PERCEPTION AND CREATION OF DIVERSE ALPHABETIC STYLES

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Abstract. The Letter Spirit project explores the creative act of artistic letter-design. The aim is to model how the 26 lowercase letters of the roman alphabet can be rendered in many different but internally coherent styles. Viewed from a distance, the behavior of the program can be seen to result from the interaction of four emergent agents working together to form a coherent style and to design a complete alphabet: the Imaginer (which plays with the concepts behind letterforms), the Drafter (which converts ideas for letterforms into graphical realizations), the Examiner (which combines bottom-up and top-down processing to perceive and categorize letterforms), and the Adjudicator (which perceives and dynamically builds a representation of the evolving style). Creating a gridfont is an iterative process of guesswork and evaluation carried out by the four agents. This process is the "central feedback loop of creativity". Implementation of Letter Spirit is just beginning. This paper outlines our goals and plans for the project.

1. Fluid Concepts and Creativity

The Letter Spirit project is an attempt to model central aspects of human high-level perception and creativity on a computer. It is based on the belief that creativity is an automatic outcome of the existence of sufficiently flexible and context-sensitive concepts — what we call *fluid concepts*. Accordingly, our goal is to implement a model of fluid concepts in a challenging domain. Not surprisingly, this is a very complex undertaking and requires several types of dynamic memory structures, as well as a sophisticated control structure involving an intimate mixture of bottom-up and top-down processing. The full realization of such a model will, we believe, shed light on human creativity.

The specific focus of Letter Spirit is the creative act of artistic letter-design. The aim is to model how the 26 lowercase letters of the roman alphabet can be rendered in many different but internally coherent styles. Two important and orthogonal aspects of letterforms are basic to the project: the *categorical sameness* possessed by instances of a single letter in various styles (*e.g.*, the letter 'a' in Times and Optima) and the *stylistic sameness* possessed by instances of various letters in a single style (*e.g.*, the letters 'a' and 'k' in Times). Figure 1 shows the relationship of these two ideas. The program will start with one or more seed letters representing a style and create the rest in such a way that all 26 share the same style, or *spirit*.

To put the goals of Letter Spirit in perspective, it is enlightening to analyze what is lacking in many AI programs touted as "models of creativity". The problem is that they *don't know anything about what they are doing*. This phrase actually has two meanings, both of which apply to the programs under discussion. The first meaning is "the program has no knowledge about the *domain* in which it is working". The other is "the program has no internal representation of the *actions* it is taking, and no awareness of the *products* it is creating". These gaps are serious defects in anything that purports to be a model of creativity.

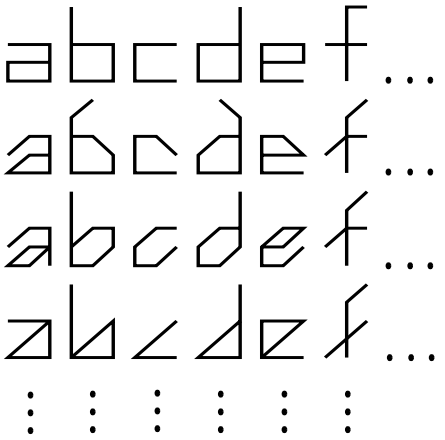

Fig. 1. Items in any column have *letter* in common. Items in any row have *spirit* in common.

We insist that for a design program to be called "creative", it must meet the following requirements:

- The program must arguably *make its own decisions*, not simply carry out a set of design decisions all of which have already been made by a human;
- The program's knowledge must be rich — that is, each concept must on its own be a nontrivial representation of some category, and among diverse concepts there must be explicit connections;
- The program's concepts and their interrelations must not be static, but rather must be flexible and context-dependent;
- The program must be able to judge its own tentative output and be able to accept it, reject it totally, or come up with plausible ideas for improving it;
- The program must gradually converge on a satisfactory solution through a continual process in which suggestions and judgments are interleaved.

We would argue that the deep (and controversial) question raised implicitly by the first point — "What would it mean for a program to make its own decisions?" — is answered by the last four points taken together.

The Letter Spirit architecture is a rudimentary model

of these aspects of creativity. As is described below, several of its features — nondeterminism, parallelism, and statistical emergence — are key elements in allowing it to achieve these goals.

2. The Motivation of Letter Spirit

2.1 The Grid

To avoid the need for modeling low-level vision and to focus attention on the deeper aspects of letter design, we eliminated all continuous variables, leaving only a small number of discrete decisions affecting each letterform. Letterforms are restricted to short line segments on a fixed grid of 21 points arranged in a 3×7 array (Hofstadter, 1985). Legal line segments, called *quanta*, connect a point to any of its nearest neighbors. There are 56 possible quanta, as shown in Figure 2.

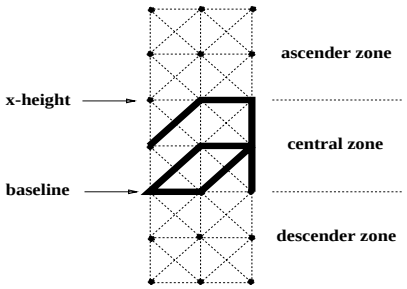

Fig. 2. The Letter Spirit grid, with one of the many possible sets of quanta instantiating an 'a' turned on.

Becauses quanta are either on or off, decisions on the grid are coarse. Surprisingly, the variety among letters of a given category is still huge — hundreds of versions of each letter and 600 full gridfonts have been designed by humans.[1] Almost paradoxically, the domain's limitations engender this diversity.

It is impossible to make tiny changes on the grid, so any two instantiations of a given letter are significantly different. Indeed, because of the coarseness of the grid, designers must tamper with the conceptual essence of letters. Decisions to add or subtract even one quantum often fundamentally affect category membership. Figure 3 shows the large distance in letter-space one can travel with minimal changes on the grid. A "small" change — the erasure of just one quantum — changes the first shape from a strong 'e' to a strong 'z'. A one-quantum addition transforms the 'z' into an 'a'. So category membership in the Letter Spirit domain is a tricky matter. In fact, modeling the process of deciding which of the 26 categories a given shape on the grid belongs to (if any) is one of the hardest aspects of the project.

As there are no surface features to manipulate at a fine-grained level, one ends up playing at the boundaries of the 26 categories. Consequently, many gridfonts are wild, sometimes having angular, blocky, spiky, sparse, or otherwise bizarre letters. Rather than striving for typefaces with high readability or letterforms beautiful at the

[1] Several human-designed gridfonts are displayed at the end of this paper. For more, see (Hofstadter, 1987).

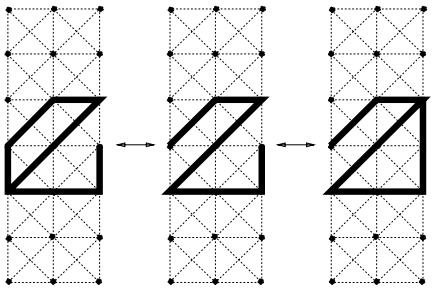

Fig. 3. Rapid metamorphosis of an 'e' into an 'a' via 'z', with merely a one-quantum change in each step.

surface level, we are attempting to understand the conceptual nature of letterforms and thereby gain insight into what imbues concepts *in general* with their fluidity. Pushing the 26 categories to their edges often results in an intellectual beauty not localized in any single letterform of a gridfont, but spread out over the gridfont as a whole — the beauty of *spirit* rather than of *letter*.

While at first glance, the Letter Spirit domain might be shrugged off as a "toy domain", this would grossly underestimate its subtlety. In spite of, or rather *because* of, the reduction to the grid, the Letter Spirit challenge is, in terms of cognitive-science issues, extremely rich. The cognitive issues are magnified, not reduced, by the act of simplifying the domain. All that has been thrown out is the need for expertise. One need not be a professional typeface designer or lifelong student of letterforms to appreciate the consistency of a well-designed gridfont. Even a novice can design a passable gridfont, though doing a sophisticated one is very difficult.

2.2 Letters as Concepts

In order to better distinguish the *concept* of a letter from various geometric shapes that may instantiate it, we introduce some terminology. We distinguish three conceptual levels, running from abstract to nearly concrete as they move toward the actual geometric letterform. The term *letter-concept* refers to the most abstract idea for drawing a letter without reference to style. This level is comprised of a set of *letter-conceptualizations*. A typical letter-conceptualization would be the notion that a 'b' consists of two "roles" — a *post* on the left side attached in two places to an open *bowl* on the right side, sitting on the baseline. A rival conceptualization for the same letter also consists of two roles — a *post* on the left side attached in one place to a closed *loop* on the right side, sitting on the baseline. These conceptualizations, possibly augmented by others, constitute the *letter-concept* of 'b'. Once a specific letter-conceptualization has been chosen, notions of style give rise to a more specific and detailed letter-conceptualization that partially specifies *how each role should be realized* (of course this conceptualization still could be realized in infinitely many ways). This is called a *letter-plan*. A letter-plan is present in a designer's mind before any marks are put on paper. The actual shape drawn on paper is a *letterform*. Letter Spirit is concerned with all these levels: play with letter-conceptualizations, creation of letter-plans, and the de-

sign of letterforms based on letter-plans.

A vivid example of the shape/concept distinction involves lowercase 'x'. For most US-educated adults, the only conceptualization for 'x' consists of a forward slash and a backward slash of the same size that cross somewhere near the middle. English children, by contrast, are taught to draw a lowercase cursive 'x' as a pair of small crescents facing away from each other but "kissing" in the middle. If we look at a printed 'x' in this way, we are suddenly struck by this new conceptualization. The shape on our retina is the same, but what is constructed in our mind's eye is very different.

2.3 Roles

The conceptual pieces into which a letter is broken in the mind's eye are its *roles*. For example, the two crossing slashes in an imagined 'x' are roles. So also are their four tips, and the crossing-point in the middle. Each role has a different degree of *importance* to the letter — the degree to which its presence or absence matters. Of course, different shapes instantiate a given role more strongly or more weakly than others. In other words, roles are also concepts with somewhat nebulous boundaries, just as *wholes* (complete letters) are. The difference is, membership in a role is easier to characterize than in a whole, so that reducing wholes to collections of interacting roles is a step forward in simplification.

The internal structure of a category is represented as a collection of interacting roles. Category membership at the whole-letter level is partially determined by category membership at the lower level of roles. In addition, *stylistic* appropriateness of a shape is judged in terms of *how roles are filled* — in other words, *how norms are violated*. Any such violation is a stylistic hallmark that must be propagated (via analogy) to other letters.

3. Creating a Gridfont

For a person, designing a gridfont takes between ten minutes and three hours (after which the font remains potentially subject to scrutiny and minor revision). The process involves myriad small operations, ranging from the mechanical to the inventive. A typical action (*e.g.*, creating a 'k' or even changing a single quantum in an already-designed letter) sets off repercussions that echo throughout the continuing design process, all over the gridfont, and at all levels of abstraction. This activity is largely guided by *a priori* notions of the interrelatedness of letter categories (*e.g.*, 'd' and 'b' are often considered to be near-reflections of each other). Many such actions occur, and eventually a stable gridfont emerges.

Dissatisfaction and contradiction either within a given letterform or between letters are the prime movers of the design process. If two or more letters seem to conflict stylistically, the resulting gridfont will be unsatisfying to a human. Letter Spirit must thus be capable of *recognizing* and *resolving* such conflicts, in order to create a coherent style. Sometimes the conflicts are subtle, and require refined artistic judgment-calls. Modeling the ability to find conflicts, diagnose them, and convert diagnoses of problems into reasonable suggestions for solutions is a key aspect of the project.

Any design decision will affect not only the letter currently under consideration but also conceptually close letters. For example, a design decision regarding the post of a 'b' is likely to have a major effect on the post of the 'd', and may also influence the *stems* of the 'p' and the 'q'. Of course, the extent and type of this influence are dependent on the particular style and are in no way mechanical. Most aspects of letterforms are likely to propagate their influence to varying extents through the entire gridfont. The propagating wave will probably cause many retroactive adjustments (major and minor) to some "already finished" letters, and give rise to ideas for letters not yet designed. One design decision will typically spark others, which in turn will spark others, and so on.

Eventually, when enough "decision waves" have washed over the gridfont, letterforms begin to have a high degree of internal consistency, and a style begins to emerge. Once the tension of inconsistency eases up, no more large-scale changes are required. Minor adjustments may continue, but the large-scale creative act will be mostly finished. This temporally-extended, serial process of integration and gradual tightening of internal consistency is an indispensable aspect of creativity, and is a well-known property of such creative acts as musical composition, the writing of poetry and fiction, the activities of painting and sculpture, the evolution of scientific theories, the design of AI programs — even the writing of AAAI Symposium papers!

4. Four Global Memory Structures

The Letter Spirit program will contain four dynamic memories, each concerned with different levels of concreteness and abstraction of shapes (and concepts pertaining to shapes). These memories are:

- the **Scratchpad**, which is *a virtual piece of paper* on which all the letters of a font are drawn and modified; as such it is more a type of external memory than an aspect of mental activity;
- the **Visual Focus**, which is *the site where perception of a given letterform occurs*; in it, perceptual structures are built up and converge to stable categorical and stylistic interpretations;
- the **Thematic Focus**, which is the program's *dynamically changing set of ideas about the stylistic essence of the gridfont under way*; in it are recorded stylistic observations of all sorts concerning letters already designed, and if and when some of these observations are perceived as falling into patterns, those patterns can be taken as determinant of the style, meaning they can be elevated to the status of explicit *themes* — ideas that play an active role in guiding further design decisions, in the sense of serving as "pressures" on the construction of further letters;
- the **Conceptual Memory**, which is the program's *locus of permanent knowledge and understanding of its domain*, and which, for each concept, has three facets: (1) a set of *category-membership criteria*, which specify the recognition requirements for in-

stances of the concept in terms of more primitive concepts; (2) a set of *explicit norms*, which encode aspects of the concept's "core"; and (3) an *associative halo*, consisting of links having time-varying lengths connecting the concept with related concepts, thus giving a sense of where the concept is located in "conceptual space" by saying what it most resembles.

A useful perspective is afforded by the following rough equivalences with familiar types of memory. The Scratchpad can be thought of as an *external memory device*; the Visual Focus as a *subcognitive workspace* (*i.e.,* a very-short-term cache-like working memory in which parallel perceptual processes, mostly occurring below the system's threshold of awareness, collectively give rise to rapid visual classification of a shape, whose final category assignment is made cognitively accessible); the Thematic Focus as a *cognitive workspace* (*i.e.,* a much slower, and thus more conscious, level of working memory in which abstractions derived from more concrete and primary perceptions are stored, compared, and modified); and the Conceptual Memory as a *permanent semantic memory* containing the system's concepts. We now describe each memory in more detail.

The SCRATCHPAD is the place where letterforms are created and critically examined. At the start of a run it is empty; by run's end it contains 26 completed letterforms. The Scratchpad contains an arbitrary number of grids, each being a 56-bit data structure telling which quanta are on and which off.

The VISUAL FOCUS is where recognition of a single letterform takes place. It can be thought of as a busy construction site where quanta belonging to a letterform are fused together in a bottom-up manner into small structures of various sizes and shapes called *parts*. The parts are then interpreted as roles, and possibly modified in the act of "mating" with roles. Any combination of instantiated roles suggests membership in one or more letter-categories.

At the beginning of a run, processing in the Visual Focus is purely bottom-up; gradually, however, as structures are built up, top-down influences enter the picture, with top-down processing guiding the "docking" of syntactic parts into semantic slots. This is explained further in (Hofstadter and McGraw, 1993).

Structure in the Visual Focus is built up in parallel by many computational micro-agents called *codelets*. A useful image is that of a large structure (like a bridge) being built by a colony of hundreds of ants. The ants work semi-independently, but cooperatively. Codelets correspond to the ants in this metaphor, and perceptual structures to the bridge. So perceptual structures develop nondeterministically but not haphazardly. From hundreds of tiny probabilistic decisions a coherent view emerges.

The THEMATIC FOCUS is the site where stylistic attributes come to be recognized, especially if they crop up in one letter after another. The more a stylistic attribute is seen as a systematic pattern, the more chance it has of making an upward shift in status — from being a casual observation, essentially a passive entity, to an active entity: an official guiding principle, or *theme*.

Such "elevation to themehood" is a little-appreciated but pervasive aspect of creative acts. In working on a gridfont, a human designer starts by being inspired by (say) a single seed letter. Aspects of this letter, borrowed analogically, suggest further letters. But each of these new letters, when looked at by a style-conscious eye, will be seen to have stylistic attributes of its own that were not implicit in the seed letter. These unexpected attributes are a result of the interaction of the constraints defining a perceived style with the unrelated constraints defining the given letter-category. In other words, these stylistic attributes are unpredictable emergent by-products of the creation of new letters. Once such an attribute is elevated to themehood, it becomes an active force in shaping further letters. This means the process is recursive — new letterforms give rise to new emergent attributes, which in turn give rise to new letterforms, and so on. The upshot is that new stylistic attributes are continually emerging. All of this adds up to an unpredictable meandering in "style space", reflecting the subtlety of the creative act.

Types of stylistic pattern that can characterize a gridfont as a whole include the following:

- A *role trait* characterizes how a specific role tends to be instantiated, independently of the letters it belongs to. A role trait is a "portable norm-violation" — one attached to a specific role (*e.g., crossbar* or *post*) and thus capable of affecting several letters.
- A *motif* is a geometric shape used over and over again in many letters. If it is very simple (*e.g.,* a two-quantum backslash crossing the central zone), it may be required to appear in complete form in every letter. If it is a more complicated shape (*e.g.,* a hexagon that looks like a tilted benzene ring), then parts of it may be allowed to be absent from various letters, so long as a reasonably substantial portion of it remains. Some styles allow a motif to appear in reflected, rotated, and/or translated form; others allow translation but no reflection or rotation; and so on.
- An *abstract rule* is a systematic constraint such as: allowing no diagonal quanta; allowing only diagonal quanta; requiring each letter to consist of precisely two disjoint parts; and so on.
- *Levels of enforcement.* The three preceding types of stylistic attribute pertain directly to shapes on the grid. A much more abstract determiner of style — in fact, a kind of "meta-level" aspect of style — is the degree to which any such constraint is considered "unslippable" (*i.e.,* absolute or inviolable), as opposed to being "slippable" (*i.e.,* allowed to be disrespected under sufficiently great pressure). The level of enforcement of a stylistic constraint — strict, lax, or somewhere in between — sets an abstract, almost intangible tone for the entire gridfont.

All these stylistic attributes are explicitly represented in the Thematic Focus and are thus globally accessible, both in the sense of being *observable* and in the sense

of being *alterable* by agents in the program. Thus all aspects of style are under control of the program.

The CONCEPTUAL MEMORY provides every concept in the domain with an internal definitional structure and a conceptual neighborhood. A concept's internal definitional structure consists of its specification in terms of simpler concepts. A concept's conceptual neighborhood consists of its links to peer concepts in conceptual space. The internal definitional structure itself breaks down into two facets: *category-membership criteria* and *explicit norms*. Finally, a concept's conceptual neighborhood is known as its *associative halo*, and one of its main purposes is to serve as the *source of conceptual slippability*. What this means is that, in times of severe pressure, the concept may "slip" to some concept in its halo, with closer concepts of course being more likely slippages. This means that the nearby concept is tried out, and possibly accepted, as a substitute for the concept itself. We now say a bit more about each of these three aspects of a concept.

Category-membership criteria specify perceptual attributes that contribute toward membership in the category, with different weights attached to the various attributes, reflecting their levels of importance. This weighted set of criteria reduces the concept to a collection of more primitive notions (*e.g.*, a letter is "reduced" to a set of interacting roles, or a role to a set of desired properties of a modified part).

By contrast, a set of *explicit norms* exists (at least for roles and wholes, which are sufficiently semantic concepts), which make the core of the concept explicitly accessible to agents seeking ways to make a weak instance of the concept stronger, or a strong instance somewhat weaker without casting its category membership into limbo. Norms represent the program's *explicit* knowledge about the internal structure of categories.

A concept's *associative halo* consists of links of varying lengths connecting it with related concepts. The links encode such information as: standard resemblances between letters, analogical relationships connecting different types of roles, conceptual proximity of various descriptors used in specifying norm violations, and so on. Knowledge of letter–letter resemblances serves a dual function: it helps in designing new letters (*e.g.*, a good heuristic for a first stab at 'u' is to rotate 'n'), and also serves as a warning that one letter tends to be confused with another (*e.g.*, 'b' and 'h' can easily be confused). The set of links from a given concept effectively gives that concept a halo of conceptually close, potential-substitute concepts — concepts to which it might slip under sufficiently great contextual pressures.

5. Four Interacting Emergent Agents

Four conceptually separable types of large-scale activities emerge from the many small actions of codelets:

1. the high-level conceptual activity of *devising a new letter-plan* (*i.e.*, either an idea for an as-yet undesigned letter or a possibility for improving an already-designed letter);
2. the intermediary activity of *translating a new letter-plan into a concrete shape* on the Scratchpad;
3. the relatively concrete perceptual activity of *examining a newly-drawn shape and categorizing it* (*i.e.*, deciding which letter of the alphabet it is, and how unambiguously so);
4. the more abstract perceptual activity of *recognizing the stylistic attributes of a newly-drawn letter, and judging them* (*i.e.*, finding "exportable" ways of describing how a given letterform violates norms, and deciding how well the letter's attributes fit with those of other letters in the developing gridfont).

It is convenient to speak as if these emergent activities were carried out by four explicit and cleanly separable modules, together comprising the totality of the program. (These agents could be likened to the agents referred to in (Minsky, 1985).) We call these hypothetical agents the *Imaginer*, the *Drafter*, the *Examiner*, and the *Adjudicator*, and will briefly describe them. However, it must be borne in mind that these modules are in some sense convenient descriptive fictions, in that each is simply an emergent by-product of the actions of many codelets, and their activities are so intertwined that they cannot be disentangled in a clean way.

The IMAGINER does not deal with, or even know anything about, the constraints defined by the grid; rather, it functions exclusively at the abstract level of *roles*. Its job is to make suggestions regarding roles, which it then hands over to the Drafter (which will attempt to implement them as parts composed of quanta). The Imaginer can make suggestions of two distinct types — *norm-violation* suggestions and *role-regrouping* suggestions. Though both types can lead to highly novel instantiations of letters, suggestions of the first type tend to be tamer than ones of the latter type.

A *norm-violation* suggestion assumes a set of interacting roles (*i.e.*, a particular conceptualization for the letter) has been specified; then, for one or more roles in that set, it suggests one or more ways of violating associated norms. For instance, suggestions such as "Bend the tip of the ascender to the right", "Use a short crossbar", "Make the bowl narrow", and so on (suitably expressed in an internal formalism) would be typical norm-violation suggestions. Though fairly specific, such suggestions require more fleshing-out to be realized on the grid.

A *role-regrouping* suggestion is more radical, in that it involves tampering with the very essence of the letter — in other words, coming up with a new conceptualization for the letter. This means taking apart one or more roles and making new roles that combine aspects of the old roles. An easy-to-grasp example is the conceptual move from imagining 'x' as two intersecting slashes to imagining it as two kissing angle-brackets. Role-regrouping is very subtle because it takes place completely at an *abstract* level. That is, no *shapes* are involved at any time; rather, the Imaginer deals exclusively with abstractions — abstractions that, to be sure, have the general "feel" of shapes, in that they are associated with spatial locations and have spatial functionalities — but such abstractions are not shapes.

Once a new conceptualization has been produced, it can be handed over directly as a suggestion to the Drafter, or norm-violation suggestions can be made in addition, and then the whole thing handed over as a package to the Drafter.

The DRAFTER, unlike the Imaginer, does know about the grid; indeed, its main function is to take the Imaginer's grid-independent suggestions and adapt them to the grid.

Here is an example that could easily come up in designing a 't' or an 'f'. A norm-violation suggestion like "Make the crossbar short", which in real-life circumstances would offer a letter-designer a full continuum of possibilities, offers much less freedom to a designer restricted to the grid. For a grid-bound 't' or 'f', a conventional (*i.e.,* norm-respecting) crossbar would be a horizontal line segment composed of two quanta. Obeying the suggestion to make it short would thus seem to offer just three alternatives: dropping the left quantum, dropping the right one, or dropping both. Dropping both quanta would seem drastic if not outrageous (although possibly the right solution for some very far-out styles); thus in all likelihood, the Drafter should opt for drawing just a single quantum, probably horizontal. Then the question is whether it should draw it to the left or the right of the ascender. This choice will certainly depend in part on precedents in other letters (*e.g.,* if the decision "Draw a quantum on the *left* side of the ascender" had already been made in the case of 'f', then 't' might want to follow suit), but will also depend on how strong the potential letter's category membership will be.

The EXAMINER's responsibility is to take the specification of a grid-letter in terms of its quanta and to determine which (if any) of the 26 letter-categories it belongs to, and how strongly and unambiguously so. It is useful to cast the Examiner's work in terms of *syntactic* and *semantic* operations.

Syntactic operations are purely bottom-up chunking operations. They serve to put quanta together in a way that would be reasonable no matter what type of shape was being recognized. In other words, they are *context-free chunkings* that would presumably arise as the result of any naturally-evolved visual system. Semantic operations, on the other hand, depend on the set of categories into which the shapes are being channeled — a writing-system-specific repertoire that, in a person, is acquired through experience. Semantic operations take the output of syntactic actions (which occur earlier in perceptual processing) and adjust it to conform to expected abstract structures. The upshot is a "marriage" of bottom-up structures coming from sensory stimuli with top-down expectations defined by letter-concepts.

All processing in the Examiner takes place in the Visual Focus. Processing begins at the level of quanta and starts out totally bottom-up. Quanta get syntactically chunked into *parts*, which are then assigned any number of syntactic labels (*e.g.,* "straight", "central-zone", "zigzag", "left-side", "slanting", etc.). Top-down semantic influence enters the picture as the labeled parts are matched up with conceptual *roles*. As the interpretation rises towards the level of letters (which we call *wholes*), even more top-down influence is brought to bear.

The ADJUDICATOR is concerned with a more abstract type of category membership — namely, *stylistic consistency*. It is not enough for a candidate letterform to be perceived by the Examiner as a strong member of its intended letter-category; that letter must also be judged by the Adjudicator as embodying the same stylistic qualities as the seed letter(s) and any already-generated letters. This requires a set of high-level descriptions of stylistic qualities to be manufactured as the alphabet develops. No single letter contains all the information about style, so stylistic attributes from various letters, as they come into existence, must be assembled in a global list belonging to the gridfont as a whole. This is of course the Thematic Focus. Thus whereas the 26 letter-categories exist in the Conceptual Memory *prior* to any run, a single stylistic category gradually comes into existence in the Thematic Focus *during* a run.

The types of stylistic attributes the Adjudicator looks at to judge a candidate letterform include *role traits*, *motifs*, *abstract rules*, and *levels of enforcement*. A letterform is inspected for the presence of established themes, and is given a "stylistic-coherency rating" according to how many themes are echoed in it.

In addition to looking for attributes that have already been established as part of a style, the Adjudicator tries to extract from any new letter *new* stylistic attributes, to extend the set of themes defining the emerging style. An attribute discovered in a single new letter may not be considered strong enough to be elevated to themehood, but if that observation is reinforced by finding it echoed in other new letters, it stands a chance of becoming a new theme and thus driving the design of further letters and the retroactive modification of older letters.

Note that stylistic attributes can emerge in a completely unpredictable fashion. If the Adjudicator happens to notice that neither the seed letter nor the first new letter generated contains any vertical strokes, then it may generalize from these two examples and thereafter strictly forbid vertical strokes. Such a decision will of course have global ramifications. On a different run where the same two letters existed, a totally different course could be taken if that observation were not made, or if the interdiction were taken somewhat loosely.

5.1 THE CENTRAL FEEDBACK LOOP OF THE CREATIVE PROCESS

The Letter Spirit challenge can be thought of as the problem of *attempting to do in one framework something that has already been done in a significantly different framework*. Here, the two frameworks are different letter-categories, such as 'd' and 'b'. A designer is handed a somewhat off-center member of the first category and the challenge is to transport its eccentricity — its stylistic essence — into the other category, or in other words, to reproduce its *spirit* in the second framework, despite the fact that the second framework is by no means isomorphic to the first. Such transport of spirit cannot be done in a reliable manner except by trial and error. Guesses must be made and their results evaluated, then refined and evaluated again, and so on, until some-

thing satisfactory emerges in the end. We refer to this necessarily iterative process of guesswork and evaluation as "the central feedback loop of creativity".

We now run through one example, and a rather simple one at that, in order to give a sense of how all four agents are involved in this loop. We suppose that Letter Spirit is given as its lone seed letter an 'f' with a conventional ascender (*i.e.,* a tall vertical stroke on the left side of the grid that curves over to the right at the top), but with *no crossbar at all* (see Figure 4). What kind of grid-letters might this seed inspire? What kind of overall style?

To begin with, the seed's letter-category must be identified (in itself a nontrivial task, given the eccentricity of the letterform). To this end, the Examiner is invoked. The quanta in the seed letter are quickly chunked together, and since there is a fairly weak juncture near the top, where the ascending line bends to the right to form an overhang, two distinct syntactic parts are made. After being suitably labeled, these parts wake up two semantic roles: *post* and *hook*, and since there is nothing else to see, no other roles are strongly activated. This pair of activated roles now activates two *wholes* — the letter-categories 'f' and 'l'. Counting against 'f' is the lack of crossbar, but counting against 'l' is the hook at the top. The power of two strongly-filled roles overwhelms the pressures for seeing 'l', and the shape winds up being seen as an 'f' whose primary stylistic attribute is the lack of anything to fill the *crossbar* role. Thus "crossbar suppressed" is the main stylistic note (*i.e.,* norm violation) attached to the letter.

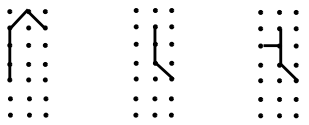

Fig. 4. The 'f' with no crossbar (left) gives rise in the Imaginer to a 't' with no crossbar (middle). This is rejected by the Examiner since it is too 'l'-like. This leads the Imaginer to slip "no crossbar" to "short crossbar", and a better 't' is created (right).

We now move from the perceptual to the generative phase. Given that 'f' and 't' are linked as similar letters in the Conceptual Memory, there is a high probability that 't' would be the next letter tackled. An obvious idea for the 't' would be to suppress *its* crossbar. Like any good copycat, the Imaginer would have little trouble coming up with that analogy, since the role *crossbar* exists in both 'f' and 't'; all it would need to do is take the norm-violation that describes 'f' ("crossbar suppressed") and copy it literally into a suggestion for the 't'. Upon receiving this norm-violation suggestion, the Drafter would have no problem converting it into a grid-oriented instruction saying, in effect, "Draw no horizontal quanta at the x-height." (Let us assume the 't's ascender would be conventional.)

The Drafter renders this attempt at 't' on the Scratchpad, leaving it up to the Examiner to look at it and make of it what it can. The quanta are quickly put together into a single perceptual part — a vertical line rising from the baseline to somewhere above the x-height. This wakes up the role *ascender*, and since there is nothing else to see, no other roles are strongly activated. This rather sparse "combination" of activated roles now sharply activates one and only one whole — the category 'l'. At this point, the Examiner, knowing that 't' was intended, pronounces the attempt at 't' a failure, and provides what is hopefully an accurate diagnosis: the fact that the role *crossbar* never got awakened at all.

This information is sent back to the Imaginer, which was, after all, the source of the idea of suppressing the crossbar entirely. So the Imaginer is now caught in the crossfire of Letter and Spirit pressures: on the one hand, it knows that suppressing the crossbar leads to disaster (this is Letter pressure), but on the other hand, it wants to follow the stylistic lead of the 'f' (Spirit pressure). Something has to give!

Luckily, there is a way out, provided by *creative slippage*, which involves consulting the Conceptual Memory for potential substitutes provided by conceptual halos. In the halo of "suppress", the Imaginer finds such close neighbor-concepts as "austerity", "minimality", "sparsity", as well as the concept "underdo" (or a more formal structure representing that idea). Thus, under the pressure created by the failure of using the concept "suppress", it is quite likely that the Imaginer will make a *slippage* — namely, it will take the nearby idea "underdo" and try it on for size. In other words, the Imaginer supposes that "underdoing" the 't's crossbar is the next-best thing to all-out suppression of it. This slippage is of course the key creative breakthrough. It now just needs some fleshing-out, still to be done by the Imaginer.

In order to translate the vaguish "underdo" into a more specific operation, the Imaginer must have information about the *meaning* of "underdo". This is available through its internal definition, which (in a suitable formalism) is given as "reduce the key dimension of". Now the Imaginer consults the norms attached to "crossbar" to find out if a crossbar has a key dimension, and if so, what it is. It finds that for "crossbar", there is only one norm involving size — horizontal length. This allows the vague "underdo" suggestion to be straightforwardly translated into a norm-violation suggestion that says, in effect, "Make a short crossbar". The Imaginer hands this to the Drafter. From our discussion above, we know that this can lead to a 't' with a one-quantum crossbar — in other words, a perfectly acceptable and style-loaded 't'. It is, of course, debatable how faithfully this 't' preserves the austere spirit of the seed letter 'f', but certainly it is a reasonable attempt.

Note that this example shows how the program can understand and imitate the *spirit* of the seed letter, rather than copying it *literally*. A key role was played here by the *conceptual halo* of the concept "suppress", which yielded the conceptually close, potential-substitute concept "underdo".

The interaction of these four agents, whereby ideas are suggested, critiqued, revised, possibly abandoned and regenerated, and so on, jibes with our intuitive sense of what human creativity really is. It seems to us fair to say that this kind of emergent, unpredictable processing constitutes a program's *making its own decisions*.

6. Conclusion

The two main predecessors of Letter Spirit are Copycat (Mitchell, 1993) and Tabletop (French, 1992) both of which create microdomain analogies in psychologically plausible ways. Both are based on models of high-level perception making use of a novel type of architecture. Top-level behavior emerges from many low-level stochastic computational actions that occur in parallel. Letter Spirit will make use of a similar architecture, but will deal much more with the internal structure of concepts, and will focus on a much larger-scale creative process that unfolds over an extended period of time.

Letter Spirit will test the applicability of our architecture to large-scale creative tasks. Its parallel stochastic processing mechanisms fall under the rubric of *emergent computation*, wherein complex high-level behavior emerges as a statistical consequence of many small computational actions. Like Copycat and Tabletop, Letter Spirit will occupy a level of cognitive modeling somewhere between connectionism and symbolic AI — the level we feel is the most useful for the understanding of high-level perception, the fluidity of concepts, and creativity.

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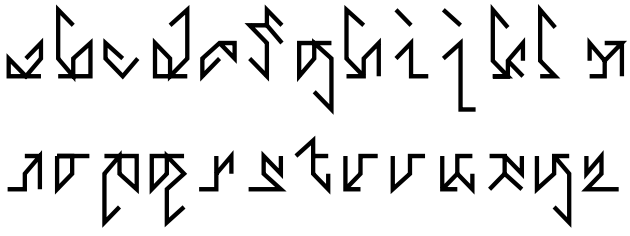
Fig. 5. Seven human-designed gridfonts illustrate various devices for assuring stylistic consistency, such as motifs and abstract rules.

Flournoy Ranch



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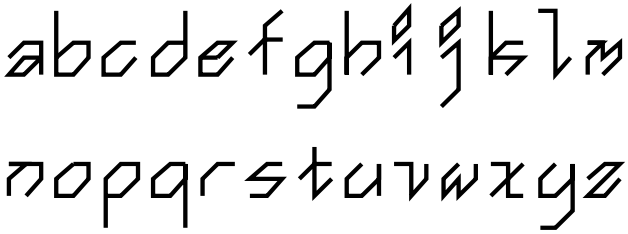

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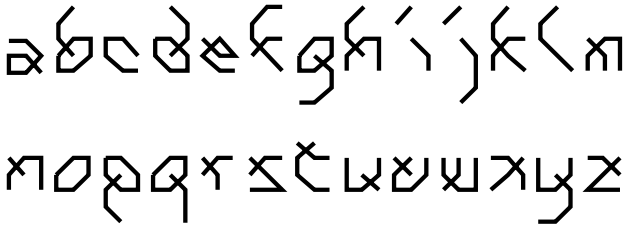

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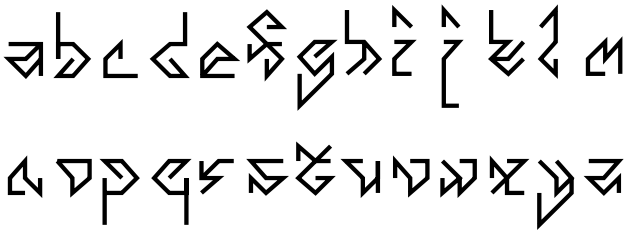

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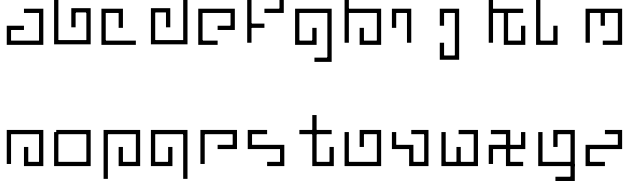
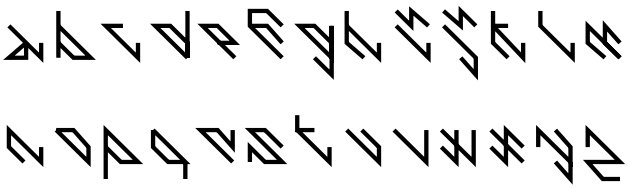


Double Backslash



Sluice