Generating 3D Scenes in the style of Keith Haring

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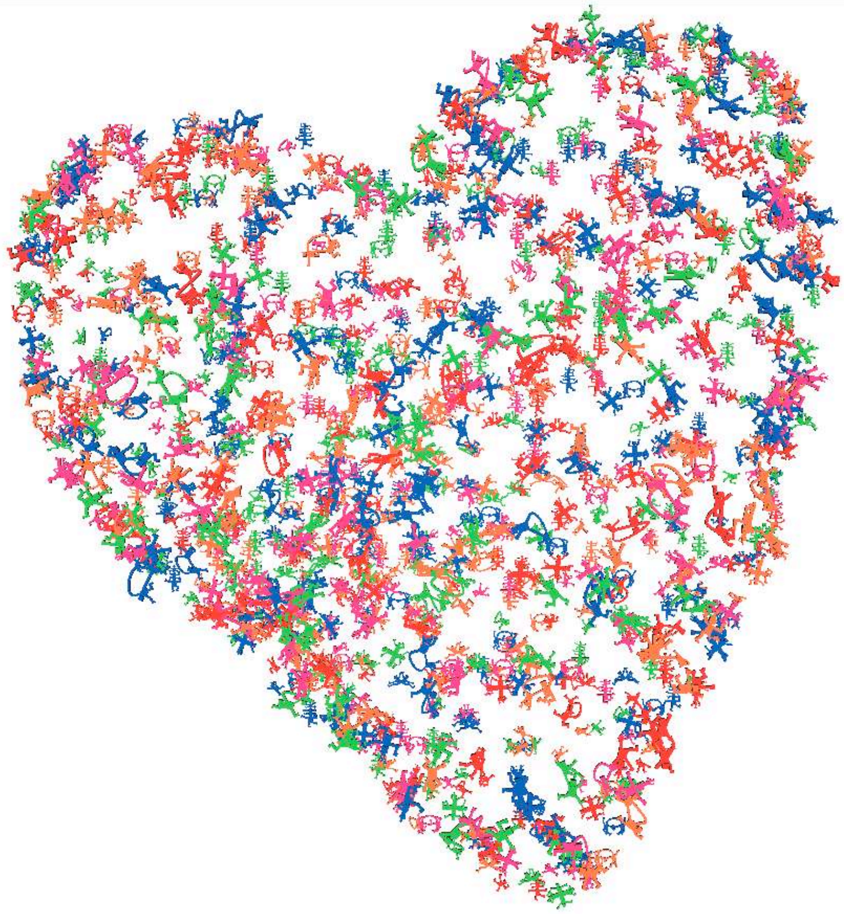


Abstract: Recently, interest in shape grammar models of pictorial style has been revived by the success of generative modelers for buildings and cities. Stochastic methods have been introduced for learning the parameters of shape grammars to adapt to different architectural or visual styles, including Mondrian. We extend those recent approaches for generating 3D graphics in the style of Keith Haring paintings, whose visual vocabulary is significantly more complex than Mondrian. We propose a four-tiered stochastic plex grammar which decomposes scenes into figures, figures into bodies, bodies into body parts, and body parts into surfaces. Each tier of the grammar is stochastic, which allows us to generate random variations of scenes while keeping the overall style of Keith Haring paintings. Because the scenes are generated as 3D graphics, we are able to animate them into generative "Keith Haring movies".

1. Introduction

Recently, interest in shape grammar models of pictorial style [1] has been revived by the success of generative modelers for buildings and cities [2]. Stochastic methods have been introduced for learning the parameters of shape grammars to adapt to different architectural or visual styles, including Mondrian paintings [4].

2. Stochastic Plex Grammars

Traditional string grammars are not adequate for building two-dimensional or three-dimensional structures. Shape grammars were introduced by Stiny and Gips [1] as a general framework for such cases, including painting and sculpture. Interest in shape grammars has been revived with spectacular results in procedural generation of cityscapes and architectural building using specialized CGA grammars [2]. Such grammars have also been extended to humanoid figures [3,4].

In this work, we use plex grammars [5] rather than CGA grammars, because they are better suited for modelling complex figures with arbitrary connections between elements, which are typical of the Keith Haring style.

As introduced by Feder [5], plex languages use a vocabulary of terminal and non-terminal *plex structures* with an arbitray number of *attaching points*. Plex grammars describe the inter-connections of plex structures in any given plex language. Typically, a plex structure A with NA attaching points can be composed with another plex structure B with NB attaching points to build a higher-level plex structure C with NC attaching points (NC < NA+NB). The plex grammar rule for such a transformation includes a list of *joints* (connecting attaching points) and *tie-points* (non connecting attaching points).

A stochastic plex grammar assigns a probability to each rule in the grammar and a probability over the list of joints and tie points in the rule. This is especially suited to the modelling of Keith Haring figures, where body parts can be inter-connected almost interchangeably. A stochastic plex grammar can also assign probabilities over other free parameters of each rule, for instance the relative distances, orientations and sizes of the left-hand side and right-hand side plex structures, but also their colors, shapes and textures.

In this work, we manually created production rules from a sample of Keith Haring paintings available on the internet. We computed empirical rule probabilities by manually labelling the grammar constituents in each paintings and counting how many times each rule was used. We also computed empirical joint probabilities by counting how many times each joint was used in its parent rule. We used the normalized counts as probabilities in all cases.

Similarly, we computed histograms of the distances, orientations, sizes, colors, shapes and textures observed in those paintings, and used the normalized histogram values as probabilities.

3. The Grammar of Keith Haring Paintings

The use of shape grammars for describing the structure of paintings goes back to at least two important papers by Kirsch and Kirsch [6] and Lauzanna et al [7] in the same issue of the Leonardo journal in 1988. This pioneering work was illustrated with examples of automatically-generated paintings in the styles of Miro and Kandinski.

More recently, Talton et al. extended the approach to stochastic grammars for generating random paintings in the style of Mondrian [3]. Their approach introduced the use of Metropolis sampling for choosing more aesthetic productions from a large number of randomly generated paintings according to a hand-tuned preference function.

We extend that approach for generating 3D graphics in the style of Keith Haring paintings [11] whose visual vocabulary is significantly more complex than Mondrian. Our system is based on a four-tiered stochastic plex grammar, which decomposes scenes into figures, figures into bodies, bodies into body parts, and body parts into surfaces.

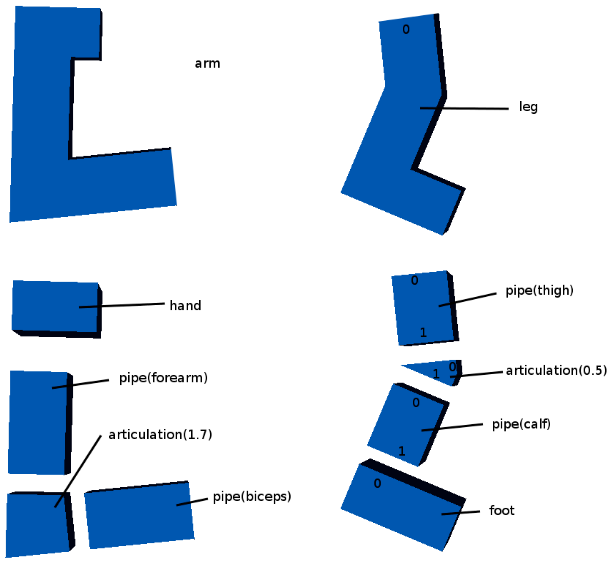
Interestingly, such structural decompositions of paintings appear to have a long tradition among art historians, starting with Alberti in 1453 [7]. According to Baxandall, such structural descriptions were originally adapted from humanist rhetoric, which praised the composition of words into propositions, clauses and sentencess [8]. Hence, Alberti praised the composition of surfaces into body parts, bodies and paintings.

What makes Keith Haring especially interesting in this context is that his paintings provide a systematic and exhaustive exploration of the combinatorial possibilities of composing figures with bodies and body parts, into very large paintings and murals. Incidentally, the combinatorial nature of Haring’s style has recently been spectacularly illustrated with a 17′ x 6′ puzzle comprised of a 32,256 pieces [16].

We now turn to a tier-by-tier description of our grammar of the Keith Haring style.

3.1 Surfaces to body parts

The first tier in our Keith Haring grammar contains rules for composing surfaces into body parts. We build torsos, arms, legs and heads by assembling together tubular surfaces, as follows:

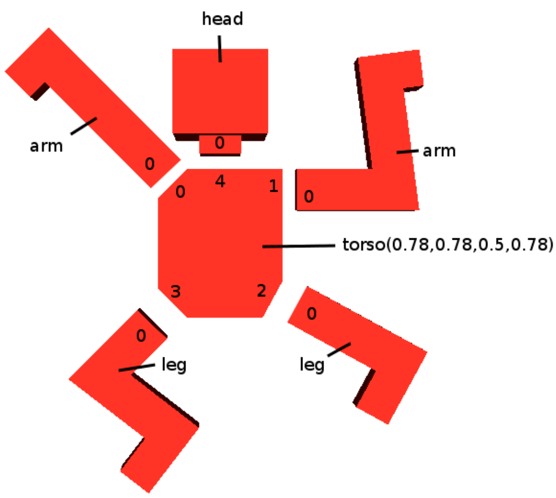


arm -> pipe(biceps) artic(1.7) pipe(forearm) hand (10xx,x10x,xx10) (0xxx)

leg -> pipe(thigh) artic(0.5) pipe(calf) foot (10xx,x10x,xx10) (0xxx)

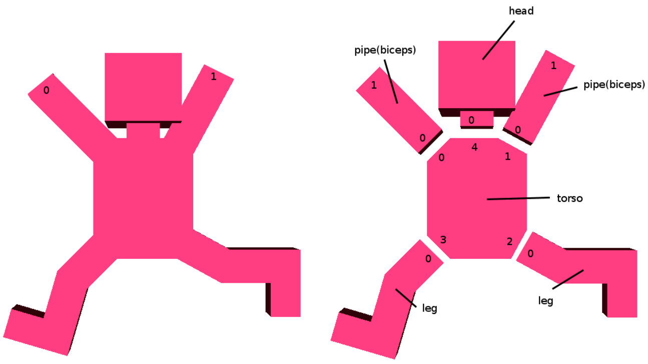
3.2 Body parts to bodies

The second tier in our Keith Haring grammar contains rules for composing body part surfaces into characters. The plex production rule for building a body is presented below.

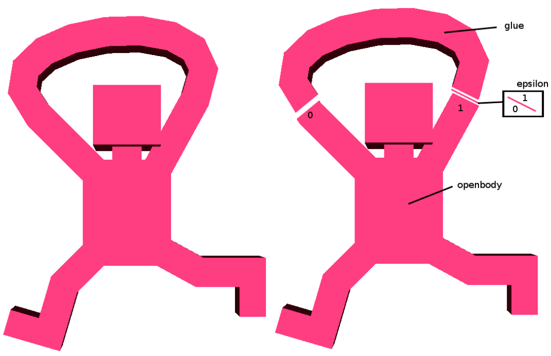


body(x,y,c) -> torso(x,y,c,0.78,0.78,0.5,0.78) arm arm leg leg head (00xxxx,1x0xxx,2xx0xx,3xxx0x,4xxxx0)

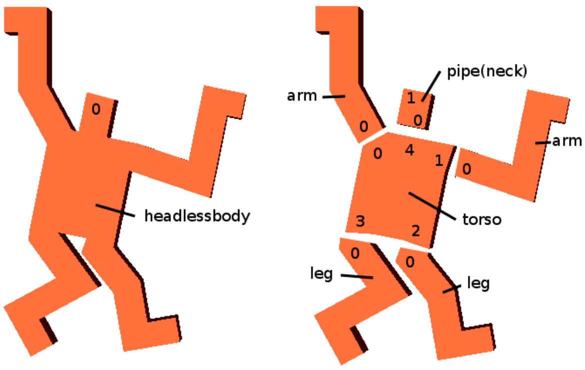
Special cases are the *open body*, where the arms contain attaching points that can connect with other bodies; the *looping body*, where the arms are connected together; the *headless body* and the *open trunk*, where the torso contains multiple attaching points that can connect to other bodies (see accompanying figures).



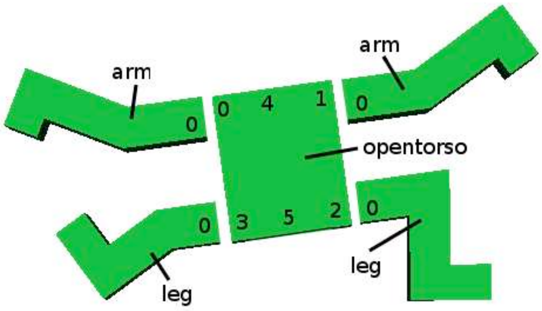
openbody(x,y,c) -> torso(x,y,c,...) pipe(biceps) pipe(biceps) leg leg head (00xxxx,1x0xxx,2xx0xx,3xxx0x,4xxxx0) (x1xxxx,xx1xxx)



looping body(x,y,c) -> openbody(x,y,c) epsilon (01,10)



headlessbody(x,y,c) -> torso(x,y,c,...) arm arm leg leg pipe(neck) (00xxxx,1x0xxx,2xx0xx,3xxx0x,4xxxx0) (xxxxx1)

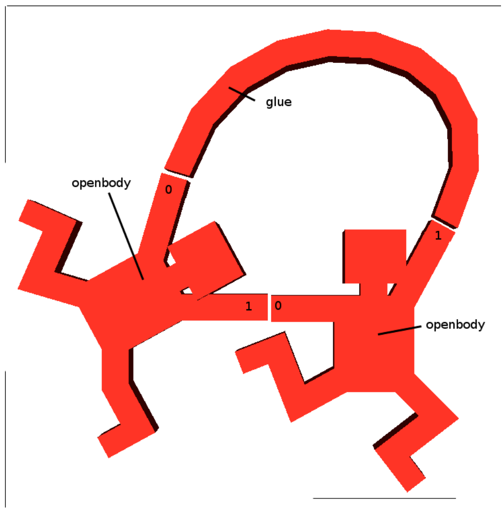


opentrunk(x,y,c) -> opentorso(x,y,c,...) arm arm leg leg

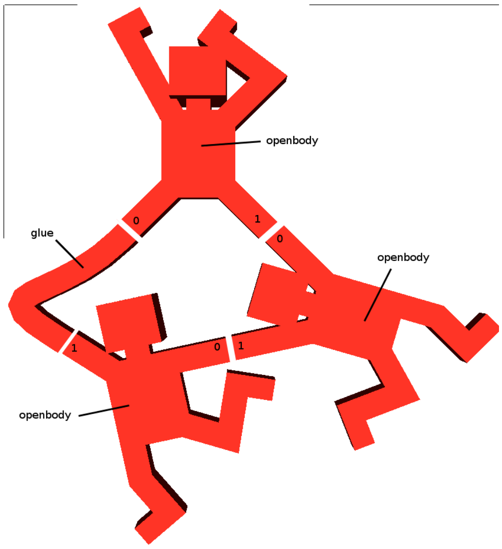
(00xxx,1x0xx,2xx0x,3xxx0) (4xxxx,5xxxx)

3.3 Bodies to figures

The third tier in our Keith Haring grammar contains rules for composing characters into figures. This tier demonstrates the creativity of Keith Haring with a large number of figures including couples, triplets, columns, bridges which can be combined together recursively.

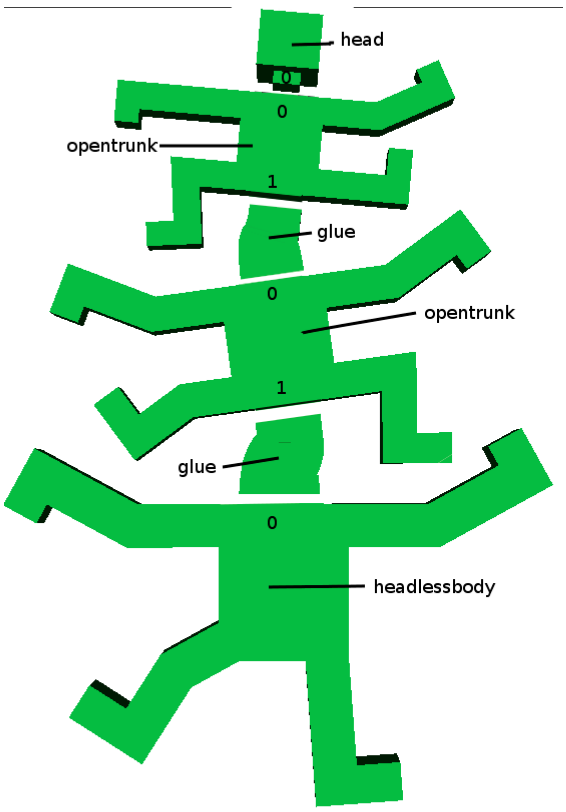


couple(x,y,c) -> openbody(x,y,c) openbody (01,10)



triplet(x,y,c) -> openbody(x,y,c) openbody openbody (01x,x01,1x0)

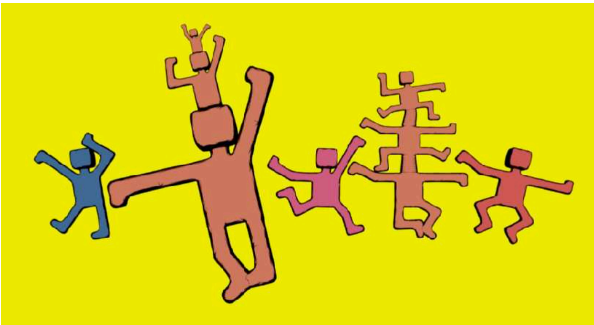
Chains are recursive structures built along the same lines ; loops are closed chains. Columns are another recursive structure characteristic of Keith Haring.



column(x,y,c,scale) -> headlessbody(x,y,c,scale)
*opentrunk(x,y+scale*0.14,c,scale*0.8)*
*opentrunk(x,y+scale*0.26,c,scale*0.64)*
head (01xx,x01x,xx00)

3.4 Figures to scenes

The fourth tier in our Keith Haring grammar contains rules for composing figures into 3D scenes. In our implementation, we only use planar figures and we place each figure by choosing the 3D location of the figure's origin and the 3D orientation of the figure's plane in camera coordinates.



4. Scene Generation

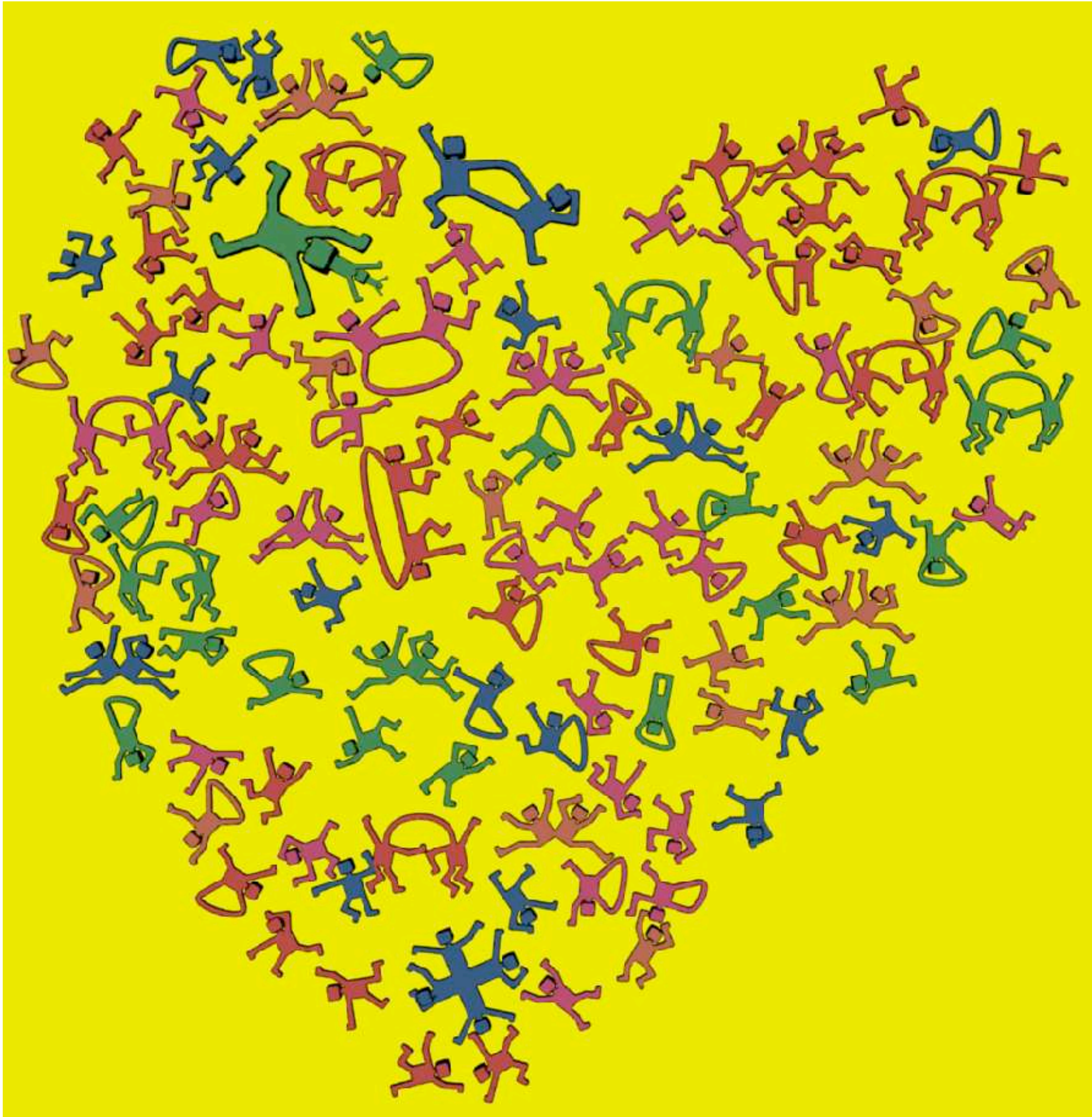
In this section, we describe how we use our grammar to randomly generate novel paintings and movies in the style of Keith Haring. Each novel scene is generated by randomly choosing rules that maximize the score of the panting with respect to a predetermined goal.

4.1 **Generative paintings**

We create novel paintings in the style of Keith Haring by generating a 3D scene and rendering it from a single viewpoint. In the following figure, we used a dart-throwing algorithm [10] to fill the planar shape of a heart with randomly generated figures without crossing or occlusion. In future work, we are planning to further extend the algorithm to also take into account other objective functions, including aesthetic or narrative goals, following the general approach proposed by Talton et al [3].

4.2 **Generative movies**

We can create movies in the style of Keith Haring by generating a 3D scene, then moving the camera and rendering the scene from the camera's viewpoint. We can also create animated movies in the style of Keith Haring by generating a 3D scene and changing it at every frame. This can be done in any different ways by inserting, deleting and moving figures relative to the scene ; by inserting, deleting and moving bodies relative to their parent figures ; or by inserting, deleting and moving body parts relative to their parent bodies. At this point, such transformations are chosen manually.



*5.*Conclusion

In this paper, we have presented stochastic plex grammars as a generic framework for representing the paintings and murals of Keith Haring and we have used that framework for generating random 3D scenes in the same style. Plex grammars appear to be ideally suited for the task. In future work, we would like to extend our approaches to other painting and sculpting styles. Another interesting avenue for future research is the generalization of stochastic plex grammars to *animation grammars* with rules describing how 3D shapes should be inserted, deleted and moved in the temporal domain to produce 3D movies.

6. References

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