language change among very many agents, as well as the computation of mutual intelligibility between any two agents; as we explain above and below, these are two core concerns of this project. While languages are represented in this way during the simulation of language evolution, underlying language vectors could be used to generate concrete *surface-level* representations of those languages (*i.e.*, conlangs), a prospect that we discuss below.

Idiolects, Dialects, and Languages

As in the real world, agents in *Islanders* instantiate their own *idiolects*, and the idiolects of multiple agents work in tandem to compose *dialects* and full-fledged *languages*. Idiolects characterize the peculiar linguistic patterns of individuals, and dialects represent the linguistic patterns of a community of speakers (in *Islanders*, a group living in the same settlement or on the same island); both are represented using the same vectorial scheme discussed in the last subsection. All three of these linguistic systems are examples of *varieties*, a useful term from sociolinguistics that we will occasionally utilize below. As we discuss shortly, language change originates in the propagation of arbitrary linguistic innovations at the level of idiolects (modeled as bit flipping). Change at the level of dialects and languages, then, is merely a corollary of idiolectal change tracked at infrequent time intervals. Specifically, once every game year, we update the vector representing a language by surveying the idiolects of its proficient speakers to assemble a new vector whose entries contain the *majority bits*, across all speaker idiolects, for each bit index. For example, if 500 speakers of a language have a `1` as the 100th entry of their idiolect vectors and 499 have a `0`, the language would take a `1` for that entry of its own vector (since it is the majority bit across the language's speakers). Dialects for each language are similarly instantiated for each settlement and island that the language is spoken in or on, though of course these procedures only operate over the idiolects of speakers living in the relevant areas.

Language Acquisition

Children in *Islanders* acquire language from parents and other individuals in their homes, as well as peers after they begin leaving their homes to interact with other agents living in their settlements. Additionally, adults may acquire non-native languages given sufficient exposure to them. In both cases, we represent *fluency* as a floating-point value between `0.0` and `1.0`, where `0.6` is the (parameterizable) threshold for *proficiency*.

Acquisition of Native Languages

Up until puberty, agents in *Islanders* may acquire native-level fluency in any language to which they are sufficiently exposed; this operationalizes the *critical period hypothesis* in linguistics (Lenneberg et al., 1967). The *acquisition rate* (rate at which fluency is acquired) for agents gradually decreases until age fourteen, and thereafter steeply. Prior to the age of four, agents will only be exposed to languages spoken in their homes, specifically languages that are spoken proficiently by residents in the home. If there are multiple such languages, children may or may not acquire multiple or all of them—this is determined probabilistically, where languages spoken by parents and/or by multiple people in the home are more likely to be acquired. Upon reaching the age of four, children begin to leave the home and socialize with other agents living in the same settlement. Here they may be exposed to many languages, which they acquire (or gain fluency in) probabilistically, where the probability of picking up a language is simply the percentage of agents in the settlement who are proficient in that language. This probability is also boosted commensurate to the degree that a language is spoken by friends of this agent. To initialize a child's idiolect for a newly acquired language, she simply inherits the current idiolect of someone in the home (most likely her mother, per the incrementation model; Labov, 2007), if it was acquired in the home, or else the vector for the current dialect of the language in her settlement.

Acquisition of Non-Native Languages

After puberty and until middle age, agents may acquire non-native languages at a `0.065` acquisition rate. Upon middle age, this acquisition rate begins to decrease exponentially. To initialize an agent's idiolect for a newly acquired non-native language, we operationalize the notion of a *foreign accent*. This is done by taking the local dialect of the language being acquired and warping each of its bits (at a 20% chance) to match the bit in the corresponding index of the agent's first language (*i.e.*, the language she is most proficient in).

Language Deacquisition

If an agent does not have access to other speakers of a language that she speaks, she may lose proficiency in that language from disuse. This often occurs when someone leaves a home island for new environs in which no languages already known by the agent are present. Specifically, language fluency decays at a rate of `0.03` per year of non-exposure.

Language Change

Like in the real world, *language change* in *Islanders* is driven bottom-up by the accumulation of minute changes occurring at the level of idiolects. As we discuss in detail in the following subsections, this process is characterized by discrete linguistic *innovations* (modeled as bits being flipped) that propagate, by a process called *adoption*, across speaker groups as agents incorporate these new forms into their own idiolects. Because dialects and languages are composed according to the idiolects of their speakers, as we explained above, idiolectal mutations will produce changes in these larger varieties as the former propagate widely.

Innovation

Similarly to biological evolution, dialects and languages change as discrete mutations in the speech patterns of individuals propagate across speaker groups (Croft, 2000); the processes driving and governing linguistic mutation, in particular, are referred to by the banner term *innovation* (Milroy and Milroy, 1985). In *Islanders*, we abstractly model innovation as *bit flipping*; that is, a discrete linguistic innovation by an individual is simulated as the flipping of a single randomly selected bit in her idiolect vector. Each year, each agent in the game world has a probability of flipping a single bit, which is determined by the agent's age and personality. Specifically, agents between four and seventeen years old have a chance of innovating that approaches 60% (an operation of the incrementation model, which posits this age range), and thereafter the chance decreases as age increases and bottoms out around middle age. Additionally, the chance of flipping a bit is depends on gender (the incrementation model asserts that girls and women are the primary drivers of language change; Labov, 1990) and speaker personality, with more extroverted agents being more likely to innovate; the latter operationalizes accounts of personality influencing innovation (Eckert, 2000).

Adoption

Linguistic innovations propagate within and across speaker groups by a process called *adoption* (Labov, 1990, 2007). In *Islanders*, we model adoption as the unconscious flipping of bits in an agent's idiolect vector to match the corresponding bits in the idiolects of nearby agents. This is done for each language that the agent speaks, and proceeds as follows. Once a year, the system collects for an agent all of her friends that live in the same settlement (and speak the language at hand) and, for each of these friends, determines a *power of influence*. An agent's linguistic power of influence over another agent is determined by the influencer's proficiency in the language under consideration (more proficient speakers are more influential) and the age difference between the two agents (influence is greater with lesser age difference). Having this, the system iterates over the agents' idiolect vectors, and, for each instance of a mismatch between the vectors, flips the bit in the idiolect of the agent who is being influenced at the probability of the derived power of influence. For example, if the power of influence for the pair of agents is 0.5, each mismatch between their idiolects would have a 50% chance of being resolved. We have innovations spread across friends close in age to match the incrementation model's account that adoption primarily occurs within peer groups (who then pass on the innovations to their children), but we note that we unfortunately fail to capture the pivotal role of social stratification in this process (since *Islanders* currently does not simulate these concerns) (Eckert, 1988; Labov, 1990).

Language Birth and Death

Over extended periods of localized innovation and adoption, dialects tend to grow apart as a function of geographic distance (Labov, 2007). Eventually, such divergence may become so substantial that speakers of related dialects become *mutually unintelligible* to one another, at which point it becomes more useful to say that one or both have evolved into *daughter languages* of the language for which they were previously called dialects. This is *language birth*, and in *Islanders*, demarcation proceeds as follows. As noted above, dialects and languages are reconstructed yearly. After this is done, the vectors for each island dialect are compared against the corresponding language vectors, and if any difference of more than 25 bits is encountered, the pertinent dialect is reified as a new language. As this process repeats, the game world's *language family* becomes more varied, and a phylogenetic tree characterizing it grows accordingly. We should also note here that the game world's *primordial language*—the language that already exists at the beginning of game time—is generated by turning its bits on at a 10% chance. All speakers alive at that time simply begin with that vector as their respective idiolect vectors. Finally, *language death*: when the last speaker of a language dies or loses fluency in it, the language vanishes with her.

DISCUSSION AND FUTURE WORK

While this method does not produce concrete languages with surface representations and rules, the abstract vectors that it *does* produce still provide interesting authorial affordances. Specifically, we isolate two crucial properties of these language vectors: their *general computability*, which they get from being vectors, and their *diegetic grounding*, which they earn by only evolving according to diegetic agent interactions. Crucially, these properties afford the computability of *mutual intelligibility*, meaning the degree to which two agents (one of whom may be a player character) can *believably* understand each other through speech. Since agent idiolect vectors are binary, this can simply be calculated as the number of bits that differ between the idiolects. We can even do this with agents who speak different languages—since all linguistic varieties embed in the same vector space—which will return greater mutual intelligibility between agents who speak more closely related languages. Having these fine-grained measures of intelligibility, a game system could dynamically hinder communication—in the style of *World of Warcraft*, noted above—between player and NPCs according to the characters' idiolect vectors. In another ongoing project, we are exploring the use of deep learning for natural language understanding in games. Specifically, this approach produces models that output rankings of plausible meaning representations given arbitrary player utterances as input. In combination with this system, we could choose *less plausible* meaning representations (*i.e.*, ones that the model ranks lower) as the player character is less intelligible to an NPC. This would make NPC understanding of the player's speech dynamic to the actual (*i.e.*, diegetic) linguistic capacities of the characters, and further, as a narrative conceit it could relieve pressure on our early NLU technology (assuming the tactic reads well at the surface). We are also developing natural language generation technology for producing NPC dialogue on the fly, and we could likewise use the same authorial affordances to deform that output (which would similarly relieve pressure on the technology). In future work, we plan to implement this connection and evaluate the resulting interaction scheme from a player perspective.

Another area of future work that would be enabled by the computability and diegetic grounding of the language vectors is the prospect of generating fully specified *conlangs*, or constructed languages, from them. We imagine that this would involve treating a vector as a genetic sequence that, by some mapping scheme, yields phenotypic traits that express in the surface representation of the language or in its rules. By this approach, related languages would produce similar conlangs, since they would have similar underlying vectors and would be generated using the same mapping scheme. For this project, language vectors would likely need to be extended past the 1000 entries that we used in this paper. This is because important language features—*e.g.*, the use of gendered pronouns—would likely require many bits, if only for the practical reason that the flipping of a single bit in a language should only correspond to a small surface-level change.

This notion of using diegetically evolved vectors as genetic sequences suggests a more generalized approach that evolves sociocultural considerations beyond language. Here, let us specifically consider *Chimeria*, an AI system that richly models social-group membership according to specifications of those groups in hand-authored *domain epistemologies* (Harrell et al., 2014). In an application of the system called *Chimeria: Gatekeeper*, an underlying domain epistemology defines the attributes that are prototypically associated with two races in a fantasy world. For instance, this epistemology specifies that members of the first race like rough-spun garments, while members of the other race prefer fine clothing. As the system stands today, agents in *Chimeria* applications inherit from a single hand-authored domain epistemology that is static and cannot change as the simulation proceeds. We can imagine, however, an extension to this system in which agents diegetically evolve vectors that represent domain epistemologies, with individual entries standing for individual sociocultural concerns, or that are used as genetic sequences that map to phenotypic traits that pertain to sociocultural concerns. Instead of operationalizing linguistic theories, this proposed integration could operationalize theories about general sociocultural transmission and evolution, *e.g.*, the influential work of Cavalli-Sforza and Feldman (1981).

Finally, we return to the specific concerns of the method we have presented in this paper to note that a major omission is a lack of modeling of *language contact*. This is the phenomenon of disparate linguistic varieties converging on small geographic areas, called *contact zones*, in which people who cannot speak to one another have to communicate for commerce or other reasons (Thomason and Kaufman, 1992). From such contact might emerge a *pidgin* language, an underspecified recombination of features of the languages in contact. When a generation of children are exposed to a pidgin, however, they adopt it as a native language and invariably flesh it out to full specification, at which point it becomes a *creole*. We currently do not model this phenomena, but we imagine this can be done by building a *pidgin vector* that recombines a subset of the contact language vectors, which could then be filled out to full-length creoles using random bits. This also remains as future work.

EXAMPLE

Islanders gameplay instances are capable of generating encyclopedias for their gameworlds, and we have hosted an example one at `https://users.soe.ucsc.edu/~jor/diol`. We invite readers to visit it and explore information about the particular language families that emerged in that gameworld.

BIBLIOGRAPHY

Adams, T. (2015). Simulation principles from Dwarf Fortress. In S. Rabin (Ed.), *Game AI Pro 2: Collected Wisdom of Game AI Professionals*.

Cavalli-Sforza, L. L. and M. W. Feldman (1981). *Cultural transmission and evolution: a quantitative approach*. Princeton University Press.

Crawford, C. (2007). Deikto: A language for interactive storytelling. In P. Harrigan and N. Wardrip-Fruin (Eds.), *Second Person*.

Croft, W. (2000). *Explaining language change: An evolutionary approach*.

Eckert, P. (1988). Adolescent social structure and the spread of linguistic change. *Language in Society*.

Eckert, P. (2000). *Language variation as social practice: The linguistic construction of identity in Belten High*. Wiley-Blackwell.

Gong, T. and L. Shuai (2013). Computer simulation as a scientific approach in evolutionary linguistics. *Language Sciences*.

Harrell, D. F., D. Kao, C.-U. Lim, J. Lipshin, A. Sutherland, J. Makivic, and D. Olson (2014). Authoring conversational narratives in games with the chimeria platform. In *Proc. Foundations of Digital Games*.

in het Veld, B., B. Kybartas, R. Bidarra, and J.-J. C. Meyer (2015). Procedural generation of populations for storytelling. In *Proc. PCG in Games*.

Johnson, M. R. (2015). Modelling cultural, religious and political affiliation in artificial intelligence decision-making. In *Proc. AI & Games Symposium*.

Labov, W. (1990). The intersection of sex and social class in the course of linguistic change. *Language Variation and Change*.

Labov, W. (2007). Transmission and diffusion. *Language*.

Lenneberg, E. H., N. Chomsky, and O. Marx (1967). *Biological foundations of language*.

Lowood, H. (2006). Storyline, dance/music, or PvP? game movies and community players in World of Warcraft. *Games and Culture*.

Milroy, J. and L. Milroy (1985). Linguistic change, social network and speaker innovation. *Journal of Linguistics*.

Portnow, J. (2011). Gaming languages and language games. In M. Adams (Ed.), *From Elvish to Klingon: Exploring Invented Languages*.

Ryan, J., M. Mateas, and N. Wardrip-Fruin (2016). A simple method for evolving large character social networks. In *Proc. Social Believability in Games*.

Shaker, N., J. Togelius, and M. J. Nelson (2015). *Procedural Content Generation in Games: A Textbook and an Overview of Current Research*. Springer.

Smith, G. (2015). Procedural content generation: An overview. In S. Rabin (Ed.), *Game AI Pro 2: Collected Wisdom of Game AI Professionals*.

Steels, L. (2011). Modeling the cultural evolution of language. *Physics of Life Reviews*.

Thomason, S. G. and T. Kaufman (1992). *Language contact, creolization, and genetic linguistics*. Univ. of California Press.