アルゴリズムとデータ構造入門
2.2.4 図形言語
(Picture Language)

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12月3日・本日のメニュー

2.2.4 Picture Language（図形言語）
1. Square-limit
2. Square limit variation, 和田の解説
3. Space Padding Functions
4. Fractal (Self-Similarity)
   1. Hilbert curve
   2. Koch snowflake
   3. Sierpinski's Gasket
   4. Peano curve
5. Circle limit

今日は必修課題の説明です．

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補足: tustk2 の読込み時エラー

- JAKLD では関係ありません．
- エラーメッセージ

```
> (load 'zorro.scm)
Loading zorro.scm...
Error:  Compile error.
| is not a pair.
To print debugger commands, type :H.
Debug[1]>
```

- cygwin上のTUS:　改行が nl (¥n) でないといけない
  - od で改行が "cr nl" か"nl"だけかをチェック．

    od -a ファイル | more

  - "cr nl" ならば，"nl" に変換

    tr　'¥r'　'　'<　ファイル　>　新しいファイル名

    空白

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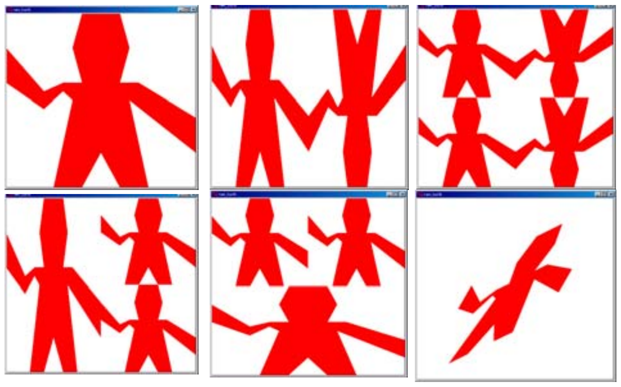
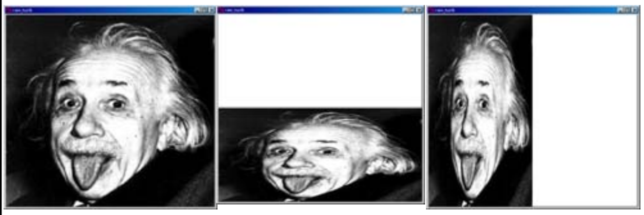
図形言語 Picture language とは



図形言語 Picture languageとは



図形言語での学習目標

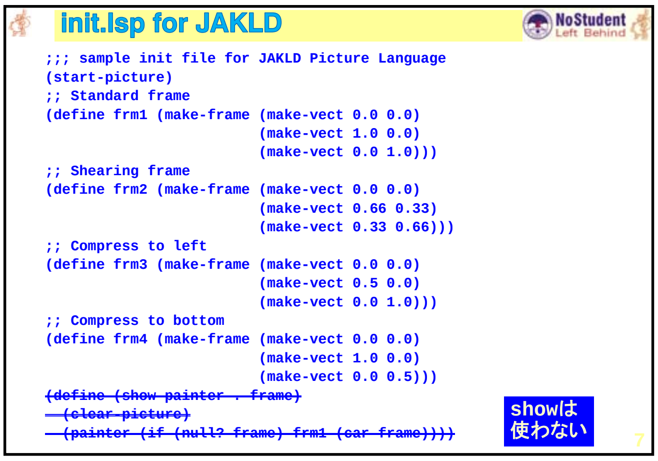
1． 図形操作の抽象化の修得

2． 実際に図形言語で，フラクタル，空間充填曲線が作成できる技術の修得

図形言語の使い(JAKLKD-READMEjp.txt)

```
% java –Xss1m –jar d:/java/scheme/jakld.tar        あるいは
% rlwrap java –Xss1m –jar d:/java/scheme/jakld.tar （コマンド行編集可）
> (load “init-jakld.lsp”)
     ここで，(start-picture) と show の定義， frm1, frm2, frm3 等の設定.
> (define orida (image->painter “orida-sensei.gif”))
> (orida frm1)      ; 標準フレーム用キャンバス frm1 で描画
> (clear-picture)   ; 描いた絵を白紙に戻す
> (orida frm2)      ; 歪んだキャンバス frm2 で描画
> (clear-picture)
> (load “wave-jakld.lsp”)  ; wave の定義を読み込む
> (wave frm1)         ; 人形を描画
> ((square-limit wave 4) frm1)    ; square-limit を描画
> (save-picture “wave.jpg”) ; 絵をjpegファイルへ出力
```

http://winnie.kuis.kyoto-u.ac.jp/~okuno/Lecture/13/IntroAlgDs/src/



init.lsp for JAKLD

```
;;; sample init file for JAKLD Picture Language
(start-picture)
;; Standard frame
(define frm1 (make-frame (make-vect 0.0 0.0)
                         (make-vect 1.0 0.0)
                         (make-vect 0.0 1.0)))
;; Shearing frame
(define frm2 (make-frame (make-vect 0.0 0.0)
                         (make-vect 0.66 0.33)
                         (make-vect 0.33 0.66)))
;; Compress to left
(define frm3 (make-frame (make-vect 0.0 0.0)
                         (make-vect 0.5 0.0)
                         (make-vect 0.0 1.0)))
;; Compress to bottom
(define frm4 (make-frame (make-vect 0.0 0.0)
                         (make-vect 1.0 0.0)
                         (make-vect 0.0 0.5)))
```

~~(define (show painter . frame)~~
~~(clear-picture)~~
~~(painter (if (null? frame) frm1 (car frame))))~~

showは
使わない

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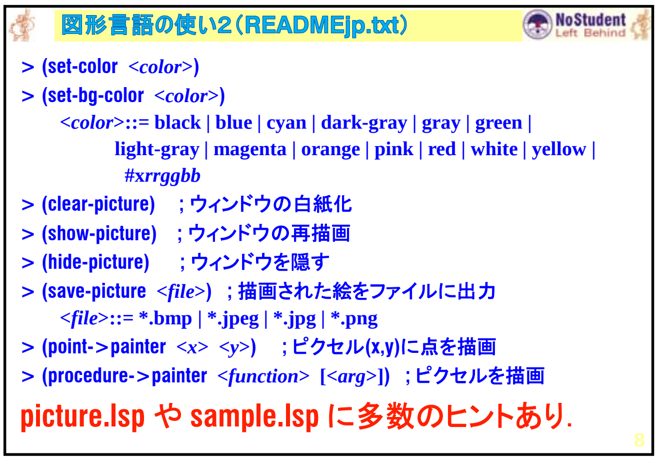

図形言語の使い2（READMEjp.txt）

> (set-color <*color*>)
> (set-bg-color <*color*>)
　<*color*>::= black | blue | cyan | dark-gray | gray | green |
　　light-gray | magenta | orange | pink | red | white | yellow |
　　#xrrggbb
> (clear-picture)　；ウィンドウの白紙化
> (show-picture)　；ウィンドウの再描画
> (hide-picture)　；ウィンドウを隠す
> (save-picture <*file*>)　；描画された絵をファイルに出力
　<*file*>::= *.bmp | *.jpeg | *.jpg | *.png
> (point->painter <*x*> <*y*>)　；ピクセル(x,y)に点を描画
> (procedure->painter <*function*> [<*arg*>])　；ピクセルを描画

picture.lsp や sample.lsp に多数のヒントあり.

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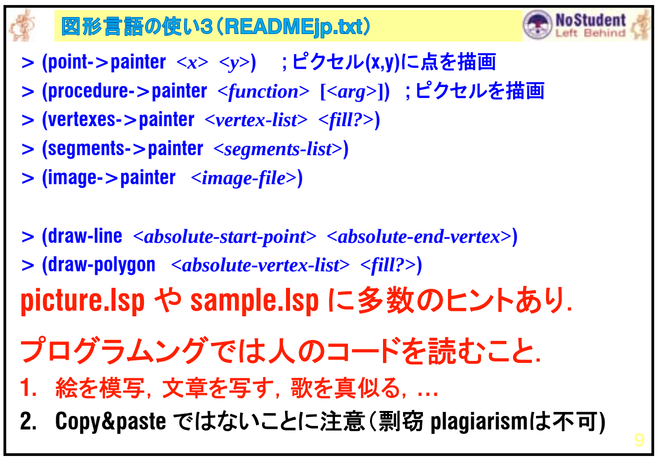

図形言語の使い3（READMEjp.txt）

> (point->painter <*x*> <*y*>)　；ピクセル(x,y)に点を描画
> (procedure->painter <*function*> [<*arg*>])　；ピクセルを描画
> (vertexes->painter <*vertex-list*> <*fill?*>)
> (segments->painter <*segments-list*>)
> (image->painter <*image-file*>)

> (draw-line <*absolute-start-point*> <*absolute-end-vertex*>)
> (draw-polygon <*absolute-vertex-list*> <*fill?*>)

picture.lsp や sample.lsp に多数のヒントあり.

プログラムングでは人のコードを読むこと.

1. 絵を模写，文章を写す，歌を真似る，…
2. Copy&paste ではないことに注意（剽窃 plagiarismは不可）

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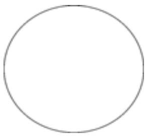
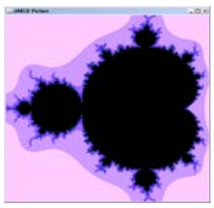
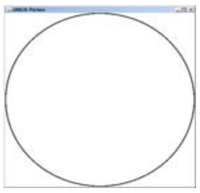
Procedure->painter in JAKLD

```
(define (circle z)
  (let ((r (+ (expt (- (car z) 0.5) 2)
              (expt (- (cdr z) 0.5) 2) )))
    (if (and (>= r 0.245) (< r 0.250))
        #x000000      ; black
      #xffffff ) ))   ; white

((procedure->painter circle) frm1)
```







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図形言語の使い(jakld)

```
% java -Xss1m -jar jakld.jar

> (load “picture.lsp”)
> (load “sample.lsp”)
> (start-picture)         ; picture windowが現れない場合実行
> (wave frm1)             ; 標準フレーム用キャンバスの作成
> (wave  frm2)
> (wave  frm3)
> (clear-picture)           ; windowを白紙に戻す
> (show-picture)           ; windowを表示
> (hide-picture)            ; windowを隠す
> (save-picture “filename.png”)  ; 絵をpngファイルへ出力
> ((right-split wave 4) frm1)
> (letterlambda frm1)
> ((right-split letterlambda 3))
> ((corner-split letterlambda)  frm2)
```

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図形言語の使い(README.tustk)

```
% tustk
> (load '/usr/local/lib/tustk/demos/picl)
> (load '/usr/local/lib/tustk/demos/picl-test)
> (make-canvas frm1)        ; 標準フレーム用キャンバスの作成
> ((square-limit wave 2)  frm1)
> (tk:update)                      ; 上記実行で描画されなかった場合や
                                          ; 再描画が必要なときに実行
> (clear)                              ; 描いた絵を消す
> ((square-limit wave 4) frm1)
> (clear)
> ((squash-inwards wave) frm1)
> (forget-canvas)               ; 現在のキャンバスを削除
> (make-canvas frm2)       ; 傾いたフレーム用キャンバスの作成
> ((square-limit wave 4) frm2)
> (output-canvas 'wave.ps)  ; 絵をPostScriptファイルへ出力
```

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図形言語の使い方（README.tustk）

- `*bg-color*`　　　　　　　　　; 背景色の定義
- `*line-color*`　　　　　　　　; 描画線の定義
- `(set! *bg-color* <色>)` ; 色の設定を変更
- <色> ; 色名(blue, "red", ...), RGB指定 ("#RRGGBB")
- 図形は painter で定義
  - 点　　　　　　`(make-vect` *<x-coordinate> <y-coordinate>*`)`
  - 線(セグメント) `(make-segment` *<from-point> <to-point>*`)`
  - 線画　　　　`(segments->painter` *<list-of-seguments>*`)`
  - 多角形(ポリゴン) `(vects->painter` *<list-of-points>*`)`
  - `(vects->painter` *<list-of-points> <smooth-or-not> <degree-of-smoothing> <filling-color>* `)`
  - `(pgm-file->painter` *<file-name>*`)` ; GIF/PPM/PGM

```
(define sicp (pgm-file->painter
                 "/usr/local/lib/tustk/demos/sicp.ppm"))
((square-limit sicp 4) frm1)
```

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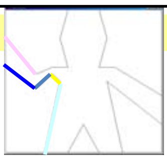
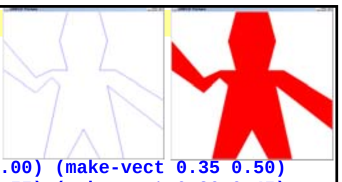
wave の定義



線を次々描いていく.

```
(define wave
  (segments->painter
    (list (make-segment (make-vect 0.25 0.00) (make-vect 0.35 0.50))
          (make-segment (make-vect 0.35 0.50) (make-vect 0.30 0.55))
          (make-segment (make-vect 0.30 0.55) (make-vect 0.20 0.45))
          (make-segment (make-vect 0.20 0.45) (make-vect 0.00 0.60))
          (make-segment (make-vect 0.00 0.80) (make-vect 0.20 0.55))
          (make-segment (make-vect 0.20 0.55) (make-vect 0.30 0.60))
          (make-segment (make-vect 0.30 0.60) (make-vect 0.40 0.60))
          (make-segment (make-vect 0.40 0.60) (make-vect 0.35 0.80))
          (make-segment (make-vect 0.35 0.80) (make-vect 0.40 1.00))
          (make-segment (make-vect 0.60 1.00) (make-vect 0.65 0.80))
          (make-segment (make-vect 0.65 0.80) (make-vect 0.60 0.60))
          (make-segment (make-vect 0.60 0.60) (make-vect 0.70 0.60))
          (make-segment (make-vect 0.70 0.60) (make-vect 1.00 0.40))
          (make-segment (make-vect 1.00 0.20) (make-vect 0.65 0.50))
          (make-segment (make-vect 0.65 0.50) (make-vect 0.75 0.00))
          (make-segment (make-vect 0.60 0.00) (make-vect 0.50 0.20))
          (make-segment (make-vect 0.50 0.20) (make-vect 0.40 0.00))
    )))
```

filled-wave の変形



JAKLD

```
(define filled-wave
  (vertexes->painter
    (list (make-vect 0.25 0.00) (make-vect 0.35 0.50)
          (make-vect 0.30 0.55) (make-vect 0.20 0.45)
          (make-vect 0.00 0.60) (make-vect 0.00 0.80)
          (make-vect 0.20 0.55) (make-vect 0.30 0.60)
          (make-vect 0.40 0.60) (make-vect 0.35 0.80)
          (make-vect 0.40 1.00) (make-vect 0.60 1.00)
          (make-vect 0.65 0.80) (make-vect 0.60 0.60)
          (make-vect 0.70 0.60) (make-vect 1.00 0.40)
          (make-vect 1.00 0.20) (make-vect 0.65 0.50)
          (make-vect 0.75 0.00) (make-vect 0.60 0.00)
          (make-vect 0.50 0.20) (make-vect 0.40 0.00) )
  #t ))
```

点をつないで，ポリゴンを作成し，色を塗る.

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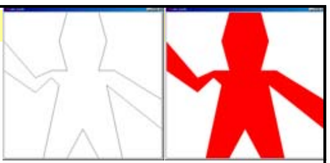
filled-wave の変形



Tustk

```
(define red-wave
  (vects->painter
    (list (make-vect 0.25 0.00) (make-vect 0.35 0.50)
          (make-vect 0.30 0.55) (make-vect 0.20 0.45)
          (make-vect 0.00 0.60) (make-vect 0.00 0.80)
          (make-vect 0.20 0.55) (make-vect 0.30 0.60)
          (make-vect 0.40 0.60) (make-vect 0.35 0.80)
          (make-vect 0.40 1.00) (make-vect 0.60 1.00)
          (make-vect 0.65 0.80) (make-vect 0.60 0.60)
          (make-vect 0.70 0.60) (make-vect 1.00 0.40)
          (make-vect 1.00 0.20) (make-vect 0.65 0.50)
          (make-vect 0.75 0.00) (make-vect 0.60 0.00)
          (make-vect 0.50 0.20) (make-vect 0.40 0.00) )    #f 0
  'red ))
```

点をつないで，ポリゴンを作成し，色を塗る．

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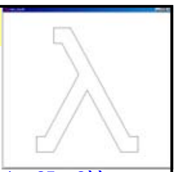
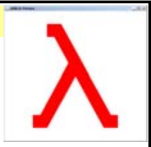
letterlambda の定義



```
(define letterlambda
  (segments->painter
   (list
     (make-segment (make-vect .45 .6) (make-vect .25 .2))
     (make-segment (make-vect .25 .2) (make-vect .2 .2))
     (make-segment (make-vect .2 .2) (make-vect .2 .1))
     (make-segment (make-vect .2 .1) (make-vect .3 .1))
     (make-segment (make-vect .3 .1) (make-vect .5 .5))
     (make-segment (make-vect .5 .5) (make-vect .7 .1))
     (make-segment (make-vect .7 .1) (make-vect .8 .1))
     (make-segment (make-vect .8 .1) (make-vect .8 .2))
     (make-segment (make-vect .8 .2) (make-vect .75 .2))
     (make-segment (make-vect .75 .2) (make-vect .4 .9))
     (make-segment (make-vect .4 .9) (make-vect .3 .9))
     (make-segment (make-vect .3 .9) (make-vect .3 .8))
     (make-segment (make-vect .3 .8) (make-vect .35 .8))
     (make-segment (make-vect .35 .8) (make-vect .45 .6))
    )))
```

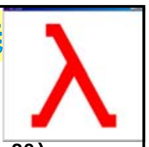
filled-letterlambda の定義



JAKLD

```
(define filled-letterlambda
  (vertexes->painter
    (list
      (make-vect .45 .60) (make-vect .25 .20)
      (make-vect .25 .20) (make-vect .20 .20)
      (make-vect .20 .20) (make-vect .20 .10)
      (make-vect .20 .10) (make-vect .30 .10)
      (make-vect .30 .10) (make-vect .50 .50)
      (make-vect .50 .50) (make-vect .70 .10)
      (make-vect .70 .10) (make-vect .80 .10)
      (make-vect .80 .10) (make-vect .80 .20)
      (make-vect .80 .20) (make-vect .75 .20)
      (make-vect .75 .20) (make-vect .40 .90)
      (make-vect .40 .90) (make-vect .30 .90)
      (make-vect .30 .90) (make-vect .30 .80)
      (make-vect .30 .80) (make-vect .35 .80)
      (make-vect .35 .80) (make-vect .45 .60) )
   #t ))
```

filled-letterlambda の定義



Tustk

```
(define red-letterlambda
  (vects->painter
    (list
      (make-vect .45 .60) (make-vect .25 .20)
      (make-vect .25 .20) (make-vect .20 .20)
      (make-vect .20 .20) (make-vect .20 .10)
      (make-vect .20 .10) (make-vect .30 .10)
      (make-vect .30 .10) (make-vect .50 .50)
      (make-vect .50 .50) (make-vect .70 .10)
      (make-vect .70 .10) (make-vect .80 .10)
      (make-vect .80 .10) (make-vect .80 .20)
      (make-vect .80 .20) (make-vect .75 .20)
      (make-vect .75 .20) (make-vect .40 .90)
      (make-vect .40 .90) (make-vect .30 .90)
      (make-vect .30 .90) (make-vect .30 .80)
      (make-vect .30 .80) (make-vect .35 .80)
      (make-vect .35 .80) (make-vect .45 .60) )
    #f 0 'red ))
```

NoStudent Left Behind

12月3日・本日のメニュー

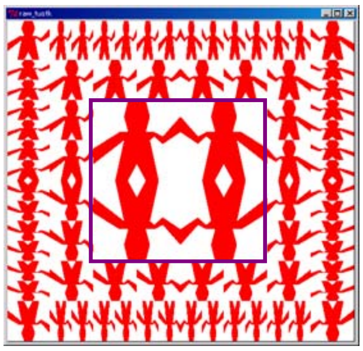
NoStudent Left Behind

2.2.4 Picture Language(図形言語)
1. Square-limit
2. Square limit variation, 和田の解説
3. Space Padding Functions
4. Fractal (Self-Similarity)
   1. Hilbert curve
   2. Koch snowflake
   3. Sierpinski's Gasket
   4. Peano curve
5. Circle limit

今日は必修課題の説明です.

square-limit n

NoStudent Left Behind



これから square-limit を作る.

左はレベル2

まず, 中央

flipped-pair(拡張版)

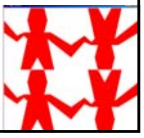
```
(define wave2
    (beside wave (flip-vert wave)) )
(define wave4 (below wave2 wave2))
(define (flipped-pairs painter)
    (let ((painter2
            (beside painter
              (flip-vert painter) )))
      (below painter2 painter2)))
```

こうすると

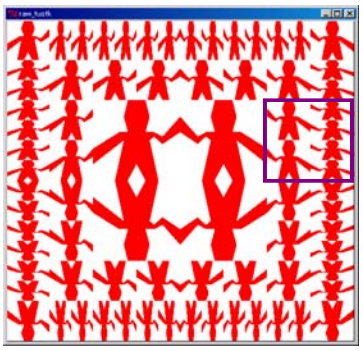
```
(define wave4
      (flipped-pairs wave))
```

wave2

wave4



square-limit n



これから
`square-limit`
を作る.

左はレベル2

次は，右側

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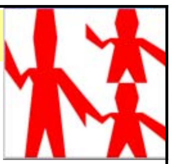
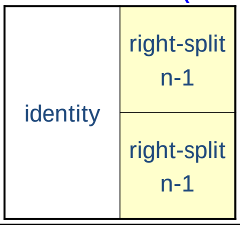
right-split n

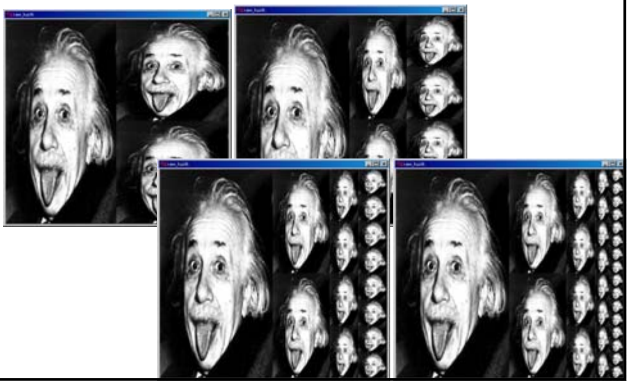


```
(define (right-split painter n)
   (if (= n 0)
       painter
       (let ((smaller
               (right-split painter (- n 1))) )
          (beside painter
                  (below smaller smaller) ))))
```

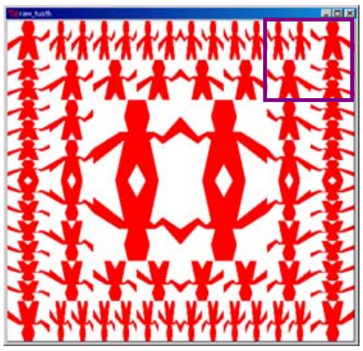


未定義の手続き
- (below bottom top)
- (beside left right)

right-split n　の動き



square-limit n



これから
square-limit
を作る.

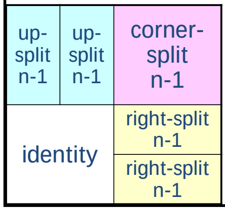
左はレベル2

今度は，角

27

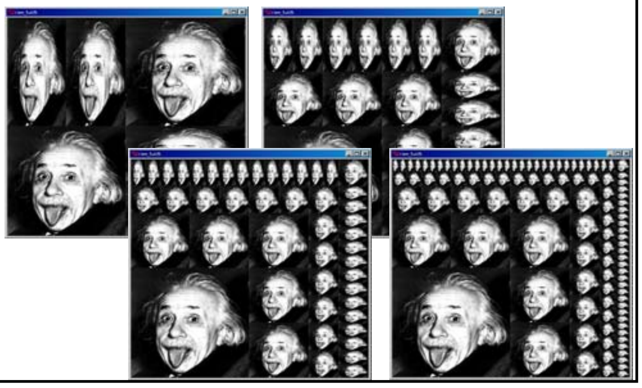
corner-split n

```
(define (corner-split painter n)
  (if (= n 0)
      painter
      (let ((up (up-split painter (- n 1)))
            (right (right-split painter (- n 1))) )
         (let ((top-left (beside up up))
               (bottom-right (below right right))
               (corner (corner-split painter (- n 1))) )
           (beside (below painter top-left)
                   (below bottom-right corner) )))))
```



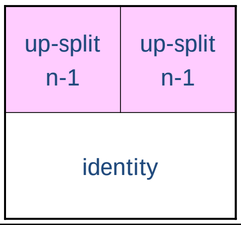
未定義の手続き
- (below bottom top)
- (beside left right)

corner-split n　の動き



Ex.2.44 up-split

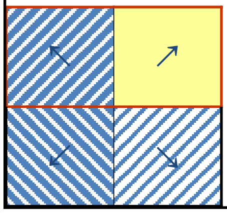
```
(define (up-split painter n)
   (if (= n 0)
       painter
       (let ((smaller
               (up-split painter (- n 1))) )
          (below painter
                 (beside smaller smaller) ))))
```



- 未定義の手続き
- (below bottom top)
- (beside left right)

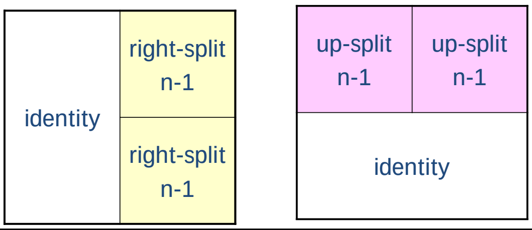
square-limit n

```
(define (square-limit painter n)
   (let ((quarter
           (corner-split painter n)) )
      (let ((half (beside
                    (flip-horiz quarter)
                    quarter )))
        (below (flip-vert half)
               half))))
```

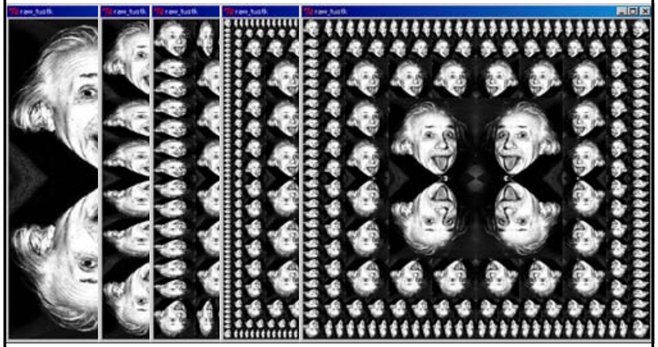


split群を抽象化

```
(define right-split (split beside below))
(define up-split (split below beside))
(define (split op1 op2)
   (op1 half (op2 quarter quarter)) ))
```



square-limit n　の動き



12月3日・本日のメニュー

2.2.4 Picture Language（図形言語）

1. Square-limit
2. Square limit variation, 和田の解説
3. Space Padding Functions
4. Fractal (Self-Similarity)
    1. Hilbert curve
    2. Koch snowflake
    3. Sierpinski's Gasket
    4. Peano curve
5. Circle limit

今日は必修課題
の説明です．

Square Limit をより抽象化

```
(define (square-of-four tl tr bl br)
   (lambda (painter)
      (let ((top (beside (tl painter)
                         (tr painter)) )
            (bottom (beside (bl painter)
                            (br painter) )))
         (below bottom top) )))
```

tl	tr
bl	br

未定義の手続き
- (below bottom top)
- (beside left right)

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flipped-pairsの別の定義

```
(define (flipped-pairs painter)
   (let ((combine4
           (square-of-four
                identity flip-vert
                identity flip-vert )))
      (combine4 painter) ))
```

ident ity	flip- vert
ident ity	flip- vert

未定義の手続き
- (below bottom top)
- (beside left right)

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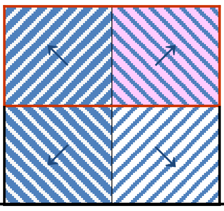
square-limit の別の定義

```
(define (square-limit painter n)
  (let ((combine4
          (square-of-four
              flip-horiz identity
              rotate180 flip-vert )))
     (combine4
        (corner-split painter n)) ))
```



flip- horiz	ident ity
rotat e180	flip- vert

41

TRON のベース ASAS on Lisp

Craig W. Reynolds (III): Computer animation with scripts and actors, *Computer Graphics*, Vo.16, No.3, pp.289-296.

```
(defop arch-fractalizer
   (param: arch-element top-color bot-color levels
           fractal-ratio height width leg-width)
   (local: (total-levels  levels)
           (offset-dist  (half (dif width leg-width)))
           (sub-tower-offset-1 (vector offset-dist 0 0))
           (sub-tower-offset-2 (mirror x-axis
                                   sub-tower-offset-1)))
   (arch-tower levels))

(defop arch-tower
   (param: levels)
   (if (zerop levels)
       (then nothing)
       (else (add-arch-level (arch-tower
                               (dif levels 1))))))
(defop add-arch-level
    (param: sub-tower)
    (grasp sub-tower
           (scale factal-ratio)
           (move (vector 0 height 0))
           (rotate 0.25 y-axis))
    (grasp arch-element
           (recolor (interp (quo levels total-levels)
                            bot-color top-color)))
    (subworld (group arch-element
              (move subtower-offset-1 sub-tower)
              (move subtower-offset-2 sub-tower)))))
```

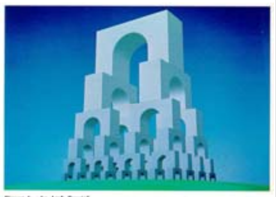


Figure 1:   An Arch Fractal

Copyright © 1982 by Walt Disney Productions and Information International, Inc.
Figure 3:   Solar Sailer Escape Sequence from TRON

TRON　Disney 映画 (1982, 2010)

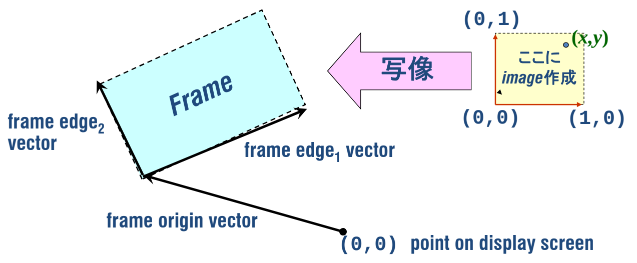
- A masterpiece of breakthrough CGI ingenuity, Disney celebrates the 20th anniversary of TRON, a dazzling film at the flashpoint of a continuing revolution in its genre. This special collector's edition showcases an epic adventure inside a brave new world where the action is measured in microseconds.
- When Flynn (Jeff Bridges) hacks the mainframe of his ex-employer to prove his work was stolen by another executive, he finds himself on a much bigger adventure. Beamed inside by a power-hungry master control program, he joins computer gladiators on a deadly game grid, complete with high-velocity "light cycles" and Tron (Bruce Boxleitner), a specialized security program. Together, they fight the ultimate battle with the MCP to decide the fate of both the electronic world and the real world!
- Tron Legacy (Dec. 18th, 2010)

12月3日・本日のメニュー

2.2.4 Picture Language（図形言語）
1. Square-limit
2. Square limit variation，和田の解説
3. Space Padding Functions
4. Fractal (Self-Similarity)
    1. Hilbert curve
    2. Koch snowflake
    3. Sierpinski's Gasket
    4. Peano curve
5. Circle limit

今日は必修課題の説明です．

Frame coordinate map



1. coordinate: unit squareに作成
2. frameに写像

$$\overrightarrow{\text{Origin}}(\text{Frame}) + x \cdot \overrightarrow{\text{Edge}_1}(\text{Frame}) + y \cdot \overrightarrow{\text{Edge}_2}(\text{Frame})$$

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Frames

```
(define (frame-coord-map frame)
  (lambda (v)
    (add-vect
      (origin-frame frame)
      (add-vect (scale-vect (xcor-vect v)
                    (edge1-frame frame) )
                (scale-vect (ycor-vect v)
                    (edge2-frame frame) )
      ))))
```

```
((frame-coord-map a-frame)
 (make-vect 0 0) )
```

の返す値: `(origin-frame a-frame)`

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Frames

```
(define (make-frame origin edge1 edge2)
  (list origin edge1 edge2) )

(define (make-frame origin edge1 edge2)
  (cons origin (cons edge1 edge2)) )
```

それぞれに対する選択子を書け.

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Painters

```
(define (segments->painter segment-list)
  (lambda (frame)
    (for-each
     (lambda (segment)
       (draw-line
        ((frame-coord-map frame)
         (start-segment segment) )
        ((frame-coord-map frame)
         (end-segment segment) )))
     segment-list )))
```

(foreach *<procedure>* *<list-of-items>*)

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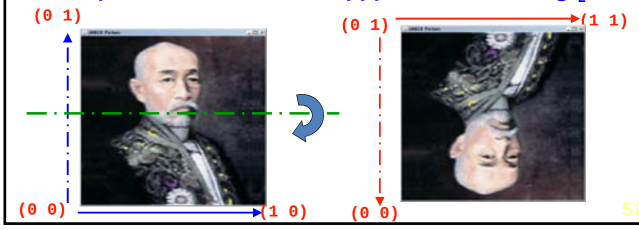
Transforming and combining painters

```
(define (transform-painter painter
                 origin corner1 corner2)
  (lambda (frame)
    (let ((m (frame-coord-map frame)))
      (let ((new-origin (m origin)))
        (painter
         (make-frame new-origin
            (sub-vect (m corner1)
                      new-origin)
            (sub-vect (m corner2)
                      new-origin)))))))
```

Transforming and combining painters

```
(define (flip-vert painter)
  (transform-painter
     painter
     (make-vect 0.0 1.0)  ; new origin
     (make-vect 1.0 1.0)  ; new end of edge1
     (make-vect 0.0 0.0))) ; new end of edge2
```



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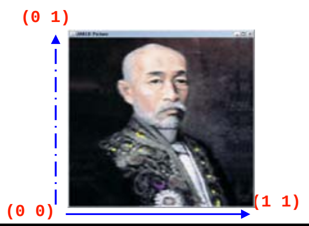
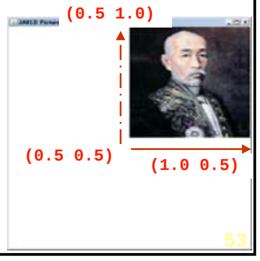
Transforming and combining painters

```
(define (shrink-to-upper-right painter)
  (transform-painter
      painter
     (make-vect 0.5 0.5)
     (make-vect 1.0 0.5)
     (make-vect 0.5 1.0) ))
```





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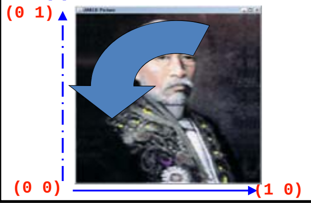
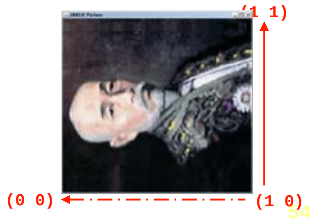
Transforming and combining painters

```
(define (rotate90 painter)
  (transform-painter
    painter
    (make-vect 1.0 0.0)
    (make-vect 1.0 1.0)
    (make-vect 0.0 0.0)
  ))
```





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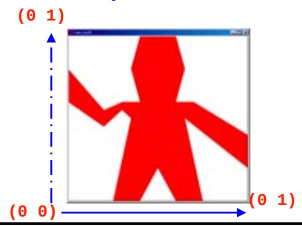
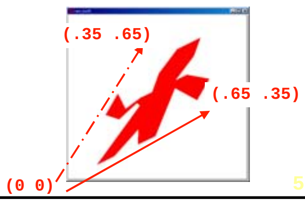
Transforming and combining painters

```
 (define (squash-inwards painter)
   (transform-painter
       painter
       (make-vect 0.0 0.0)
       (make-vect 0.65 0.35)
       (make-vect 0.35 0.65)))
```





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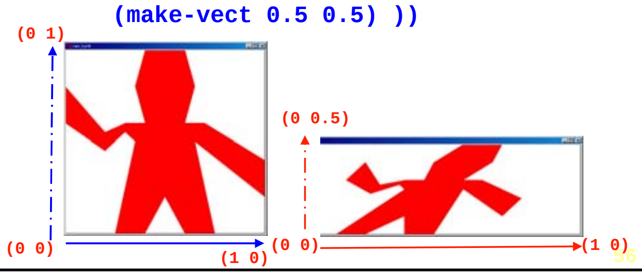
傾いたフレーム

```
(define frm2
    (make-frame
      (make-vect 0 0)
      (make-vect 1.0 0)
      (make-vect 0.5 0.5) ))
```



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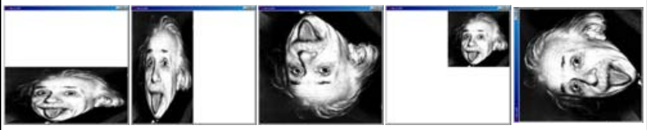
transform-painter（まとめ）



```
(define (half-vert painter)
  (transform-painter
     painter
     (make-vect 0.0 0.0)
     (make-vect 1.0 0.0)
     (make-vect 0.0 0.5)) )

(define (half-horiz painter)
  (transform-painter
     painter
     (make-vect 0.0 0.0)
     (make-vect 0.5 0.0)
     (make-vect 0.0 1.0)) )
```

```
(define (flip-vert painter)
  (transform-painter
     painter
     (make-vect 0.0 1.0
     (make-vect 1.0 1.0)
     (make-vect 0.0 0.0)) )
```

```
(define (shrink-to-upper-right painter)
    (transform-painter
      painter
       (make-vect 0.5 0.5)
       (make-vect 1.0 0.5)
       (make-vect 0.5 1.0)) )
```

```
(define (rotate90 painter)
  (transform-painter painter (make-vect 1.0 0.0)
                             (make-vect 1.0 1.0)
                             (make-vect 0.0 0.0) ))
```

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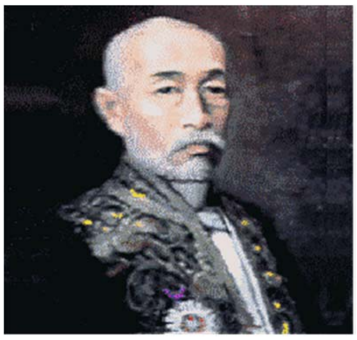
Gifに出力，animated GIF作成



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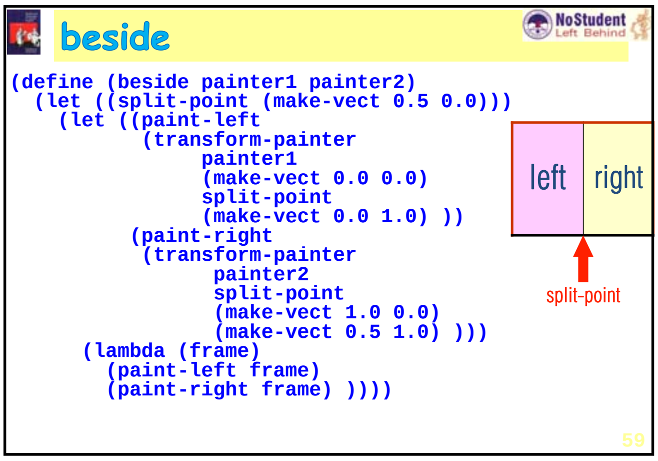

beside

```
(define (beside painter1 painter2)
  (let ((split-point (make-vect 0.5 0.0)))
    (let ((paint-left
           (transform-painter
                painter1
                (make-vect 0.0 0.0)
                split-point
                (make-vect 0.0 1.0) ))
          (paint-right
           (transform-painter
                 painter2
                 split-point
                 (make-vect 1.0 0.0)
                 (make-vect 0.5 1.0) )))
      (lambda (frame)
        (paint-left frame)
        (paint-right frame) ))))
```

left
right
split-point

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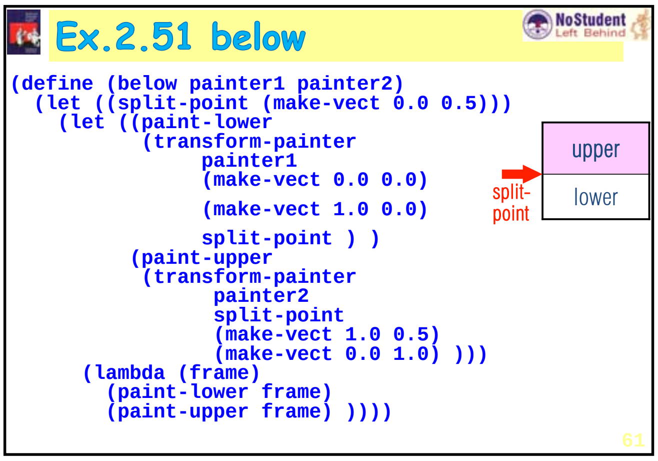

Ex.2.51 below

```
(define (below painter1 painter2)
  (let ((split-point (make-vect 0.0 0.5)))
    (let ((paint-lower
           (transform-painter
                painter1
                (make-vect 0.0 0.0)

                (make-vect 1.0 0.0)

                split-point ) )
          (paint-upper
           (transform-painter
                 painter2
                 split-point
                 (make-vect 1.0 0.5)
                 (make-vect 0.0 1.0) )))
      (lambda (frame)
        (paint-lower frame)
        (paint-upper frame) ))))
```

upper
split-point
lower

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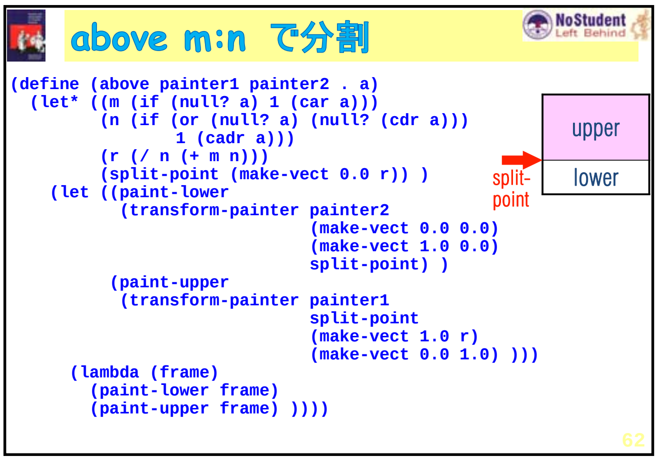

above m:n で分割

```
(define (above painter1 painter2 . a)
  (let* ((m (if (null? a) 1 (car a)))
         (n (if (or (null? a) (null? (cdr a)))
                1 (cadr a)))
         (r (/ n (+ m n)))
         (split-point (make-vect 0.0 r)) )
    (let ((paint-lower
           (transform-painter painter2
                              (make-vect 0.0 0.0)
                              (make-vect 1.0 0.0)
                              split-point) )
          (paint-upper
           (transform-painter painter1
                              split-point
                              (make-vect 1.0 r)
                              (make-vect 0.0 1.0) )))
      (lambda (frame)
        (paint-lower frame)
        (paint-upper frame) ))))
```

upper
split-point
lower

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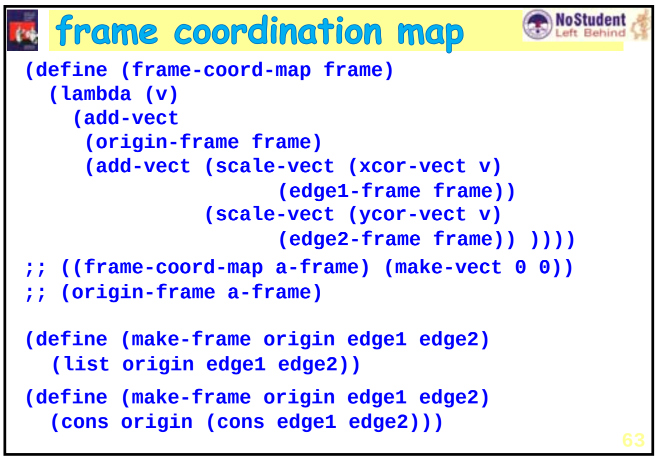

frame coordination map

```
(define (frame-coord-map frame)
  (lambda (v)
    (add-vect
     (origin-frame frame)
     (add-vect (scale-vect (xcor-vect v)
                           (edge1-frame frame))
               (scale-vect (ycor-vect v)
                           (edge2-frame frame)) ))))
;; ((frame-coord-map a-frame) (make-vect 0 0))
;; (origin-frame a-frame)

(define (make-frame origin edge1 edge2)
  (list origin edge1 edge2))
(define (make-frame origin edge1 edge2)
  (cons origin (cons edge1 edge2)))
```

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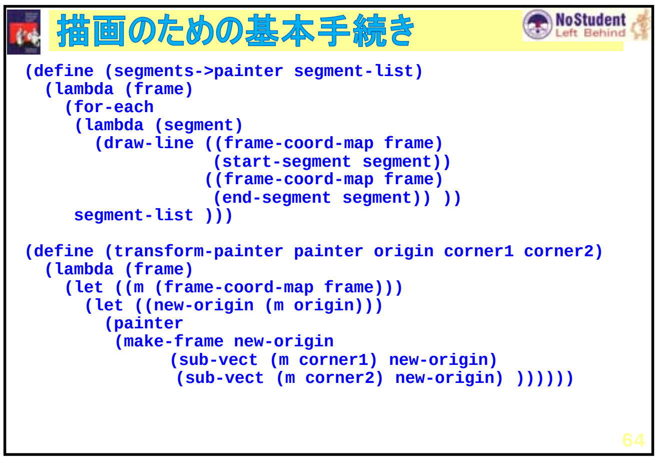

描画のための基本手続き

```
(define (segments->painter segment-list)
  (lambda (frame)
    (for-each
     (lambda (segment)
       (draw-line ((frame-coord-map frame)
                   (start-segment segment))
                  ((frame-coord-map frame)
                   (end-segment segment)) ))
     segment-list )))

(define (transform-painter painter origin corner1 corner2)
  (lambda (frame)
    (let ((m (frame-coord-map frame)))
      (let ((new-origin (m origin)))
        (painter
         (make-frame new-origin
               (sub-vect (m corner1) new-origin)
                (sub-vect (m corner2) new-origin) )))))))
```

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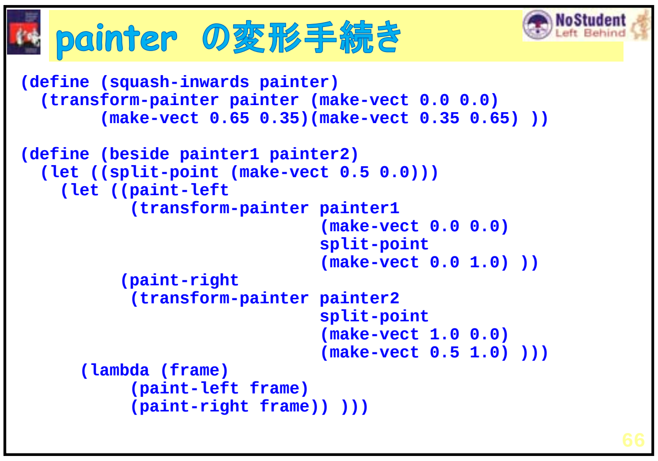

painter の変形手続き

```
(define (squash-inwards painter)
  (transform-painter painter (make-vect 0.0 0.0)
        (make-vect 0.65 0.35)(make-vect 0.35 0.65) ))

(define (beside painter1 painter2)
  (let ((split-point (make-vect 0.5 0.0)))
    (let ((paint-left
           (transform-painter painter1
                              (make-vect 0.0 0.0)
                              split-point
                              (make-vect 0.0 1.0) ))
          (paint-right
           (transform-painter painter2
                              split-point
                              (make-vect 1.0 0.0)
                              (make-vect 0.5 1.0) )))
      (lambda (frame)
           (paint-left frame)
           (paint-right frame)) )))
```

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Stratified Design (成層設計)

図形言語のような設計法

- 各レベルでの部品化
  - Square-limit
  - below, beside
  - transform-painter
  - draw-line

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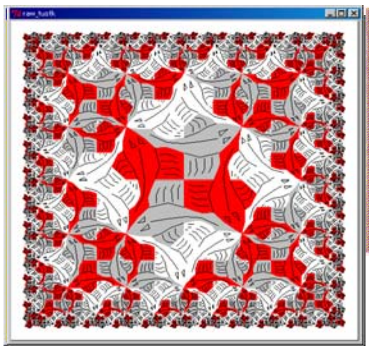
Escher's square-limit



■和田：関数画家、『情報処理』、Vol.46, No.10 (2005) 1163-1171

■http://www.ecs.soton.ac.uk/~ph/papers/funcgeo2.pdf

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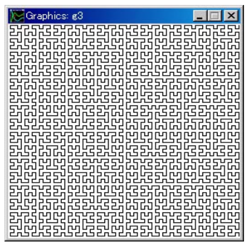
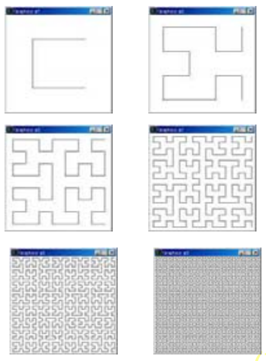
Hilbert curve の作成方法



(hilbert 5)



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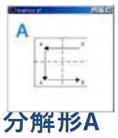
Hilbert curve の作成方法

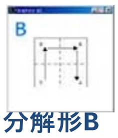
4つの基本形
1．基本形A： D⇒A⇒A⇒B
2．基本形B： C⇒B⇒B⇒A
3．基本形C： B⇒C⇒C⇒D
4．基本形D： A⇒D⇒D⇒C

基本形A



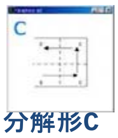
分解形A

基本形B



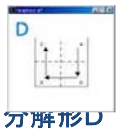
分解形B

基本形C



分解形C

基本形D



分解形D

Hilbert curve の手続き

1．各基本形に対して，レベル0ならコ型を書くための頂点のリストを求める．
2．さもなければ，分解形を再帰的に呼び出し，頂点を求める．
3．求まった頂点リストから segment を求め

vectors->segment と

segments->painterを使って作成する．

(vectors->segment *<list of vectors>*)

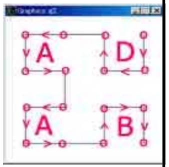
(segments->painter *<list of segments>*)

vertexes->painter を使用してはいけない．

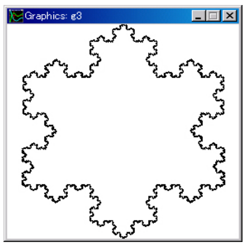
Hilbert curve の手続き

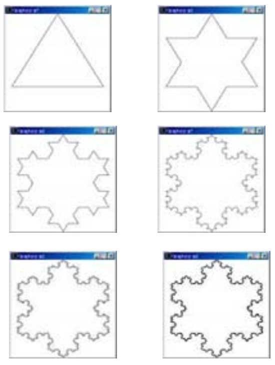
```
(define (hilbert-a p0 q0 p1 q1 i)
  (let ((xs (/ (+ (* 3.0 p0) p1) 4.0))
        (ys (/ (+ (* 3.0 q0) q1) 4.0))
        (xm (/ (+ p0 p1) 2.0))
        (ym (/ (+ q0 q1) 2.0))
        (xl (/ (+ p0 (* 3.0 p1)) 4.0))
        (yl (/ (+ q0 (* 3.0 q1)) 4.0)) )
    (if (= i 0)
        (list (make-vect pl ql) (make-vect xs ql)
              (make-vect xs ys) (make-vect xl ys) )
        (append (hilbert-d xm ym p1 q1 (- i 1))
                (hilbert-a p0 ym xm q1 (- i 1))
                (hilbert-a p0 q0 xm ym (- i 1))
                (hilbert-b xm q0 p1 ym (- i 1)) ))))

(define (hilbert n)
  (segments->painter
    (vectors->segments (hilbert-a 0.0 0.0 1.0 1.0 n))) )
```



Koch snowflake の作成方法

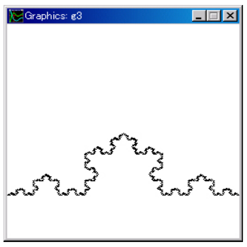


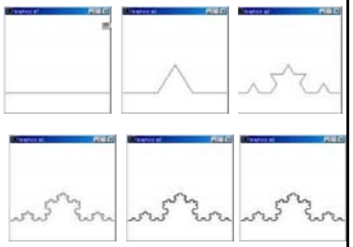


(koch 5)

Koch snowflake の作成方法

線分の分解





Koch snowflake の手続き

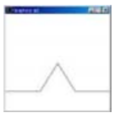
1. 各線分に対して，レベル0なら，三角形の頂点リストを求める.
2. さもなければ，分解形を再帰的に呼び出し，頂点を求める.
3. 【JAKLD】求まった頂点リストから 折れ線を　vertexes->painter を使用して作成.【Tustk】求まった頂点リストからsegment を求め vectors->segment と

   segments->painterを使って作成する.

(vectors->segment <*list of vectors*>)
(segments->painter <*list of segments*>)

Koch snowflake（続）

```
(define (koch-line p0 q0 p1 q1 r i)
  (if (= i 0)
      (list (make-vect p0 q0) (make-vect p1 q1))
      (let* ((r1 (/ r 3.0))
             (x3 (/ (- p1 p0) 3.0))
             (y3 (/ (- q1 q0) 3.0))
             (xs (/ (+ (* 2.0 p0) p1) 3.0))
             (ys (/ (+ (* 2.0 q0) q1) 3.0))
             (xl (/ (+ p0 (* 2.0 p1)) 3.0))
             (yl (/ (+ q0 (* 2.0 q1)) 3.0))
             (xm (+ (* 0.5 x3) (* 0.866 y3) xs))
             (ym (+ (* 0.5 y3) (* -0.866 x3) ys)) )
          (append (koch-line p0 q0 xs ys r1 (- i 1))
                  (koch-line xs ys xm ym r1 (- i 1))
                  (koch-line xm ym xl yl r1 (- i 1))
                  (koch-line xl yl p1 q1 r1 (- i 1))
          ))))
```



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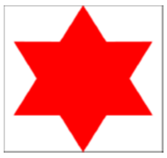
Koch snowflake の手続き(続)

```
(define (koch n)
  (let* ((h (/ 0.75 0.86))
         (p0 (/ (- 1.0 h) 2))
         (p1 (- 1.0 p0)) )
    (segments->painter
      (vectors->segments
        (append
          (koch-line p0 0.25 p1 0.25 1 n)
          (koch-line p1 0.25 0.5 1.0 1 n)
          (koch-line 0.5 1.0 p0 0.25 1 n)
        )))))
```



let* は let と違い、変数値対を順番に評価

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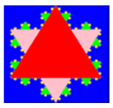
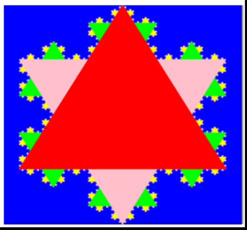
色つきKoch curve の手続き

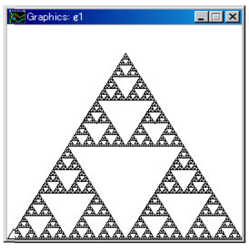
```
(define (koch-fill n . args)
  (let* ((h (/ 0.75 0.86))
         (p0 (/ (- 1.0 h) 2))
         (p1 (- 1.0 p0))
         (color (if (null? args) 'red (car args))) )
    (vects->painter
      (append (koch-line p0 0.25 p1 0.25 1 n)
        (koch-line p1 0.25 0.5 1.0 1 n)
        (koch-line 0.5 1.0 p0 0.25 1 n))
      #f 0 color )))

(define (fun-koch x)
   ((koch-fill 5 'pink) x)
   ((koch-fill 4 'while) x)
   ((koch-fill 3 'yellow) x)
   ((koch-fill 2 'green) x)
   ((koch-fill 1 'pink) x)
   ((koch-fill 0 'red) x)
  )
```

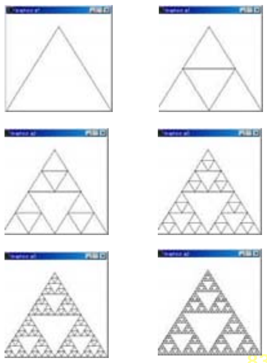




Sierpinski's Gasket の作成法



(sierpiski 6)



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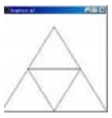
Sierpinski's Gasket の手続き

```
(define (gasket p0 q0 p1 q1 i)
  (let* ((xm (/ (+ p0 p1) 2.0))
         (ym (+ (* (- p1 p0) 0.866) q0))
         (xs (/ (+ (* 3.0 p0) p1) 4.0))
         (xl (/ (+ (* 3.0 p1) p0) 4.0))
         (ys (+ (* (- p1 p0) 0.433) q0)) )
    (if (= i 0)
       (list (make-vect p0 q0) (make-vect p1 q1)
             (make-vect (/ (+ p0 p1) 2.0) ym)
             (make-vect p0 q0) )
       (append (gasket p0 q0 xm q0 (- i 1))
               (gasket xm q0 p1 q0 (- i 1))
               (list (make-vect p0 q0))
               (gasket xs ys xl ys (- i 1))
               (list (make-vect p0 q0) )))))

(define (sierpenski n)
  (segments->painter
    (vectors->segments (gasket 0.0 0.0 1.0 0.0 n)) ))
```



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色つきSierpinski's Gasket

```
(define (gasket-fill p0 q0 p1 q1 i color)
  (let* ((xm (/ (+ p0 p1) 2.0))
         (ym (+ (* (- p1 p0) 0.866) q0))
         (xs (/ (+ (* 3.0 p0) p1) 4.0))
         (xl (/ (+ (* 3.0 p1) p0) 4.0))
         (ys (+ (* (- p1 p0) 0.433) q0)) )
    (if (= i 0)
       (list (vects->painter
               (list (make-vect p0 q0)
                     (make-vect p1 q1)
                     (make-vect xm ym) )
               #f 0 color))
       (append (gasket-fill p0 q0 xm q0 (- i 1) color)
               (gasket-fill xm q0 p1 q0 (- i 1) color)
               (gasket-fill xs ys xl ys (- i 1) color) ))))

(define (sierpenski-fill n . args)
  (let ((color (if (null? args) 'red (car args))))
    (do ((i (gasket-fill 0.0 0.0 1.0 0.0 n color) (cdr i)))
       ((null? i))
      (i frm1) )))
```

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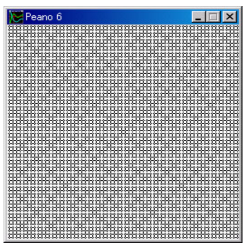
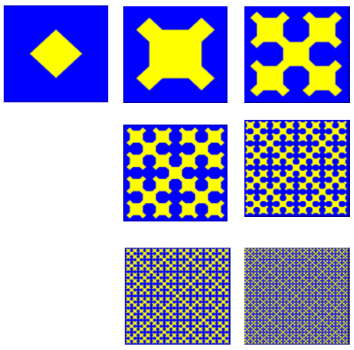
Peano Curve の作成方法





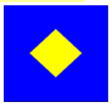
(peano 6)

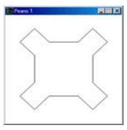
Peano Curve の手続き

```
(define (peano-a p0 q0 p1 q1 i)
  (append (peano-a-1 p0 q0 p1 q1 i)
    (peano-a-2 p0 q0 p1 q1 i) ))

(define (peano-a-1 p0 q0 p1 q1 i)
  (let ((xs (/ (+ (* 3.0 p0) p1) 4.0)) (ys (/ (+ (* 3.0 q0) q1) 4.0))
        (xm (/ (+ p0 p1) 2.0)) (ym (/ (+ q0 q1) 2.0))
        (xl (/ (+ p0 (* 3.0 p1)) 4.0)) (yl (/ (+ q0 (* 3.0 q1)) 4.0)) )
    (if (= i 0)
        (list (make-vect xm yl) (make-vect xs ym))
        (append (peano-a-1 xm ym p1 q1 (- i 1))
                (peano-d-1 p0 ym xm q1 (- i 1))
                (peano-d-2 p0 ym xm q1 (- i 1))
                (peano-a-1 p0 q0 xm ym (- i 1)) ))))

(define (peano-a-2 p0 q0 p1 q1 i)
  (let ((xs (/ (+ (* 3.0 p0) p1) 4.0)) (ys (/ (+ (* 3.0 q0) q1) 4.0))
        (xm (/ (+ p0 p1) 2.0)) (ym (/ (+ q0 q1) 2.0))
        (xl (/ (+ p0 (* 3.0 p1)) 4.0)) (yl (/ (+ q0 (* 3.0 q1)) 4.0)) )
    (if (= i 0)
        (list (make-vect xm ys) (make-vect xl ym))
        (append (peano-a-2 p0 q0 xm ym (- i 1))
                (peano-b-1 xm q0 p1 ym (- i 1))
                (peano-b-2 xm q0 p1 ym (- i 1))
                (peano-a-2 xm ym p1 q1 (- i 1)) ))))
```





図形言語に複素数を導入

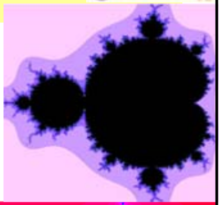
$$z_{n+1} = z_n^{\ 2} + C$$
$$z_0 = C$$

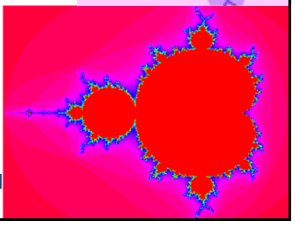
が収束する点 $C = (x, y)$

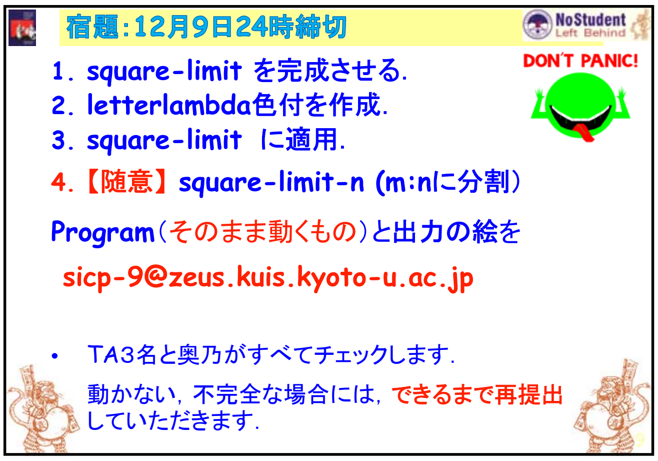
Mandelbrot Set

procedure->painer 使用

http://mathworld.wolfram.com/MandelbrotSet.html







宿題：12月9日24時締切

1. square-limit を完成させる．
2. letterlambda色付を作成．
3. square-limit に適用．
4. 【随意】square-limit-n (m:nに分割)

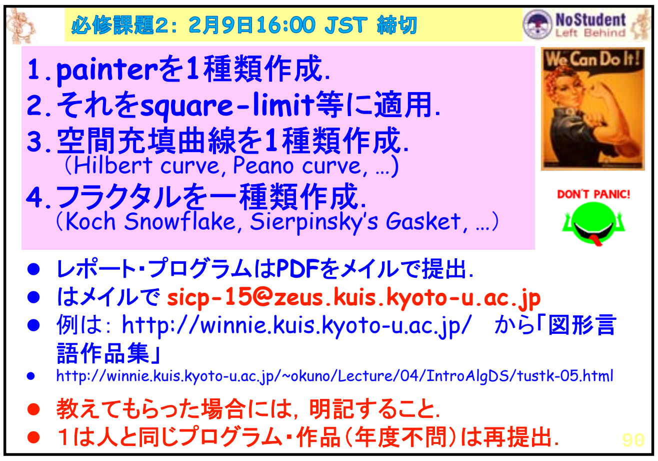
Program（そのまま動くもの）と出力の絵を

sicp-9@zeus.kuis.kyoto-u.ac.jp

- TA3名と奥乃がすべてチェックします．

  動かない，不完全な場合には，できるまで再提出していただきます．

NoStudent Left Behind
DON'T PANIC!



必修課題2: 2月9日16:00 JST 締切

1. painterを1種類作成．
2. それをsquare-limit等に適用．
3. 空間充填曲線を1種類作成．
   （Hilbert curve, Peano curve, …）
4. フラクタルを一種類作成．
   （Koch Snowflake, Sierpinsky's Gasket, …）

- レポート・プログラムはPDFをメイルで提出．
- はメイルで sicp-15@zeus.kuis.kyoto-u.ac.jp
- 例は：http://winnie.kuis.kyoto-u.ac.jp/　から「図形言語作品集」
- http://winnie.kuis.kyoto-u.ac.jp/~okuno/Lecture/04/IntroAlgDS/tustk-05.html
- 教えてもらった場合には，明記すること．
- 1は人と同じプログラム・作品（年度不問）は再提出．

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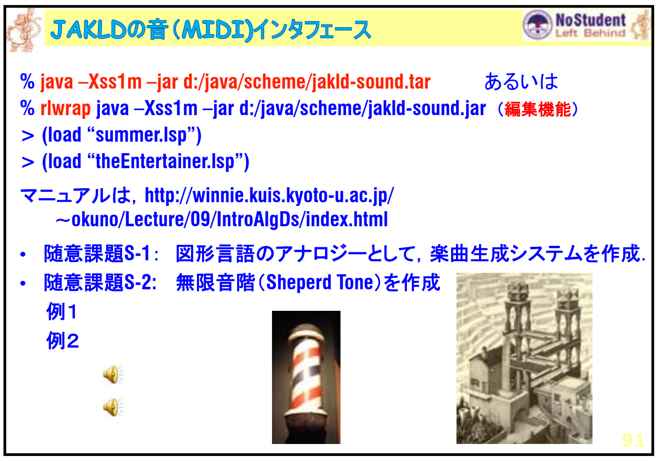
NoStudent Left Behind
We Can Do It!
DON'T PANIC!



JAKLDの音（MIDI）インタフェース

```
% java –Xss1m –jar d:/java/scheme/jakld-sound.tar　　あるいは
% rlwrap java –Xss1m –jar d:/java/scheme/jakld-sound.jar （編集機能）
> (load "summer.lsp")
> (load "theEntertainer.lsp")
```

マニュアルは，http://winnie.kuis.kyoto-u.ac.jp/
　~okuno/Lecture/09/IntroAlgDs/index.html

- 随意課題S-1：図形言語のアナロジーとして，楽曲生成システムを作成．
- 随意課題S-2：無限音階（Sheperd Tone）を作成
  例1
  例2

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NoStudent Left Behind

Scot Joplin The Entertainer by 大塚君

```
; ===========================
; initialization
; ===========================
(define synth (get-synthesizer))
(define seqr (get-sequencer))
(set-receiver seqr synth)

(define seq (sequence 384))
(define trk0 (create-track seq)) ; track 0 (high part)
(define trk1 (create-track seq)) ; track 1 (right hand)
(define trk2 (create-track seq)) ; track 2 (left hand (bass))

; ============================
; write the score here
; =============================
(set-mml trk0
 "C0@0l16k60t75"
;;Intro
 "o6 dec<a^16bg8"
 "r2r2r4"
 "o5 q110d0g8 r8^8^16 r8"
;;Melody
 "t70o6 r2 r4^16 cdd+ecde^16<b>d8c4^8"
)

(set-mml trk1
 "C1@0l16k60t75"
;;Intro
 "o5 dec<a^16bg8 >dec<a^16bg8 dec<a^16baa-g8r8"
 ">q110g0b8 r8^8^16"
;;Melody
 "t70o4 dd+e>c8<e>c8<e>c^4^16"
 "o5 c0e d0f d+0f+ e0g c0e d0f e0g^16 <b0>d d0f8 c0e4^8"
 )

(set-mml trk2
 "C2@0l16k60t75"
;;Intro
 "o4 r2 dec<a^16bg8 dec<a^16baa-g8r8"
 "q110 g0<g8 r8^8^16"
;;Melody
 "t70o3l8 g0b <c >e0g0>c <<g0>g g0b-0>c <<f0>f a0>c"
 "<<e0>e g0>c <<g >e0g0>c <<g >f0g0b c e0g0>c <<c0>e0g0c8.."
)
```

```
; ==============================
; set the sequence and play
; ==============================
(set-sequence seqr seq)
(start-sequencer seqr) ; run the sequencer

; ==============================
; close the devices
; ==============================
(close-device synth)
(close-device seqr)
```

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図形言語の作品

- Gallery に掲載
- http://winnie.kuis.kyoto-u.ac.jp/
  から「図形言語作品集」をクリック
- 面白いものは講義等で使わせてもらいます

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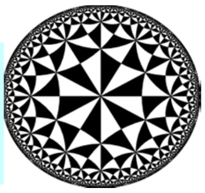
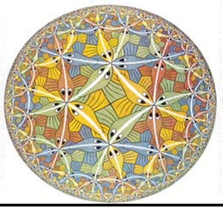
随意課題3：2月15日午後5時締切

circle-limit を作成せよ。

プログラムはメイルで
　okuno@i.kyoto-u.ac.jp





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Escher's Square-Limit（1）

H.G. Okuno　　M.C. Escher

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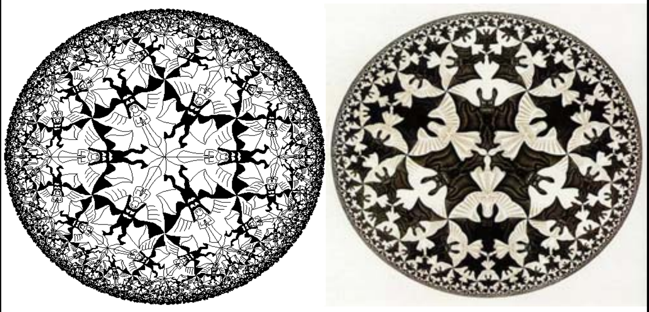
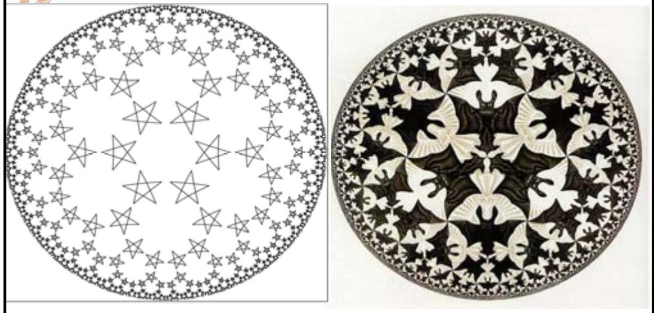
EscherのCircle-limit IV (1960)

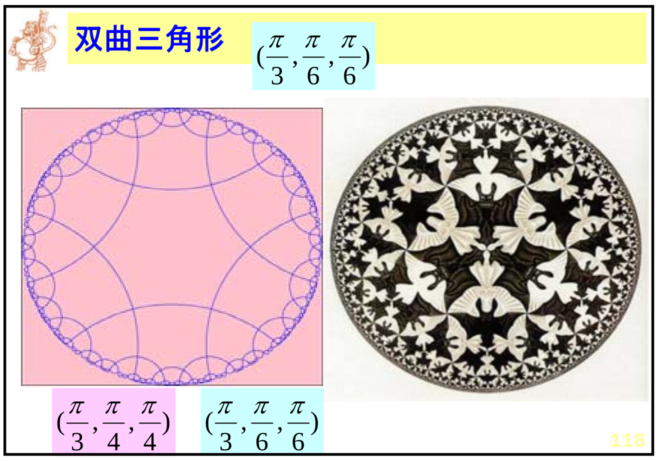


Y.Y. Huang
（2008年度入学）　　M.C. Escher

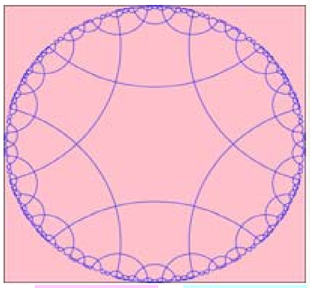
EscherのCircle-limit IV (1960)



前田一貴
（2005年度入学，数理　学振（DC1））　　M.C. Escher



双曲三角形 $(\frac{\pi}{3},\frac{\pi}{6},\frac{\pi}{6})$



$(\frac{\pi}{3},\frac{\pi}{4},\frac{\pi}{4})$ $(\frac{\pi}{3},\frac{\pi}{6},\frac{\pi}{6})$

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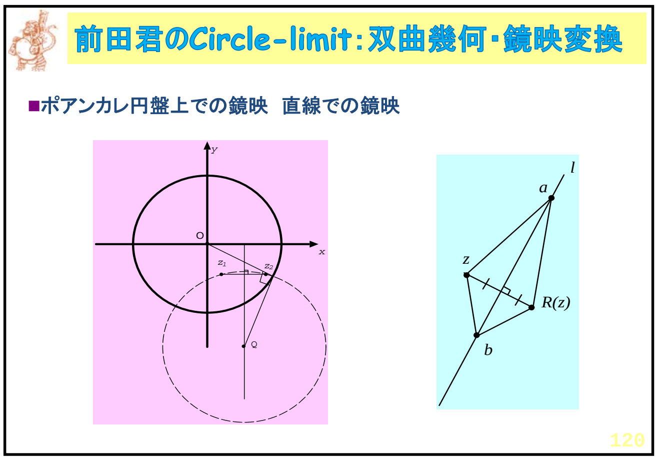
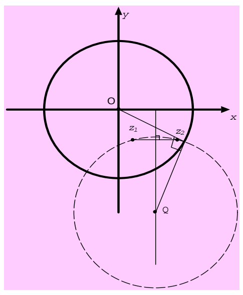
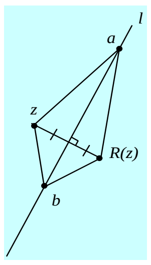


前田君のCircle-limit:双曲幾何・鏡映変換

■ポアンカレ円盤上での鏡映 直線での鏡映





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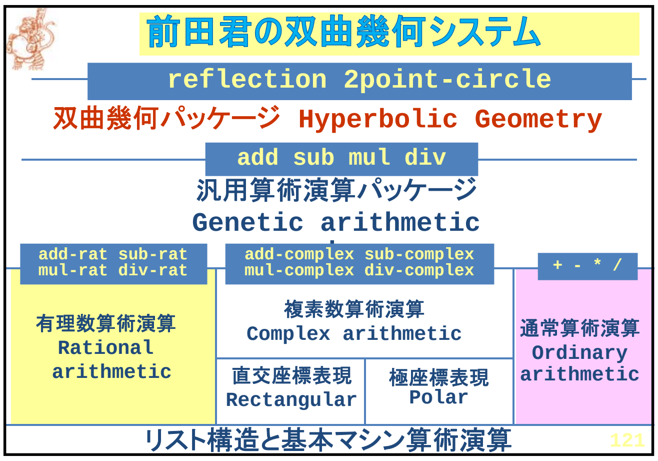

前田君の双曲幾何システム

reflection 2point-circle

双曲幾何パッケージ Hyperbolic Geometry

add sub mul div

汎用算術演算パッケージ
Genetic arithmetic

add-rat sub-rat
mul-rat div-rat

add-complex sub-complex
mul-complex div-complex

+ - * /

有理数算術演算
Rational arithmetic

複素数算術演算
Complex arithmetic

直交座標表現
Rectangular

極座標表現
Polar

通常算術演算
Ordinary arithmetic

リスト構造と基本マシン算術演算

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