WILL YOU HAVE A YAM?
A STUDY IN AGENCY AND REPRESENTATION.

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ABSTRACT

Systems of architectural representation, and their implied balance of agency, are a potential site of tectonic, spatial, and programmatic reinvention. By altering only the roles of those involved in the design / construction process, and the system of representation employed, one will necessarily reinvent the architecture produced.

My semester circulates around two devices – two games. String, as performed in the game of cat’s cradle, which can be thought of as a kind of one-dimensional folding; and paper, which evolved as an attempt to bring the properties of the string’s one-dimensional folding into two dimensions. The problem of this thesis is to reimagine these devices as systems of representation – as drawings, or as bridges between drawing and building. Further, to ask: How can a drawing practice which is inspired by these devices, and contains inherent properties derived from these devices, become generative of a building practice?

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The impulse of this project stems from what I see as a basic problem of architecture, something which, in retrospect, has been in my mind since my very early design studios:

As architects we do not make buildings, we make drawings for buildings. Our practice is marked by, arguably born from, the engagement with systems of representation which offer us access to, and authorship of, works yet-to-be, and simultaneously keep us at a distance from these works - always engaging them through at least one layer of abstraction, through instructions to be carried out by others.
In his essay “Drawings”, Stan Allen argues that this viewpoint misses the point a bit – he asserts that architects make projections, which are the means to negotiate the gap between ideas and material, “a series of evasions, subterfuges, and ruses through which the architect manages to transform reality by necessarily indirect means.”

More than a layer of abstraction through which thoughts must pass to become material (perhaps as portrayed in the images to the left), Allen sees architectural representation as a part of the fluid connection between these two modes.
Of course, architectural representation is not a monolithic endeavor. Allen continues: “There are those that argue that architecture resides in the design rather than the realized building: that the architect's intentions are expressed most directly through notation, and can only be diminished through the complexity and unpredictability of reality. Others argue that drawing is simply a means to building – irrelevant once the work is constructed, and that only the realized structure has meaning.”

For Allen, both of these viewpoints artificially fix the fluidity of drawing practice, they share a notion of drawing as pure abstraction, disconnected from reality. In contrast, he presents architectural drawing as inherently impure, unclassifiable, and multiple; its link to the reality it designates as complex and changeable.

This thesis is guided by two premises: First, that thinking, drawing, and building, are all part of one fluid practice, united by (and also biased by) the representations which govern them. Second, that there are as many ways of building as there are ways of drawing – and vice-versa. This is evidenced by the variety of representational techniques presently available to the designer each offering a unique set of roles for the parties involved: each “packaged” with its own system of agency.
Drawing Practice

Building Practice
If building and drawing are indeed part of one fluid practice, then one approach for intervention might be to begin with some desired properties of building, or properties of space, and extract back into drawing practice. One could imbue a method of drawing with properties of building, or properties of space — and then play within that system: perhaps allowing oneself to be guided by the system’s properties in order to gain a greater fluency in the chosen language of building, or perhaps intending to play at the system’s boundaries looking to discover its aberrations and oddities to produce new forms and unexpected relationships.

My initial proposals for this thesis were concerned with exactly this... the invention of a method of representation, a game which generates (and is derivative of) an architectural proposition. The standard of judgment of such a game would be if it is satisfying, in an architectural sense, to play.

This is not what you find in the following pages.

I found that this methodology was in many respects, was a simple reversal of my initial bias.

While the invention of a representational methodology is one thing, the invention of one which both contains the properties of some predefined architecture and is satisfying to engage something else entirely. I found myself with no map, no method for the creation of such a system.

So, while I think it’s valid for a system to work in the linear way diagramed here...
Creating such a system isn’t a linear process. Rather than behaving like a scientist, I found that it is more productive to behave like an alchemist:

And so this thesis has taken on as it’s methodology not the production of a designed object, or even of a design system, but rather the establishment of a sort-of open investigation, a one-man laboratory for the imagining and testing of alternate representational systems and alternate relationships between those involved in the act of making.
The first and second stations of Cat's Cradle [3]

Four stations of a fold
Rather than begin with either a building practice or a drawing practice, and work toward the other, I chose to begin with an existing representational device which seemed to me to be bridging these two. The string, as engaged in the diagrams above, seemed to me on purely an instinctual level to both embody the ‘satisfying’ aspects of gameplay that I found missing in my initial proposals while still manifesting a mathematic or constructive logic that structures this “free play”.

Later in my process I included another device – the folding of paper. These two are essentially interchangeable in that I sought to engage them both as a sort-of physical computer, an analog calculator of topology, intersection, and layering.
So, here is the focus of my thesis: String and paper – simultaneously drawing and building, and in them a microcosm of architectural production.

And my linear methodology became a cyclical one.
Drawing Practice

String

Paper

Building Practice
My semester circulates around these two devices — two games. The string, which can be thought of as a kind of one-dimensional folding; and the paper, which evolved as an attempt to bring the properties of the string's one-dimensional folding into two dimensions.

My problem for the semester, as I formulated it, was to reimagine these devices as design tools — as drawings, or as bridges between drawing and building. More specifically, I wanted to know how a drawing practice which is inspired by these devices, that contains inherent properties derived from these devices, can become generative of a building practice.

I suppose you could say the product of my efforts this semester would be the map that I found to be missing from my earlier attempts...
A map that I can begin to construct now, in retrospect.

To this end, I have reorganized my investigations along properties that began to emerge over the course of the semester and that I’ve outlined above - rather than along chronological lines. Looked at in this way, each of these properties can describe a section through my semester’s project – each a thread that connects the behavior of the string to that of the paper. In this translation I hope that some essential qualities begin to emerge and some idea about a bridge between drawing and building is suggested.

What follows is a tour of my semester’s work, organized by these threads: this includes readings and mappings of string games, translation of those readings into methods of reading and drawing in paper, and finally, in each thread, a cursory description of how what I’ve learned might become generative of a building practice.
INTERSECTION / CONNECTIVITY
The intersection and connectivity thread seems a natural starting point in that upon first glance, the cat’s cradle seems to be all about creating ever more complex patterns of intersections of a single string.

My first instinct upon looking at the string was to find a way of describing and understanding these intersections. So, to this end, I filmed myself moving through a series of poses in order to draw the configuration of the string at each of these frozen moments in time – like a filmstrip.

The result you see here is fairly straightforward and descriptive, but producing these drawings did aid in noticing how the string was wrapping around the fingers.
INTERSECTION/CONNECTIVITY
From there, I abstracted this observation to a topological diagram that describes the path of the string traveling around the fingers, and shows where it intersects itself, generating closed loops or zones.

Here, the black dots represent the fingers, the red line the string, and the red dots are where the string intersects itself. The important issues mapped are the topology of the string – its zones and intersections. Noticeably left out of the mapping is the string's length, which in the diagrams is allowed to vary, but obviously in reality remains constant. This fact is only relevant at this stage in that it demonstrates that each of these mappings extracts only selective information, they privilege one particular reading, and discourage others.
INTERSECTION/CONNECTIVITY
This diagramming method, while very simple, proved to be fairly robust in that it is able to describe a wide range of poses, and in that it served to inspire thinking in other threads – in particular one that I'll talk about later dealing with the overlapping of zones.

But perhaps more importantly, it lead to another reading which better describes intersection as it occurs in cat's cradle...
LENGTH OF STRING: 48"
DISTANCE BETWEEN HANDS: 7"
Which was the one you see to the right.

This method of mapping was motivated by the desire to look more carefully at the different ‘spaces’ which were occurring simultaneously within cat’s cradle, a property which I think adds greatly to the complexity of the game. The two spaces occurring in any pose are, first, the knotted 3-dimenional space of the hands and the string winding around fingers, and second, the 1-dimenional space of the string itself – intersecting itself at a series of points.

This diagram is created by contorting the string into a pose, marking the intersections, and then unwinding the string to take note of the pattern of intersections.

In a way, this is a map of the knot from the point of view of the string winding it’s way back and forth from hand to hand.
INTERSECTION/CONNECTIVITY
Here is documentation of the process, performed on a more complex pose...
Which generates a more complex map.

At this point, it's relevant to pause for a moment and question the use of this map. In one sense, it has value in and of itself — it has some form of aesthetic value I think, (as evidenced by the fact that I've printed it out really large and hung it on the wall) and it may even be somehow useful as a descriptor of string games... although to whom outside of the “string figure” community, I'm not sure.

To me, it has value for two reasons: First is a clear and precise method for dealing with the issues it addresses, and only the issues it addresses — it is, in this sense, clean, perhaps more so than the previous topological mapping I showed. Second, there's a level of richness here despite (or perhaps because of) the fact that it doesn't resemble the system which it's mapping, and I would assert that it is this quality which makes a projection an ideal candidate for transposition onto other systems...
Moments such as this mapping that prove to be so portable are one thing that I've structured my semester in search of, to varying degrees of success. Later connections between systems may not be as clean as this one - they may be a bit more tenuous.

I suppose that the real test of any of these mappings is in the transposition, and that sometimes it's important leave the ones we love, so we see here that the circle of intersections becomes a square of intersections...
...and the square becomes a sheet of paper. Now, rather than the one-dimensional string folding in three-dimensions to produce intersection, the two-dimensional paper folds in three dimensions to produce the same pattern. We're in a whole new world now, of course, as with that extra dimension comes another degree of freedom and a less deterministic result.

This issue of determinacy is an important one, and could be discussed relative to everything described thus far: the pattern of intersections called for by this diagram can be produced in paper in a number of different ways, just as it could produce a number of configurations of string.

From a mathematic or a computer science point of view this may prove to be a problem, but to a designer it's an opportunity, and defines the "design space" of any given system as it can refer to the number of possible outcomes that satisfy the requirements of the system.

However, it can also refer to the amount of control the user is able to exert over the designed object.
In any case, I took it as my responsibility to not just leave it with the observation that one pattern of connections can produce many possible pattern of folds, and sought to find out why – I wanted to know what drives this difference, and how I might take advantage of it.

As it turns out, it has to do with, first of all, the order in which one chooses to match points.

The order of folding seen on the upper diagram requires only three steps to match all the points, because the first fold aligns with a line of symmetry, while the lower fold requires more. This particular property of paper led to some other mappings in the "layering / overlap" strain which I'll go over later, but there is another level of complexity here...
A single intersection between two points can be performed in multiple ways while still satisfying the rules of the game – which are, as they weren’t stated explicitly before, that all points become coincident when the paper is folded flat, although other layers of paper are allowed to come between them.

I have worked out a set of rules which drive this game, a “rulebook” of sorts, and assembled set of possible configurations, which (while by no means exhaustive) can be thought of as a kind of “playbook”, both of which I’ll address in the “typology and grammar” strain, for now it suffices to say that the “design space” of the game is fairly large, and in that the many of the rules of the game are already implicit in the physicality of the paper, one doesn’t have to know the rules of the game in order to play - it’s fairly easily engaged.

So, the next question is... what is it good for? As with the circle diagram, I would first argue that this game is interesting in and of itself, however I will also make a first, proposal as to how a system such as this might be combined with a constructive or spatial logic...
INTERSECTION / CONNECTIVITY
With each of these strains, I’ve tried to begin with an obvious, literal method of transitioning from my mappings and games, which are essentially drawings, into something which can begin to be suggestive of a building practice, or some property applicable to a building practice or that contains a more architectural logic.

To the right is a straightforward approach: one could imagine the paper to represent an architectural fabric of whatever scale which requires two forms of adjacency: one laid out within the fabric, and one which connects disparate points of the fabric.

Not a bad impulse, but perhaps a bit literal.
To reduce this idea to its essentials, it may be helpful to switch our representation to something a bit less prescriptive of form, perhaps the kind of floor area diagrams that we've all seen our share of, that don't prescribe a particular geometry and only denote relative area, and, if you'd like, adjacency.
So now, removing the particular geometry of the folded paper and looking only at the percentage of overlap between zones, we arrive at a device which rearranges and remixes area. In part this process is deterministic, in that one can layout the original zones and points of connection, and in part indeterminate in that the paper may behave in ways unexpected to the user.

I would never suggest that any of these architectural propositions become generative of a complete work of architecture or that they might be used to directly make a building. Rather, I see as the site of these proposals the many representations we use as architects which address only one particular aspect of a more complete architecture. In this case, I've tried to re-imagine the paper folding game as a kind of "programmatic calculator" – or an "adjacency mixer". Others that follow address other issues – each according to what I see is a good mapping between property of drawing to property of building.
INTERSECTION / CONNECTIVITY
Layering / Overlap
OVERLAP / LAYERING
The issue of layering and overlap was initially raised by a problem I observed with my first intersection diagrams.

Attempting to produce a simple spatial reading of the same set of poses I recorded before, I observed that strings tended to lie on one, two, or three planes in space between the hands, and produced the mapping to the right which describes these planes.

Immediately, a problem arose: While the strings tended to lie on a plane at the conclusion of a performed pose, most of the rest of the time they didn't. Further, even while in a pose, the strings were planar only when the hands were held perfectly symmetrical, and the fingers were regarded as having no dimension. This is a fairly large swath of possible poses to be unable to account for within any representational system, which makes what you see here, in my judgment, a fairly weak system.
LAYERING / OVERLAP
In addition, the intersections that I was mapping in the previous strand weren’t necessarily intersections at all. Or, more specifically, some were only intersections according to the position of the hands in space rather than the pose.

So I set out to make a system capable of differentiating between intersections, which I defined as a true tangle in the string as opposed to overlaps which may be separated if the hands are shifted into a slightly different, or asymmetric position.
So, borrowing a method from knot topology, I made a series of small models out of string and pins which mimicked the overlaps called for in various poses, but with the string separated vertically as much as possible – leaving the strings intersecting only where they must as called for by the pose.
What this technique reveals is that each pose has a very specific "section", or layering order.
LAYERING / OVERLAP
Some of the poses can be completely separated in space such that the string never intersects itself, such as this one.
LAYERING / OVERLAP
While others contain intersections which are a necessary result of the pose, and will exist no matter how one turns one's hands.

What results is a representation which is very good at describing layering order and differentiating between types of intersection, but quickly runs into a problem of scale. First, because these models are extremely small...
LAYING / OVERLAP
… but also because the method downplays the significance of intersections which occur at very small scales – such as loops or twists pulled tightly around the finger. A better way of visualizing this is to read the strings as thick volumes or tubes…
In each of the models pictured on the following pages, the string is modeled as a one-dimensional line wrapping around a pair of "hands", as represented as a set of points approximating the possible positions that a string may lie. The line is then "thickened" by sweeping a three-dimensional tube around it. The resultant models appear as somewhat different configurations than their associated string pose (pictured on the left) because, while one's actual hands are capable of changing position relative to one another, I've chosen to model this series with the points always in the same position.

While this approach makes the overlapping and joint configuration more clear, the orientation relative to the hands is lost— which tends to abstract the models.
Abstraction also occurs in that, as I've discussed before, the configuration of strings is represented as a frozen moment in time. This makes it very difficult to visualize how one might achieve any particular configuration (no matter how simple) and how to move from one configuration to the next – an obvious advantage of the procedural mapping methods.
Fig. 755.

Fig. 753.
However, when one applies a similar method of “thickening” to the paper folding I discussed earlier, I found that the sequence of poses, or in this case folds, was in a sense “written” into the layering order, as can be seen in the drawing to the right.

I’ve gotten quite a bit of mileage out of this method of mapping: while very close to the literal folded paper it’s very good at exposing the complexities of moving from the two-dimensional paper to a three-dimensional fold. It’s made fairly simply by arranging the zones created by the crease pattern of an unfolded paper on top of one another in the appropriate order, and then “exploding” it, essentially exaggerating the z-direction.

This particular drawing is a mapping of one of the folds we saw in the intersection strand, where a set of points are mapped by successive simple folds. What it reveals is that when paper is folded by a series of simple folds, meaning by folding along the one line which bisects the line which connects the two points to be joined, the order of the points in this representation is determinate: the points joined first are the closest, the next set are the next closest, etc…
LAYERING / OVERLAP

- First fold
- Second fold
- Third fold
- Fourth fold
- Fifth fold
In addition, a fairly nice visualization of the movement from two-space to three-space is achieved if one draws the lines which connect these points in three space, as you see to the right.
Adding to the complexity of this way of thinking, the layering order for any particular fold isn’t determinate: as demonstrated by a puzzle pictured to the right that I learned from Martin and Erik Demaine, both professors in Computer Science and Artificial Intelligence Lab here at MIT that were over at the studio for a wine and paper folding party. The idea of the puzzle is to fold the sheet of paper shown on the left on the crease lines so that the layering order spells the word “architect”.

I didn’t solve the puzzle, the result you see on the right was performed for me, but I learned that one folding pattern can generate a family of possible layering orders, which greatly increases the design space of the “exploded fold” mapping shown on the previous page.
folds by Erik and Marty Demaine
So much so that an exploration of the possible “design family” of such a mapping seems relevant: each “design” here is essentially a map of two parameters: the division of a square-shaped area into smaller zones, and the “order” in which these zones are stack in space – which, as we have seen, is often related to the order in which they were created.

This was accomplished in large part by creating rules by which others could produce folds – which are discussed in greater detail in the “grammar and typology” section.

The design examples shown on the right were produced in various fashions, and mostly by someone besides the author. Some were made by attempting to find as many ways as possible to connect two given points, some by connecting a set of points, and some were made with an “aesthetic” intention, meaning intending to avoid formal “sameness” in the set.

I should mention that a small “cheat” was employed here – all the “vertical” planes connecting the horizontal folds is “invented” material, not present in the original paper and only a result of the extrusion. I don’t view this as a problem in and of itself, but it does color the mapping in a significant way.
LAYERING / OVERLAP
So, the obvious thing to do to move this exercise into a building practice is to simply imagine the exploded mapping of a fold as directly occupiable at some arbitrary scale.

This is problematic for me, first on purely aesthetic grounds – I think these folds would make ugly buildings.

But second, there is no correlation between the properties that the system is providing and the ones that one may want in designing a, what, concrete slab building? Also, the “cheats” that I mentioned before take center stage with these designs, and serve to give them all a very particular formal similarity. Specifically, it appeared to me that all of the designs contained a very strong directionality – usually a result of the last fold performed on them establishing a dominant boundary at one edge, essentially a relic of fold order resulting in unintended consequences.

I began to wonder if that were something that I might take advantage of…
81  LAYERING / OVERLAP
...so, I made a game which does just that..., imagine beginning with a folding sequence, such as this one that we've seen before...
... and at each stage of it's folding, a contour line is drawn at its perimeter, marking the boundary of the paper for each step, as shown in the diagram to the right.

This line can be expressed in the 2-space of the unfolded paper as well.
These lines can be read as boundaries and could enclose adjacent zones obtained by marking the areas of the paper which are exposed on either side. Further, they could accumulate over time with each step, each zone getting progressively weaker as the sequence continues.
LAYERING / OVERLAP
What results is again two-dimensional information: A field of overlapping zones of varying strengths.

Essentially, it is a map of crease pattern, layering order, and sequence, but does not obviously correlate of any of them. I imagine that while certain properties of this device would feel very much under control by the user, such as the density and relative size of these zones, others would be beyond his control, such as the exact geometry of the field.

While it's difficult to characterize this diagram as a “building practice” as such, I would assert that it's close to one, and may be deployed to address architectural qualities such as “soft edge” and “variable boundary”, which certainly makes the system transportable to the realm of architecture.
Figure 90
The figural strain of investigation is the bastard child of the group: I found it interesting and important as a point of origin that sparked other ideas, but quickly abandoned it when it came to translating into a building logic. I believe it's important to cover briefly, however, if only to demonstrate how it facilitated my move from more geometric readings to more procedural ones.

Most string figures have some end goal, or pose which is typically a graphic representation of an object or scene meant to be viewed from one vantage point, usually a party besides the "string artist".
34. Two Kangaroos¹ (*Afo*)

FIG. 34

FIG. 34A.—THE KANGAROOS

[13]
Others involve some action on the part of the user to aid in the telling of a visual narrative.
WILL YOU HAVE A YAM?

Sixth: Release the loop from the left index and hold it erect between the left index and thumb (Fig. 800). This loop represents a Yam. Offer this hand to another person: He says, "Have you any food for me?" You say, "I haven't any," pulling the right hand strings at the same time; the "Yam" disappears and all the strings come off the left hand. The same can then be repeated with the right hand.

The loop that stands up (the left index loop) represents the thief looking over the fence of the garden in which he is about to steal. Pull the strings tight, and the man, seeing he is discovered, jumps down.
Pictured on the right is a very involved example of a narrative told through a series of poses, called "Tallow Dips", in which a series of poses are performed in sequence which aid in the telling of something approaching a short story.

This kind of reading of string is important, first because these figures are the popular objective to the game (the point of making string figures) — but also because I think that this also may have something to do with why the system is so easily engaged, and may have something to do with the way one remembers sequences of action and learns to anticipate results - in a much different way than if the actions were described geometrically. This is a valuable lesson when beginning to make procedural mappings of a system, which we will see in the following strain.
"A man stole a pound of tallow dips, and bringing them home hung them on a peg."

"And being very tired he sat down on a chair and went to sleep."

"It was dark when he woke up, so he got a pair of shears to cut off a tallow dip."

"While he was cutting off the dip a constable came to arrest him, bringing along his tipstaff."

"The constable put handcuffs on the thief and marched him off to prison."
It could be argued that paper folding behaves less in this way. While the terminal pose in origami is usually figural, the steps in between are less so than they are in string games, and it's difficult to imagine that a story consisting of a sequence of figural forms could be constructed out of paper in the same way as string (although not at all impossible), as the string is more topologically flexible.

On the other hand, the strength of the figural form in origami is greater than in string — these folds resemble the animals they are intended to much more so than does the previous slide of the string kangaroo. I would argue that this is perhaps not necessarily a good thing, that the string encourages a viewer with a very active imagination, and that may have something to do with why it's so fun.
Wild Boar (Sus scrofa) ©2003 by Joseph Wu

Transposition of any figural system into a constructive logic seems tricky to me, but architects and viewers of architecture often engage in this kind of reading, so I thought I'd give it a go.

To the right are the results of my efforts.
The "grammatic" strain relates closely to what at my midterm review I was referring to as "procedural" mappings, and was partially sparked by the narrative string game "tallow dips" seen in the previous strain. Rather than mappings of geometry, this strain is concerned with mappings of procedures—beginning with speculation on how to make a map of the process of making a string figure and my dissatisfaction of the textual descriptions I had been using to teach myself.

So, how does one begin to make a procedural description of string figures?

Initially, I thought of co-opting the form of the musical score, with time extended in the vertical direction, and the position of the strings on the hands in the horizontal. Solid dots represent a closed loop, and white dots an open one.

An obvious problem with this model as I've worked it out here is that most of the emphasis is placed on a sequence of configurations, each frozen in time like a filmstrip—and doesn't offer enough description of which procedures to take to achieve these configurations.

In addition, the notation fails to describe the sequence of overlap which was found to be so essential in the a previous exercise—as is evidenced in the upper configuration where at least two possible sting poses can be interpreted from a single "frame".

So, this method was abandoned.
5. Pass each thumb away from you (under all the strings) and take up from below with the back of the thumb the far little string, and return the thumb to its former position without touching the other strings.

4. Release the loops from your thumbs and separate your hands.

3. Bring the hands together again, and put the left index under that part of the string crossing the palm of the right hand which is between the strings on the right index, and draw the loop out on the back of the left index by separating the hands.

2. Bring the hands together, and put the right index up under the string which crosses the left palm, and draw the loop out on the back of the finger by separating the hands.

1. Put the little fingers into the loop of each string, and separate the hands.

You now have a single loop on each little finger passing directly and uncrossed to the opposite little finger. Turning the hands with the palms away from you, put each thumb into the little finger loop from below, and pick up on the back of the thumb the near little finger string; then, allowing the far little finger string to remain on the little finger, turn the hands with the palms facing each other, return the thumbs to their extended position, and draw the strings tight.
Another more basic starting point is to codify the relationship between the hands and the string with a straightforward index of all possible string positions, as seen to the right. In this way, one can describe a configuration of strings with something besides literal pictures, or lengthy text descriptions.

This method is in one sense a bit obvious, but also very powerful and one can see traces of it in almost all of the other mappings discussed. On its own, however, it still fails to describe the proper overlap of strings, and only deals with frozen moments in time. From only a description such as the ones on the left of the slide one could never reproduce the pose described, however...
...what it does allow is an improvement on the purely textual description of sequence – or at least a shortening of it. The benefit of using this kind of description is that it deals directly with what happens between the frozen moments of the filmstrip model. If one follows these shorthand directions exactly, the proper geometric configuration is sure to appear.

Pictured on the opposite page to the left is a textual description of “opening a” from a book of string figures. (“opening a” is a standard opening which recurs in many figures). On the right is my “shorthand” version. This method can be reduced further, and made much easier to understand with the addition of simple diagrams containing geometric information, similar to the filmstrip format we first saw but with the addition of at least the beginning of a mapping of how to move from one frozen state to another.
More than half of the string figures described in this book open in the same way; to avoid constant repetition therefore, we may follow Drs. Rivers and Haddon, and call this very general method of beginning "Opening A".

1. Put the little fingers into the loop of each string, and separate the hands. You now have a single loop on each little finger passing directly and uncrossed to the opposite little finger.

2. Turning the hands with the palms away from you, put each thumb into the little finger loop from below, and pick up on the back of the thumb the near little finger string; then, allowing the far little finger string to remain on the little finger, turn the hands with the palms facing each other, return the thumbs to their extended position, and draw the strings tight.

There is now, on each hand, a string which crosses the palm, and passing behind the thumb runs to the other hand to form the far little finger string.

3. Bring the hands together, and put the right index up under the string which crosses the left palm, and draw the loop out on the back of the finger by separating the hands.

4. Bring the hands together again, and put the left index under that part of the string crossing the palm of the right hand which is between the strings on the right index, and draw the loop out on the back of the left index by separating the hands.

You now have a loop on each thumb, index, and little finger. There is a near thumb string and a far little finger string passing directly from one hand to the other, and two crosses formed between them by the little near finger string of one hand becoming the far index string of the other hand, and the far thumb string of one hand becoming the near index string of the other hand.

1. Put RL5 into the loop of each string, and separate the hands.

2. Turning the hands with the palms away from you, put RL5 into RL4 from below, and pick up, on the back of RL5, RL4n; then, allowing RL4f to remain on RL4, turn the hands with the palms facing each other, return RL5 to their extended position, and draw the strings tight.

The configuration is now: R5, Rpalm, R4 -> L4, Lpalm, L5

3. Bring the hands together, and put R1 up under Lpalm, and draw the loop out on the back of the finger by separating the hands.

4. Mirror, repeat 3

The configuration is now: R5n->L1n, L1f->R4n, R4f->L4f, L4n->R1f, R1n->L5f, L5n->
Just as it was possible to list all possible places that a string may fall on the hand, a taxonomy of possible movements is also possible, and is pictured on the left. At this point, I suppose one could say the mapping is moving from the procedural to the algorithmic: there are actions (or functions) one can perform, objects to perform actions on, and properties to accompany both of them. A pseudo-java or pseudo-C is possible, and is pictured on the right.

The good thing about this form of representation is that it's completely explicit – it's unmistakable what is meant when one says things in it, however what's traded-off is ease of engagement. In fact, it's probably the most difficult to engage of any described so far, and impossible to "design" in -- in that you have to know exactly what you want to say before you say it. It would be very difficult to invent a new string figure by working purely within this system, but it may have other possibilities.

This isn't just my assertion, and was verified in a very unscientific "field test" that I conducted -- not only on this representation, but others I've discussed previously as well.
Create a loop around...

A finger: loop_f (arguments)
A wrist: loop_w (arguments)
A palm: loop_p (arguments)

Release a loop from...

A finger: noloop_f (arguments)
A wrist: noloop_w (arguments)
A palm: noloop_p (arguments)

Transfer a loop from one place to another
trans (condition 1 - condition 2)

Expand a loop to include more elements
trans (condition 1 - condition 2)

Create a twist in a loop (reverse it's direction)
twist_CW (loop)
twist_CCW (loop)

Wrap a loop around an additional number of times
multiply (loop, #)

Repeat a set of actions, with hand variables mirrored
repeat_mirror (line)

Separate the hands, and draw the strings tight
sep

• Work below, or above some string while performing action
  action (argument [a, string])
  action (argument [b, string])

1. loop_f (RL5); sep
2. trans ( RL5 - RL5,RL4 [b, RL5] ); sep
   The configuration is now: R5, Rpalms, R4->L4, Lpalm, L5
3. trans ( Lpalm - L5,R1, L4 [b, Lpalm] ); sep
4. repeat_mirror (3)
   The configuration is now: R5n->L1n, L1f->R4n, R4f->L4f, L4n->R1f, R1n->L5f, L5n->
My intent with these tests was to facilitate satisfying play through a series of exercises which introduced the various qualities of the string to players relatively unfamiliar with the game.

Some questions asked during the exercise were: How and when does one learn to anticipate the results of one’s actions? Is the fact that the system allows for complexity without understanding a desirable quality to players, or will the system seem out of their control?

One essential idea raised during this event was that of fluency. After the structured games concluded, players found that play within the system after they had gone through the exercises was much more satisfying than before they had gone through them—that they had become more fluent in the system. What seemed to be essential for achieving this that the players develop an intuition for the taxonomy of possible moves (or of the moves which generate a somehow useful result), and what the result of various moves might be:

This idea of fluency is of particular interest to me, as it may indicate a comfortable balance between the interests of the user and the characteristics and complexity of the system.
Test 01: Geometric
one party attempts to reproduce the pose performed by another party by re-aligning marked intersections.
(page 15)

Test 02: Geometric
a single party attempts to reproduce a series of poses as represented in thread-and-needle models.
(page 18)

Test 03: Geometric
a single party attempts to reproduce a more difficult series of poses as represented in thread-and-needle models.
(page 18)

Test 04: Procedural
two parties attempt to play Cat's Cradle, receiving only verbal "coded" instructions from a third party.
(page 33)

Test 05: Geometric
a single party attempts to reproduce a more difficult series of poses as represented in thickened tube models
(page 22)
Accompanying a taxonomy of possible moves, a taxonomy of global procedures, or moves arranged into phrases and sentences, seems useful—particularly when considering that the representation that I had been using thus far, derived from the string figures book, was driven by directing the user toward a final goal or pose, while the procedures more of interest to this thesis are more about exploration and invention.

So, toward that end the language seen to the right was developed, which borrows the form of an organizational diagram or flow chart.
This form of mapping might be used to document a user’s exploration in string, the squares here are operations one performs on the string, and the circles represent a moment when one separates one’s hands to assess the changes that have been made – in a sense “arriving” at some sub-pose.

The technique could be expanded to show a larger sequence, a network of possible poses and how to arrive at them. At an extreme this may begin to describe a string figure universe, representing the moves of more than one user over the course of time, through which one could plot one’s own course as figures are created, destroyed, and new configurations emerge.
A similar approach could be applied to the paper as well, and to some extent many of its qualities have been described in the previous strains.

But applied here, I looked at the problem from two directions, first from the point of view of lines in two-space which define folds, and second from the point of view of points, which are reflected about these lines.
In that there are rules by which these lines “behave” in a sense, and I set out to define them – or at least talk to people who already had, and from them produce “rulebook” of sorts which could be used to structure the games involving folded paper.

To the right is a graphic representation of some piece of these rules, which proved to be more complicated than required to become literate in the games. The abbreviated version is as follows: Two types of lines are possible—dashed and solid, representing folds in opposite directions.

One line can exist one its own, as show to the right.
But two can never meet at a point without producing something three dimensional (something that won’t fold flat), which is against the rules. Neither can three. That isn’t to say that a three dimensional folded system isn’t worth pursuing, just that it’s outside the system explored here.
Moving forward, any even number of fold lines greater than three may meet at a point, as long as alternating angles add up to 180 degrees. In most of the folds made in these exercises, four lines intersecting is very common, and more than six is never seen.

Moving on to types of folds allowed, in a four-line intersection, three must be of one type (dashed or solid) and one must be of the other. Reflection of folds made as “children” of previous folds also occurs, but this is dependant on the layer order chosen by the player, and I chose not to try and formalize this.
Once a basic rulebook is established, the question becomes: what kinds of things does this set of rules allow which weren’t perhaps possible before, and how can this begin to move toward something which offers a constructive logic?

A major benefit of the rulebook is that it allows the definition of a formal method for combining folds produced separately, and resolving one fold against another. Folds can be combined in the two-space of the paper by extending the lines of one fold into another following the rules outlined above or can be more freely combined in the three-space of the fold, both with the knowledge that a single flat sheet can always be unfolded.
This could lead to some kind of infinite universe of folds, like the universe of string figures we discussed earlier...
Or to something much more controlled, but just as scalable... such as pleating or tiling patterns.
From "Folding Architecture"
Sophia Vyzoviti [19]
I was interested in something which was more engageable as a design tool, however – so I developed the following small game:

There are two parties, party "a" seen in the diagram on the top, and party "b" seen below. Both are allowed to operate on a masked area of a two-dimensional infinite field by drawing lines – dashed or solid, according to the rulebook I outlined before.

They operate in turns, first party "a" draws some lines in his area, Then party "b" picks another area to operate within, and a's lines are extended over if they intersect, at which point party "b" may draw lines, which may force changes in a's lines.

The game goes on like this until both get tired, and then the composition is resolved, trimmed at some edge, and then folded up.
This game was also "field tested" as discussed previously, but proved to be very difficult to engage to those not already versed in the rules laid out in the rulebook. The players often made "mistakes", deviations from the allowed set of moves, and none of their designs were able to produce a design which could be folded flat.
TOPOLOGY / ZONE / AREA
To begin a discussion of the topological strain, I’d like to return for a moment to the topological diagrams with which I began, and that you can see here to the right.

At one point in the semester, I realized that there was enough of a data set in this representation (with one addition perhaps) to extract and transfer to another medium – that I could "build" something very simple from what I had at this point.

The diagram shown to the right is for a "proportional machine" – the premise being that the string I was using throughout each of these poses was always the same length, but each pose was a different width depending on the configuration of the tangle. By measuring the length of the string against, say, how far apart my hands are while in a particular pose, one can generate a system for proportioning an area which is held constant.

The basic idea is: length of string maps onto area. Area is held constant, but the proportion changes based on the parameters of the pose.
Taking this idea further, in that each pose contains a number of zones which also have a perimeter area, one can subdivide these initial proportioned rectangles into smaller zones — who's areas, I conjectured, would add up to the larger rectangle.

Only, as it turns out, they sometimes don't. The example on the right shows that, because the zones of some poses share sides, sometimes the sum of the subdivisions will add up to more than the overall area. Clearly a problem, but also a possible opportunity, as we have seen with previous systems which are less than completely deterministic: It may be up to the designer what to do with this "left over" zone.

Chronologically speaking, this is actually the first the architecture machines that I proposed, and in retrospect, is less compelling than some others that came later. I bring it up more as a description of process, as it did serve to establish my basic procedure — 1st row: description, 2nd row: abstraction (or reading), 3rd row: extraction, 4th row translation — that I think is still evident in the rest of my process.
I did make one attempt develop this system – and thought it could possibly begin to generate not just proportioned area, but also proportioned volume.

The basic idea you see in the diagram on the right was to apply divisions as slices to an extruded volume – which is rotated in various axes as it moves along in sequence and builds up a kind of history of slices and offsets. On the one hand, I would criticize this technique as moving too directly to some architectural “output”, while on the other this output not relating in any fundamental way to the property I was attempting to map. In addition, it doesn’t address the most interesting part of the “data set”, that left-over area which sometimes occurred.

However, this exercise did get me thinking about how to map a history of action onto form, which inspired methods that I talked about earlier in the presentation.
I think the paper perhaps suggests more in the way of a topological machine.

To the right is the result of a test of sorts, I was wondering if the edge of the paper had any impact on the kinds of folds one can make, especially considering I had been working with the square origami paper exclusively. It seems obvious in retrospect, but we can see here that we can cut the path between two connecting points down to a small strip which still can be folded in the same way as the larger rectangle. Further, one can cut the strip down to an infinitely thin line that in folded in the same way as the rectangular paper.

With this discovery, we can see that all we need to describe the geometry of a folded sheet is a sort of folded section.
Conversely, I wondered if the paper could be expanded infinitely and maintain the same folding pattern. This turns out to be possible as well, with one caveat... if two lines which were previously not intersecting were to be expanded until they intersect, then “something” would have to happen to resolve them, normally the addition of additional lines as prescribed in the “rulebook”.
This property of a "variable edge" with a constant topology seemed to offer possibility, especially in relation to the two-space/three space relationship set up in the previous thread.

So, here we see the two space and three space for a particular fold, this one performed by Rori Dajao, a participant in my field tests.
And here is the "expanded" version.
Now, imagine that there are two parties — each only allowed to operate in one of these spaces. The party in the 2-space, the "planner", is only allowed to draw lines with his red pencil, similar to the "field test" we discussed in the previous thread, which are translated into folds. His concern is two dimensional division and area.

The party in 3-space, the "sculptor", is only allowed to use his exacto blade to cut and expand edges of the form prescribed by the planner. His concern is spatial composition and relation.

Of course, the work of each of these parties appears and effect the space of the other...
The 3d work of the sculptor appears in the 2d space of the planner...
And vice-versa.

So, here is a representational device which is, I think pretty interesting. Its generative in the sense that form might emerge that neither party would expect, not that would be obvious with knowledge of the rules that drive it. But I think that it may approach the transparency and engageability that the string and paper games contain, and allow for it's users to become fluent and skilled players – It encourages invention.
ILLUSTRATION CREDITS

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