Q3. What inspired your seminal research into shape grammars in the early 70's? What fields/interests was it coming from, and who was it for?

A3. I've always been interested in what visual artists and designers see and do. What are they up to? Inventing shape grammars was my way of finding out. First, it seems OK today to use calculating to help explain things, so shape grammars are a good place to start. And second, shape grammars expand calculating in an unexpected way with embedding, and thereby include art and design. Calculating with shape grammars says something about what artists and designers see and do, and reversing this, what artists and designers see and do says something truly new about what calculating should be, and why shape grammars are necessary to embed and fuse shapes and their parts, as rules apply in a process that's totally open-ended. Turing and John von Neumann invented the kind of symbolic calculating taken for granted in computers, and used all over today. But maybe there are real alternatives. Von Neumann suggests as much when he compares the "visual analogies" needed for symbolic calculating (spatial relations like a triangle or a square in a square, and other descriptions like this that are built up in terms of units) and what happens if you try to describe putting something into a picture or a Rorschach test, in a personal way that's intuitive, fickle, and an ongoing surprise –

> The ability to see triangles is an infinitesimal fraction of the visual analogies in geometry, which in turn is an infinitesimal fraction of all the visual analogies you can recognize, and describe. But you can't describe interpreting a picture, putting something into a picture. Everyone will put something into a Rorschach test, but this depends on his[/her] whole personality and history, and is supposed to be a very good method to infer what kind of a person he[/she] is. (*Theory and Organization of Complicated Automata*)

What good is calculating or using computers, if every shape is a Rorschach test and not a visual analogy, when deciding what to describe in a picture never ends? What would calculating be like if Turing and von Neumann were painters and not simply logicians? This is a pretty good way to look at shape grammars – visual calculating opens uncharted possibilities via art and design. This may come as something of a shock; without shape grammars, it seems really farfetched that art and design are calculating. Seeing how shape grammars work proves this equivalence. I'm not very keen on multiple cultures – notably, art and science

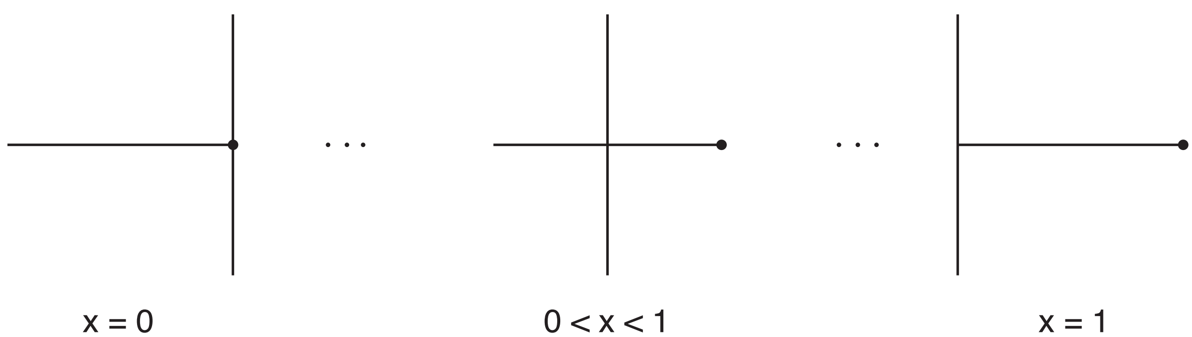
– where what makes sense in one is obscure in another. Some try to balance cultures with rival points of view, by sporting different hats on different days – even when this works, it doesn't justify hats individually, settle their differences, or excuse their flaws. For the mathematician Gian-Carlo Rota, it's combinatorics and then discretely, phenomenology, but he doubts all divisions in math and with Stanislaw Ulam, bets on a key aspect of shape grammars in calculating – seeing *as*, as a Rorschach test. (Ulam played a large part in 20th century math and physics; von Neumann and he invented cellular automata, mostly defined for patterns and forms in square grids, yet nonetheless, utterly symbolic.) Sometimes, mathematicians are complicated and easy to like – asked about his two hats, Rota simply replies, "I am that way." That way isn't for me. Hats tend to be like visual analogies in how they work – once they're on, they don't add anything new, and they're inevitably invidious. Hats are distinct and independent, and look their own way. Even with a rack full, you can only try one on at a time. Wearing special hats on successive days doesn't change the view – it's privileged in each hat, fixed and focused to sort things out in a single way. You're a painter on a Monday and a physicist on a Tuesday. Art and science go on as usual, neither influencing the other from one day to the next. Maybe this is right for closed cultures with high walls for borders, but are walls worth building and borders worth patrolling? What's gained, and what's lost? And surely, hats are swapped hesitantly – things that go smoothly in one may rub in another. Monday's hat may be worrisome or embarrassing, if it's out of style or new, or you fancy Tuesday's hat as much or more, with no way to ease this anxiety. Maybe it's better to enjoy crazy hats without putting them on – pretend they fit or leave them on the rack. Where do hats come from anyway; how are they made? A well-worn hat feels nicer than the rest; it puts everything right, with pleasing sights in easy view. Hats let everyone off the hook to keep to old ways of looking at things. I don't swap hats to vary my point of view, although I do like to try them on in fluid succession to see how they differ, and go together in an enveloping blur – most Saturdays at Salmagundi in Boston's Jamaica Plain. It's a lot like trying rules in shape grammars to see how shapes change. Boundaries dissolve to assimilate and fuse, in order to re-divide with caprice and originality. Diverse things meld and commingle to modify one another mutually in one culture, coadunate for surprising gains. It's the crux of my seminar (*salon*) at MIT, for shape grammars in art and design, and their locus in literature, criticism, etc. – to grow many things in visual calculating that seem unlikely to root and thrive. For example, shape grammars yield Owen Barfield's "participation" and "figuration" at the quick of experience, in the ongoing use of rules to embed and fuse shapes. Participation (using rules) is "original" whenever figuration (embedding) is immediate, and we're aware of it – this is a crucial task for the "primitive mind" – and participation is “final” in the conscious/imaginative re-creation/reaffirmation of “collective representations” or “idols” (any of the visual analogies we know and use) in prior figuration. (This communion-like ritual brings in some really cool math, at least for shapes – graphs, topologies, and other visual analogies are defined in retrospect after rules are tried, to ensure a kind of narrative continuity.) The contrast between Barfield’s original and final participation can be wrought in lapidary detail, but this isn’t necessary – the taxonomy isn’t key. What matters most is that participation in figuration never ends when there are rules to try; embedding goes on freely, even at the risk of “chaos and inanity” in a “fantastically hideous [extravagant] world” – “We should remember this, when we see pictures of a dog with six legs emerging from a vegetable marrow [shape] or a woman with a motor-bicycle substituted for her left breast.” (This is from Barfield’s *Saving the Appearances: A Study in Idolatry*. He uses "saving the appearances" in its original sense – different descriptions/hypotheses for the same things/phenomena are equivalent. This OK’s all there is, dividing shapes into parts. But exactly what is, is impossible to decide. Shapes aren't Galilean, where scientific truth is final, and something to defend. Artistic/figurative truth relies on Epicurean plurality, and not Ockham’s Razor. Seeing takes in whatever it likes, unthreatened by more; it saves the appearances in a myriad ways.) Of course, there’s no reason to be extreme or far-out, or even to allow for mild alternatives – Barfield is conservative and religious, with a sincere respect for objective nature (a rainbow, a thrush singing, and other leafy idols) and a profound sense of obligation to origins and continuity. This is more than enough to worry about shape grammars, and to limit and control their use. Shape grammars discard idols wantonly, disfiguring nature indifferently as they do, to save the appearances with six-legged dogs chasing bikes in disturbing places; they “revert to original participation (which is the goal of pantheism, of mediumism and of much so-called occultism),” and Barfield is quick to reject this entirely – “it is no part of the object of [my] book to advocate a return to original participation.” But shape grammars go on anyway – unperturbed, they calculate shamelessly with whatever “[original] participation renders … less predictable and less calculable.” Many who sport special hats fight shy of shape grammars, as well. It seems that shape grammars don’t belong in art and design; their fate was permanently sealed in architecture, as they were invented. Serge Chermayeff called for a new kind of practice – “Let us not make shapes: let us solve problems.” And Leslie Martin urged much the same – forms should be “’built to a purpose’ and thought out rather than drawn.” This turns away from delight (beauty) in the Vitruvian canon to focus on scientific procedure and research. The key to calculating in art and design, however, isn’t to ground them in problem solving and thinking, but to keep them visual with shapes and drawing. This emphasizes delight, as it gives art and design full sway to add in science at any time – explicitly, when shape grammars align with description rules, maybe for visual analogies for practical things, and in implicit ways, with weights and their scattered algebras. (There’s a nice example of weights in A4, for fifty shades of grey and their successors.) The three categories in the Vitruvian canon interact in shape grammars – coadunate, to foster reciprocal relationships in an ambiguous/creative process. The easy swerve of firmness (physical performance) and commodity (utility) toward science and proven results is scant reason to give up delight in art and design. John Ruskin puts delight ahead of firmness and commodity in *The Seven Lamps of Architecture* – the uncanny, numerical congruence with my own seven questions and answers may be telling. Firmness and commodity are necessary to support building, but lacking the aesthetic third (decoration and ornament) that’s “above and beyond … common use,” there’s no architecture – so much the worse for problem solving and thinking. Delight is what makes a building architecture. No matter, the “architectural scientist” takes the objective view and another tack. He/she denies variable “appearances” – superficial drapery, decoration and ornament, etc. – to expose “‘naked’ [invariant] built form with all articulation, openings and decoration ignored [stripped away].” This is at once necessary and an appeal to convenience and utility; it facilitates “encoding [describing/representing] built forms … so that all possibilities can be counted.” These are the underlying facts and figures of analysis and classification that delimit and direct problem solving. Must building be so clinical – with no vibrancy and visual draw? What happened to delight? Building is crucial in a diseased and disordered world begging for experts (architects) with scientific hats to solve pressing problems and to think out remedies to urgent needs, in ranges of choice (a design space) defined and settled in prior research, and tested for use in the real world. Maybe delight has a salutary purpose after all, as the one true measure of effective choice for built forms. This no-nonsense, get-down-to-business relationship is given in a handy formula

$$\text{firmness} + \text{commodity} = \text{delight}$$

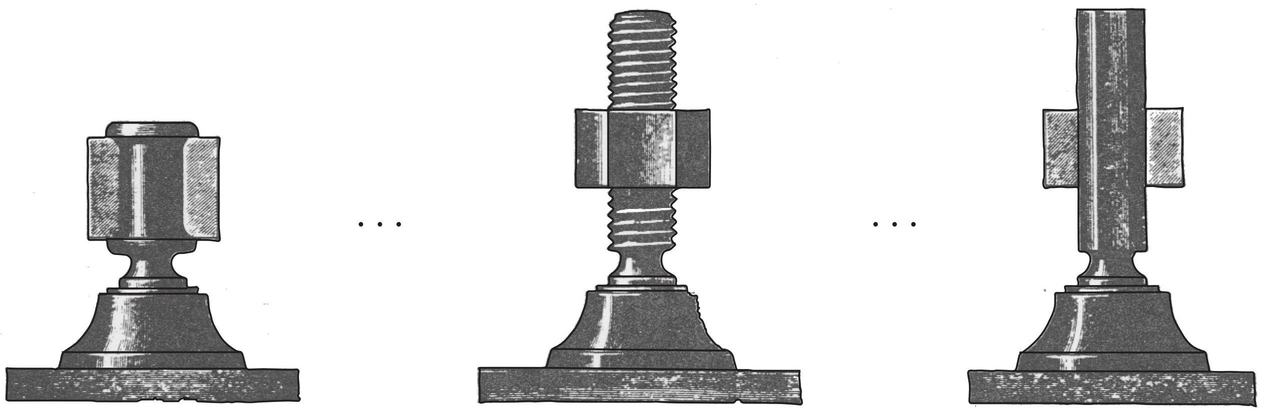
that may include Chermayeff and Martin; it lets experts participate confidently in a proven equality, trained in advance what to do. Without appearances, though, this is hopelessly incomplete – with no chance to see, there’s nothing to hold (fuse) things together or to distinguish (embed) them separately, that’s intuitive with the right feel. Vitruvian delight is vital; it’s for visual calculating in shape grammars – no hats required.

Today, artists/designers, engineers, historians, scientists, and other professionals loath to error continue to fret – embedding is too licentious, or likewise, generous and inclusive, flouting fixed divisions and tried-and-true norms; shape grammars track too close to genius/folly at its source, embracing strange devices (rules) that are better left alone; maybe visual calculating works in theory, but without symbols, it's trivial and won't do for computers. Shape grammars run art and design through calculating to make it visual, and thereby open up art and design – in this way, they tie in other subjects and blur established boundaries freely. Why not try a different method with odd ways of going on, to see what surprises this holds? Only blind prejudice or a mathematician's love of rigor – usually, a good thing – would keep to fixed (standard) divisions, with this hat or that one to limit seeing and saying, when new divisions are obvious and true. In fact, participation in the way I talked about it in A1 spells the end of hats. (This also goes for Barfield's original participation, even if the goal, in final participation, is to consecrate hats and their contents. In both, the key is figuration, and included in it, there's art and design – originally, as things are defined/resolved and change, and finally, in alternative histories of this recounted from memory or reproduced in other modes of figuration, anything goes from true stories to fake news, fantastic myths, and dark tales to varied graphs and topologies.) Seeing exceeds what hats allow singly, or in succession. In shape grammars, rules provide the impulse to see things anew. What's settled and known doesn't stay that way for long – to add an inclusive prefix (see the initial parentheses in A4) to Ezra Pound's formula in *ABC of Reading*, it's changed-charged with meaning.

In my student days at MIT, I signed up for Marvin Minsky's "Theory of Symbol Manipulation and Heuristic Programming" – or a like concatenation – to find out what artificial intelligence (AI) was about, from one of its inventors. I remember enjoying this a lot, as I worked on symbolic descriptions of pliers and similar hand-tools. This was a big success, although my method left a lot out – there was more to see than I could say. Rumor had it that Minsky, with his odd sense of fun, liked to play around with silverware at the kitchen table. The goal was to combine knives, forks, and spoons in stable designs of ever-increasing complexity. This made breakfast a real challenge – so much for intelligence. Nonetheless, it was a kind of calculating, with visual analogies (spatial relations) for rules. Of course, this involved seeing; in fact, I discovered later that it goes far better in shape grammars than in AI – it's what I do comprehensively in "Kindergarten Grammars," only to discard as too narrow. And maybe that's what I'm getting at – sooner or later, AI wears thin. Even with Minsky as the Pied Piper, symbol manipulation wasn't beyond doubt – it relied on visual analogies in place of things, ignoring obvious features and properties. The incumbent abstraction gave me a migraine that only shape grammars could cure, with rules directly in sync with my eye (seeing) and hand (doing). Shape grammars let me abandon symbols, and this meant Minsky's AI, as well. AI influenced shape grammars – hand-tools were a promising start – but it wasn't how I wanted to calculate. (John McCarthy, Minsky's double in AI, was a grad student in math at Caltech when von Neumann was there, at the Hixon Symposium to talk about the theory of automata, and how visual analogies probe the limits of calculating in a picture or Rorschach test. Years later at Stanford, McCarthy returned to visual analogies as the symbolic basis for AI, and tried them in clever ways in computers. His constructive/parametric descriptions – not unlike spatial relations for knives and forks and spoons – combine units in terms of intentions and goals, in given ranges of choice. For example, "a vertical line, connected at its middle, to a horizontal line segment going to the right," defines two cantilevers, for the leading point x of the horizontal segment at 0 and at 1, and varied crosses in the open interval, one with bilateral symmetry when x is at 1/2. The three cases line up neatly and are easy to see, each is two lines configured in a visual analogy or spatial relation–

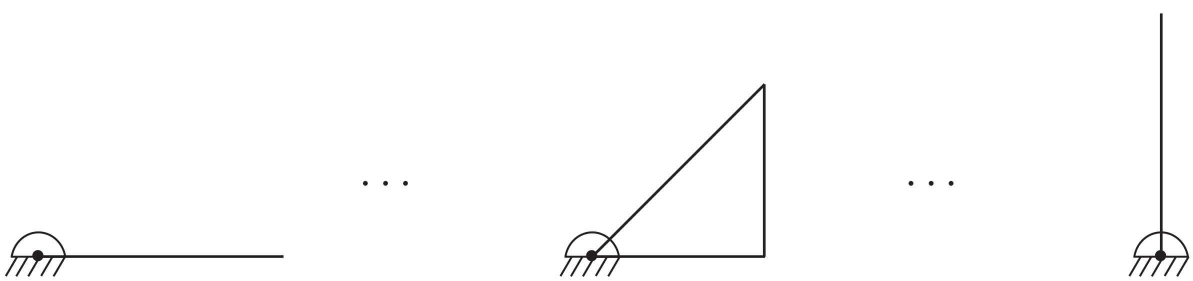


A century earlier, Franz Reuleaux used the same method for machinery, to classify the forms of a nut and bolt in terms of the pitch-angle θ of the screw – the standard twisting pairs with helical motion are flanked at 0 by a turning pair with rotary motion, an axle and wheel, and at $\pi/2$ by a sliding pair with translational motion on a linear track. For Reuleaux, it goes like so –



θ = 0 … 0 < θ < π/2 … θ = π/2

This suggests a continuous transition starting with an easy stroll on level ground or a horizontal surface, through heart-pounding climbs up inclined planes on rising diagonals, to a heart-stopping ascent up a perpendicular, or a vertical wall –



θ = 0 … 0 < θ < π/2 … θ = π/2

Looks can be deceiving – like beauty, they're skin deep, superficial and fleeting, only in the eye of the beholder. This may obscure timeless structures shared by many things. The parametric structure of McCarthy's two lines, one moving with respect to the other, is exactly the same for Reuleaux's nuts and bolts, and the corresponding inclined planes – the mapping f from x to θ is $f(x) = \pi x/2$. McCarthy framed a catchy slogan for AI, when he established his research lab at Stanford; it worked as a heuristic and guide– "description and not merely discrimination." This ties seeing to structure. Visual analogies are given for shapes, to recite in words how to draw them and how to recognize them, over the phone without having to see. Shape grammars aren't this way. They greet description versus discrimination with a listless yawn. Embedding is the sine qua non of discrimination, that is to say, perception, without description. Shapes aren't visual analogies, at least none before calculating starts, and one and sundry in retrospect as calculating goes on.) To get shape grammars, it was easy to copy generative grammars for natural languages like English or Greek – Noam Chomsky's pioneering work in linguistics – but it was evident right away that much more than symbols and recursion were needed for visual calculating. In a generative grammar, the symbol "A" is just an A, and it's always independent of the rules I try. And if I add two A's side-by-side, maybe they touch right leg to left leg, I still have just two A's with nothing more possible – they're like the members of a set. But in a shape grammar, the shape "A" is an A, a triangle on top of a little table, and any other parts I see – actually, indefinitely many different parts depending on the rules I try, even indefinitely many A's with shorter and shorter legs. (Are A's the same as McCarthy's lines? What about the two squares in the rule in A1, when I rotate the inside one to increase its size, and what about the K's and k's in the original squares?) And if I put two A's leg to leg, I can find more parts. There may be an M or an N, rows of jack-o'-lantern teeth (triangles above hexagons), a raven hunting scattered seeds (M with a central beak between two splayed legs), twin peaks (an inverted b; M cut bilaterally), a baby finch's gaping beak (M undivided), cat's ears, and anything else my eye can find or my finger can trace. This also works with K's – in four K's with perpendicular spines and overlapping arms or limbs of other kinds, there are a pair of squares, four triangles, and a myriad-times etc. What's going on? Well, whatever parts I see, in terms of the rules I try in any way I wish. Embedding is why this works. In a generative grammar, embedding is only "identity" – A's are units, the given "atoms of computation." Each is an A no more or less; alone or in any combination, their identity is never in doubt, they're always the same. In a shape grammar, embedding allows for more than identity. An A includes any part I can see (embed) in it, and once A's are combined, they fuse and disappear – literally, they lose their identity, so that I can see other things, even A's. Neatly, identity is a special case of embedding; shape grammars allow for both. Limiting embedding to get identity separates visual calculating and symbolic calculating (Turing machines, generative grammars, etc.). Open-ended ambiguity in the one is simply monotonous counting in the other. With embedding, rules do what I see even if it's not what I've drawn – there's no memory of this. Those trained in drafting in the old-fashioned way with HB pencils, and pen and ink, and T-square and triangles grasp this perfectly – they draw the longest lines they can find and are free to see as they please. (Ivan Sutherland rejects this outright in "Sketchpad" – pen and ink only make dirty marks on paper. Sketchpad relies entirely on computer structure, with visual analogies or combinations of units as stored descriptions of shapes to say what they are – in effect, computer renditions of Barfield's collective representations in final participation, settled once and for all with no chance to change. This is the unquestioned prototype for all computer-aided design or CAD in use today, including trendy parametric modeling tools. Herbert Simon, Minsky's and McCarthy's compeer in AI, goes farther in *The Sciences of the Artificial*. On the one hand, Simon praises Sutherland's groundbreaking invention for allowing in intentions and goals via constraints to which drawings and their parts must conform – Simon is certain that drawing requires a hierarchy of parts for "observation and understanding." Then on the other hand, he concludes that design is more like oil painting – spots of pigment applied on board or canvas in an ever-changing pattern, with intentions and goals entirely in flux. And Simon is sincere about this, with no hint of absurdity, irony, or paradox – Sketchpad, drawing, and painting are merely "combinatoric play" with building blocks or units, of many predefined and richly varied kinds. Surely, von Neumann would scratch his head and laugh. The whole point of drawing and painting is that pictures/shapes aren't visual analogies – there are no units, without an end to seeing.) Shapes alter not once or once in a while, but to every rule I try – and to every identity $x \rightarrow x$, as well. At the risk of seeming oddly romantic, seeing is alive as heartbeat and breath in the in-out pulse of an embed-fuse cycle of new perception. Whenever I try a rule, no matter which one, whatever part I see is brand-new – it's always embed-fuse, embed-fuse, etc. Visual calculating in shape grammars unfolds in a metabolic process; it isn't mechanical repetition with fixed components and standard parts. That's the importance of calculating without symbols, to go beyond units and calculating as it's supposed to be. This lets art and design all the way in, so that seeing (drawing, painting, etc.) overtakes thinking as the way to figure things out.[1] (MIT's motto is *Mens et Manus* – the English translation of the Latin is Mind and Hand. This ties the abstract and the concrete, or theory and practice. It's the first thing to learn as an incoming student, to solve problems and to think in "The MIT way." It's also how MIT engineers invented CAD, with visual analogies – Steven Coons's "patch" to stitch surfaces together; Douglas Ross's "plex" to define things in terms of data or indivisible units combined in structures for algorithms; and later, the work of Sutherland on Sketchpad, and of others on solid modeling, etc. And even now, it's exactly the same – in CAD, computers manipulate descriptions or representations for practical ends, and efficient making in manufacturing, assembly, etc. To architects and engineers, both at MIT and not, CAD, including building information modeling or BIM, is only "data organization and operators suited to that organization." Shape grammars try another method more attuned to impulse and intuition. Shapes are described on the fly in untold ways, and hence, eschew the visual analogies and invariant structures that count when it comes to computers – shape grammars need something else to go on, to boost visual calculating. The artist's formula Eye and Hand seems a pretty good bet, to ground practice in new perception instead of theory. The resulting analogy is evident and worth notice – cancelling out Hand as a common factor, it's

CAD **:** Mind **::** shape grammars **:** Eye

The mind settles on descriptions that the eye intuitively ignores, to see in extravagant ways – proof once again that seeing supersedes thinking. The three-tuple Eye, Mind, and Hand, and its permutations are equal and inclusive, and no doubt, prudent, but they obscure the real value of switching from symbolic calculating to visual calculating. Somehow, Mind takes over, convinced that its descriptions are key – in definitions, graphs, and hierarchies/trees that aren't to be tampered with. Mind in words and language drives seeing – in sync with McCarthy's slogan – with no way to reverse this to go from seeing to words, as the artist's formula encourages, directly and in reciprocal processes. In fact, Eye and Hand allow for more than Mind and computers. Anything computers can do, is for free in shape grammars – symbols and codes are a special case of shapes. The MIT way brims with confidence, and is widely and rightly admired; nonetheless, it may be vexingly incomplete, riddled with blind spots. It needs filling in, lest it miss what's easy to see. It's probably just one more hat.)

Positive influences are conspicuous, too – in particular, William James (sagacity and embedding in *The Principles of Psychology*) and Oscar Wilde. I have a fantastic Phil May drawing on my office wall; it shows James McNeill Whistler replying mordantly to Wilde – who's amused, smoking a cigarette. I'm sure Wilde and Whistler would see immediately what shape grammars are about. In the "Critic as Artist" and elsewhere in *Intentions*, Wilde talks about poetry and visual art, and the critic as artist, as if he were describing visual calculating in shape grammars. In fact, Wilde and von Neumann also overlap, with uncanny fidelity. It seems that pictures and the Rorschach test are indistinguishable, exact copies almost word for word – "The one characteristic of [any] _ _ _ _ _ _ _ _ _ _ _ _ _ _ is that one can put into it whatever one wishes, and see in it whatever one chooses to see." Is this Wilde, or von Neumann? Is it art, or calculating? It must be a "beautiful form." I guess visual analogies fail in any recursive rule for a beautiful form or a Rorschach test – for any arbitrary blot, elaborate fret, entangled line, haphazard mark, intricate maze, irregular part, luxurious plan, seductive tile, or undoubted unit. It's truly amazing how extravagant seeing can be. And equally for any ambiguous text (play or poem) and for any memorable time. Shape grammars unlock Wilde's "critical spirit" to unite the critic and artist – to see things as in themselves they really are not. This goes for every beautiful form, and for the Rorschach test, as well. Pictures are definite (finite) things that can be described in indefinite (infinite) ways, and poems, etc. run on the same track. Shape grammars exploit the recurrent ambiguity in seeing and new perception – forever vast and open-ended. There's a "moment-to-moment flexibility in the treatment [definition] of facts [parts]" – both in politics (the line is George Orwell's in *Nineteen Eighty-Four*), where sense is easy to alter with conviction (sincerity) and not, and also in art and design. The ongoing risk of "chaos and inanity" may be unsettling to many, maybe terrifying, but persuading (educating/training) everyone to see correctly in one way with rote finality – as some are encouraged to speak correctly – is no alternative, dispensing privilege and safeguarding false security. Art/calculating is charged with meaning, as rules change what I see with wanton vitality. The equivalence between art and calculating is a splendid example of the critical spirit at work. In whichever way the ratio is defined, each is seen as it really is not. Then again, this also makes it possible to deny shape grammars totally – the computer scientist does because they're silly, strictly for art and design, and the artist/critic/designer follows suit because they're merely for empty calculating. It's funny how easy it is to agree. That's the big snag with hats – what's interesting goes entirely unnoticed in their differences, with no awareness of missing anything. Maybe this explains why there are only a few who grasp what shape grammars actually do, who make use of them eagerly as the way into art and design, and who exploit them as a way to calculate. There's something in shape grammars for the computer scientist and the artist/critic/designer alike – when they're taken seriously, and when they're not.

So, who are shape grammars for? I started out using them to paint – I remember warming up on Paul Klee's drawings in *The Thinking Eye*, notwithstanding the synonymous formula Eye and Mind that limits shapes in terms of visual analogies and other symbolic descriptions of their parts (Mind expressed fully in words and language) – and then for visual design, mostly in architecture, to calculate anything from ornamental designs (for example, Chinese ice-rays and symmetrical window lattices) to Palladian villa plans replete with articulation (porticos and wall inflections), windows and doors in enfilades, and decoration, and even to present-day projects like Alvaro Siza's. But shape grammars are really for anyone who wants to design visually, whether it's in art, architecture, graphic design, urban design, or engineering and product design. They work with description rules and weights to link form, function (use), material (color, etc.), and ways of making (assembly and manufacturing processes, even painting and drawing) in sundry relationships at any scale from the nano to the human and the humungous. This goes beyond computer modeling as usual – there's no loss of anything that's visual along the way. Moreover, it serves to divide shapes on the fly, and to record changing divisions in terms of retrospective graphs, hierarchies, topologies, and kindred structures. Shape grammars trace what I see in different ways, and let me overstep any discontinuities in analysis and synthesis; they describe things already known anew, as in themselves they really are not, and they make new things of many and varied kinds. (To the poet and critic S. T. Coleridge, synthesis implies "indifference." Every shape is the synthesis of a thesis and an antithesis, but the shape/synthesis doesn't care about opposing descriptions or visual analogies – there are "myriad myriads" like them primed for instant use. All of these save the appearances. Better yet, this is "the effect of reducing" – here, multiple descriptions to a single shape, and it's the same way in shape grammars with "reduction rules." Coleridge ascribes indifference to things that are alive and that grow, to plants and poems, and maybe to you and me. This goes for shape grammars, even if not for every generative process. At one time, I was 99.44% sure that all generative grammars had lives of their own; thanks to Coleridge, I'm now more restrained about organic/romantic analogues. Analogues and metaphors may help to explain shape grammars – to tie them to familiar things – but shape grammars are indifferent to this, ready to assimilate descriptions that vary arbitrarily and clash. It makes pretty good sense to play around with shape grammars on their own, and not to anticipate too much what they do – relationships I expect to go one way just as often go another way. With shape grammars, it's routine to be surprised.)

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[1] James Gips and I worked together on hand-tools, as undergraduates at MIT. We were able to describe them in finite state machines (regular expressions). In retrospect, this was our start on shape grammars, and, in fact, just a few years later (1972), we published our seminal paper. (It's worth noting that originally shape grammars were paired with material specifications, including coloring rules and like devices for painting and sculpture. In fact, there's always been a close relationship between shape grammars and making – formatively, 40 years ago in the rational approach to Chinese ice-ray lattice designs, and in the thumb and forefinger rule in "Kindergarten Grammars" to define and use spatial relations. This is mostly craft and handwork – not too surprising, as shapes themselves are drawings.) Gips went on to develop the first computer implementation of shape grammars with applications in artificial perception, as a PhD student at Stanford in the AI Lab (SAIL) – he was always keen on John McCarthy. Gips turned to visual analogies to represent shapes, hewing to standard computer practice, then and now. His original software showed the usefulness of visual calculating and opened a key area of research that continues to thrive. At the same time, I was doing my PhD at UCLA. I focused largely on embedding and how shapes fuse when rules are tried in shape grammars (reduction rules for maximal elements, registration marks for partitions of shapes and their transformations, etc.), and on reciprocal relationships between visual calculating, and art and design. Building on this work, Ramesh

Krishnamurti did the first computer implementation of shape grammars to take embedding as the starting point for calculating – this was somewhere around 1980, the first third of the decade. Gips and I published our original paper on shape grammars before we started our PhD studies at Stanford and UCLA –

Stiny, George and James Gips. 1972. Shape Grammars and the Generative Specification of Painting and Sculpture. Pp. 1460–1465 in *Information Processing 71*. C. V. Freiman, ed. Amsterdam: North-Holland.

This was followed by two additional publications (our PhD dissertations) to expand the use of shape grammars and establish research goals that are ongoing –

Gips, James. 1975. *Shape Grammars and their Uses.* Basel: Birkhäuser.

Stiny, George. 1975. *Pictorial and Formal Aspects of Shape and Shape Grammars*. Basel: Birkhäuser.

Symbols with visual analogies and spatial relations aren't shapes; they differ in terms of the dimension i = 0, 1, 2, 3 … of basic elements – points, lines, planes, solids, etc. For i = 0 (points), things are like symbols, where embedding is simply the special case of identity; otherwise, things are like shapes, where embedding is expressed fully and shapes have indefinitely many different parts. Gips's computer implementation of shape grammars was 0-dimensional; in contrast, Krishnamurti's was 1-dimensional. Going from 0 to 1 may seem easy enough – no sweat – but don't be fooled, it marks the enormous shift from counting to seeing and ambiguity, and a marked change in what's required to calculate. This subsumes S. T. Coleridge's prescient division separating "fancy" (i = 0) and "imagination" (i > 0). I describe the split more fully near the end of A4 and implicitly, in the preceding parentheses comparing Norbert Wiener's distinction for counting and statistics in *Cybernetics* with identity and embedding in shape grammars. Fancy and imagination also run throughout my ensuing answers. Like many things, fancy and imagination can go together (i ≥ 0), so that both are kinds of calculating that meld for mutual advantage. (Whether or not Coleridge's imagination extends this far is an open question.) The first time I considered calculating in different ways was for shape grammars and set grammars, where the latter are symbolic and always 0-dimensional – the members of sets (shapes in spatial relations) are distinct and independent, in the same way points are when they combine. This isn't the case for lines, etc. that fuse according to reduction rules – the same reduction rules work for embedding, as well. The original reference for set grammars is short and gets right to the point –

Stiny, George. 1982. "Spatial Relations and Grammars." *Environment and Planning B* 9: 113-114.

In tandem with shape grammars, Gips and I outlined an algorithmic approach to aesthetics, highlighting constructive and evocative modes of description, and their composition. Forty years later, this seems mostly trivial stuff, at least it does to me. Constructive and evocative descriptions are indistinguishable in shape grammars – rules for one work

for the other in the same way. Identities $x \rightarrow x$ provide good examples for both. Nonetheless, there's still a lot of enthusiasm for algorithmic aesthetics, especially when it comes to the evaluation measure E_z that compares unity and variety, or order and complexity. And who knows, there may be ways to make this right. Coleridge is keen on reducing multitude (variety) to unity in a special kind of poetic (natural/organic/romantic) process in which things fuse in undivided (largest) wholes, and re-divide to recreate (see the parentheses that concludes A3, and the discussion of imagination in A4); as engineers, Gips and I framed E_z mathematically, to incorporate trendy algorithmic information theory, counting discrete symbols or smallest units in a standard, predefined vocabulary – tediously, unit by unit. But no more – I've given up on trying to be au courant with technical/mechanical devices. Today, my sympathies are entirely with Coleridge and his organic analogues. I've always been something of a closet romantic, seeking delight in everything I see – not forever, but purely for now. Of course, there may be some math in this, too. Visual calculating in shape grammars, when there's embedding, and shapes and their parts fuse, assimilates algorithmic aesthetics fully –

Stiny, George and James Gips. 1978. *Algorithmic Aesthetics: Computer Models for Criticism and Design in the Arts*. Berkeley and Los Angeles: University of California Press.