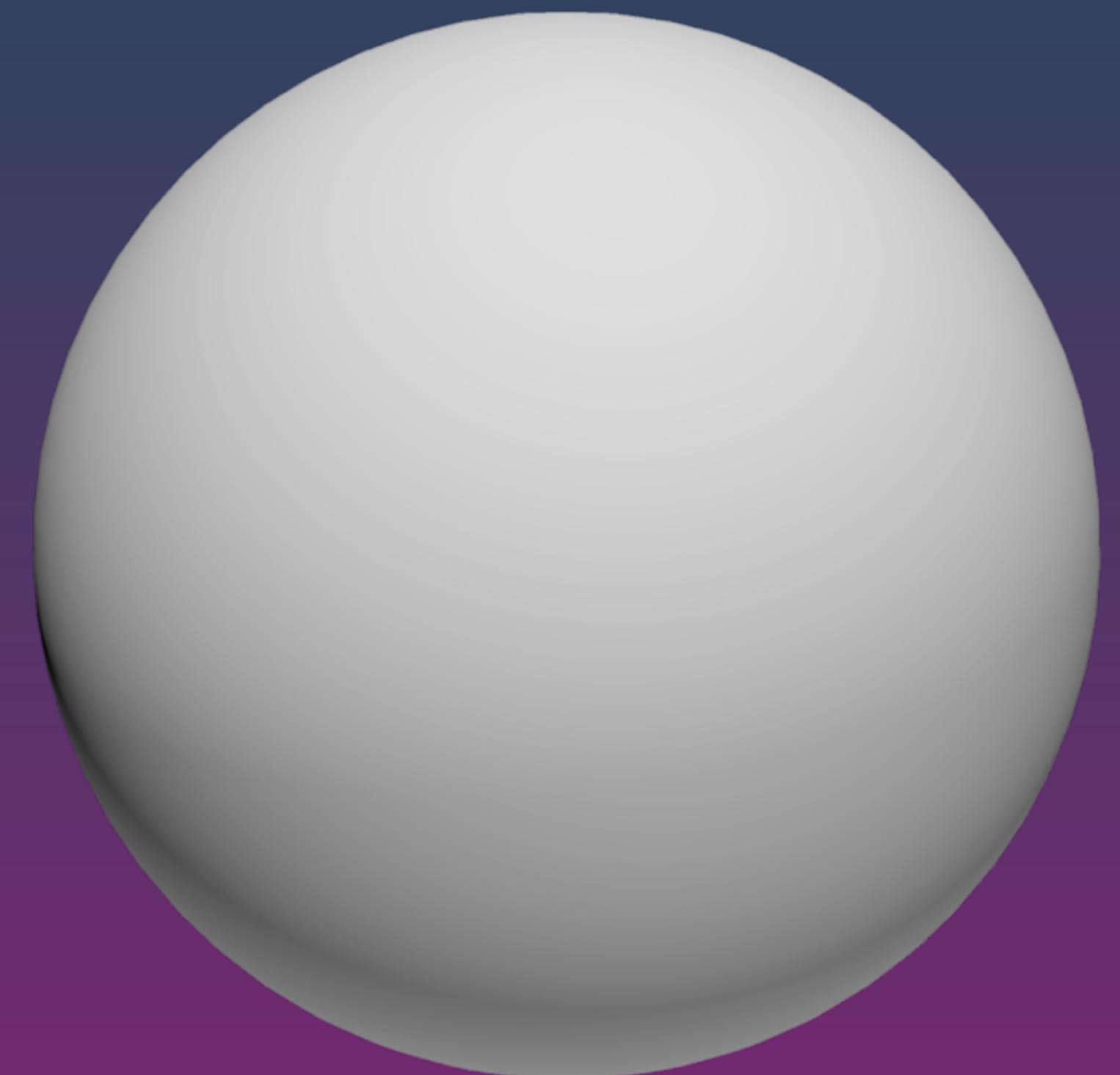
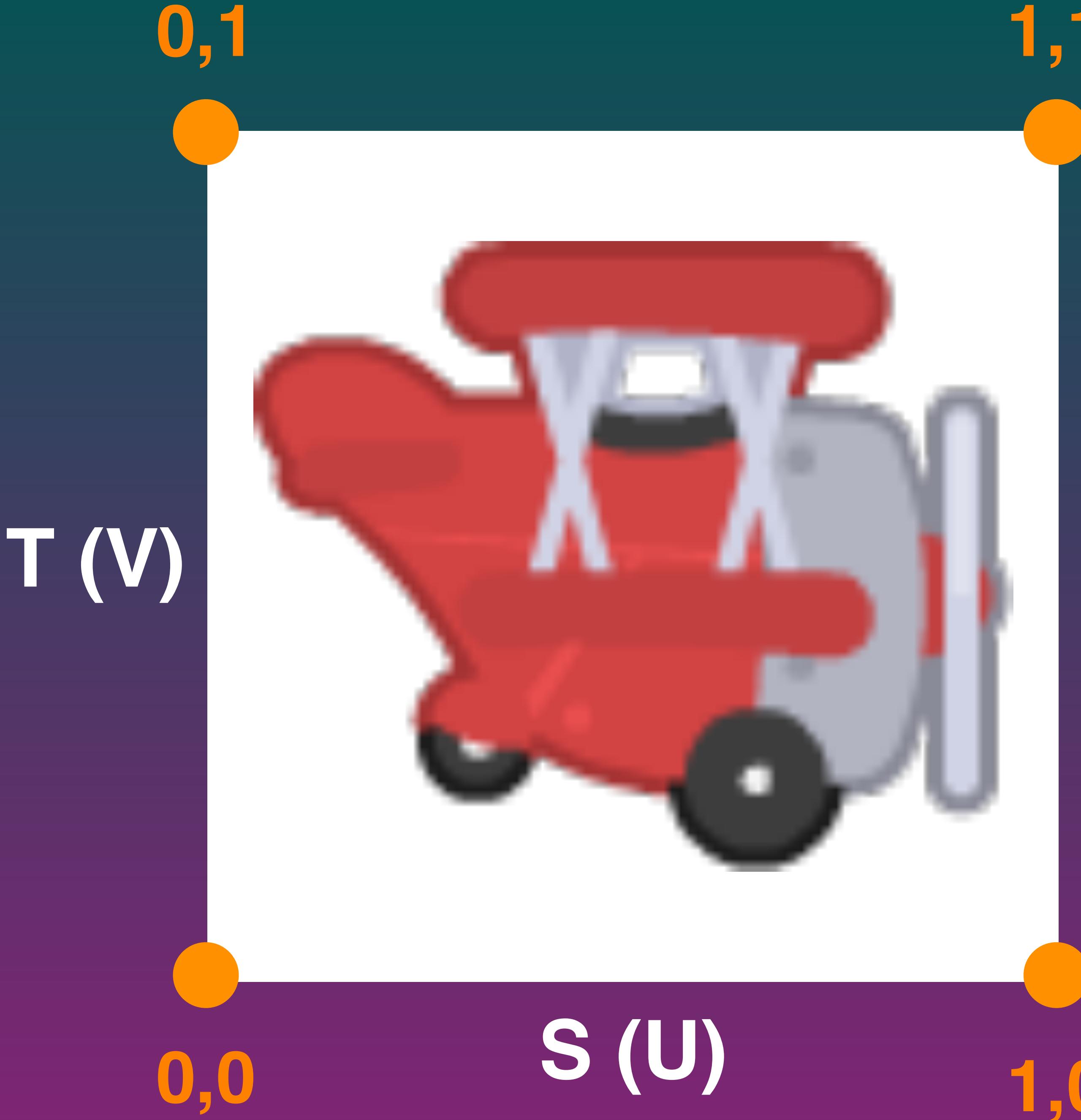


Graphics Foundations

Part 3



Texture coordinates



Texture coordinates
are defined in 0-1
units called UV
coordinates, not
pixels!

0.1



1.1

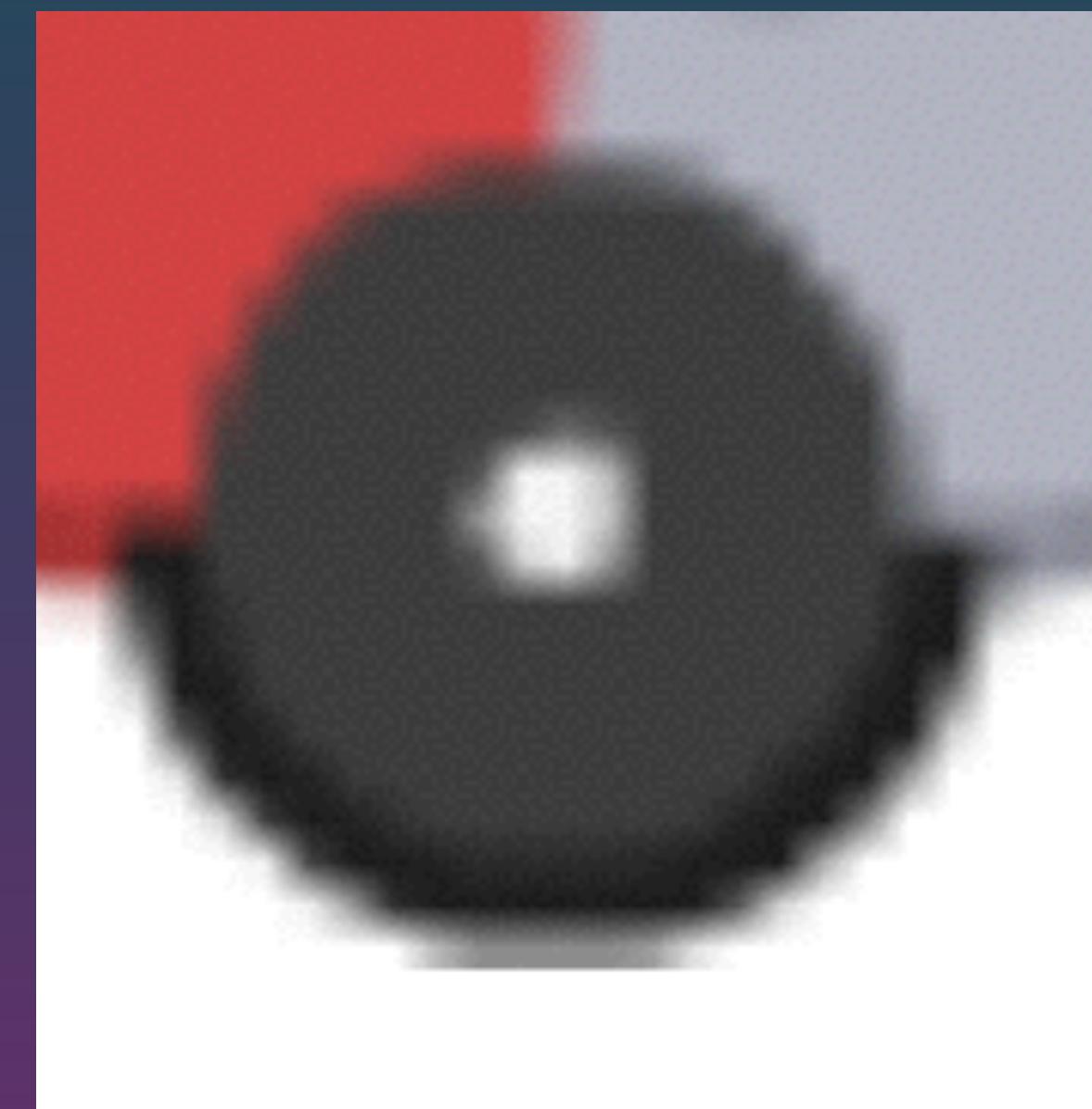
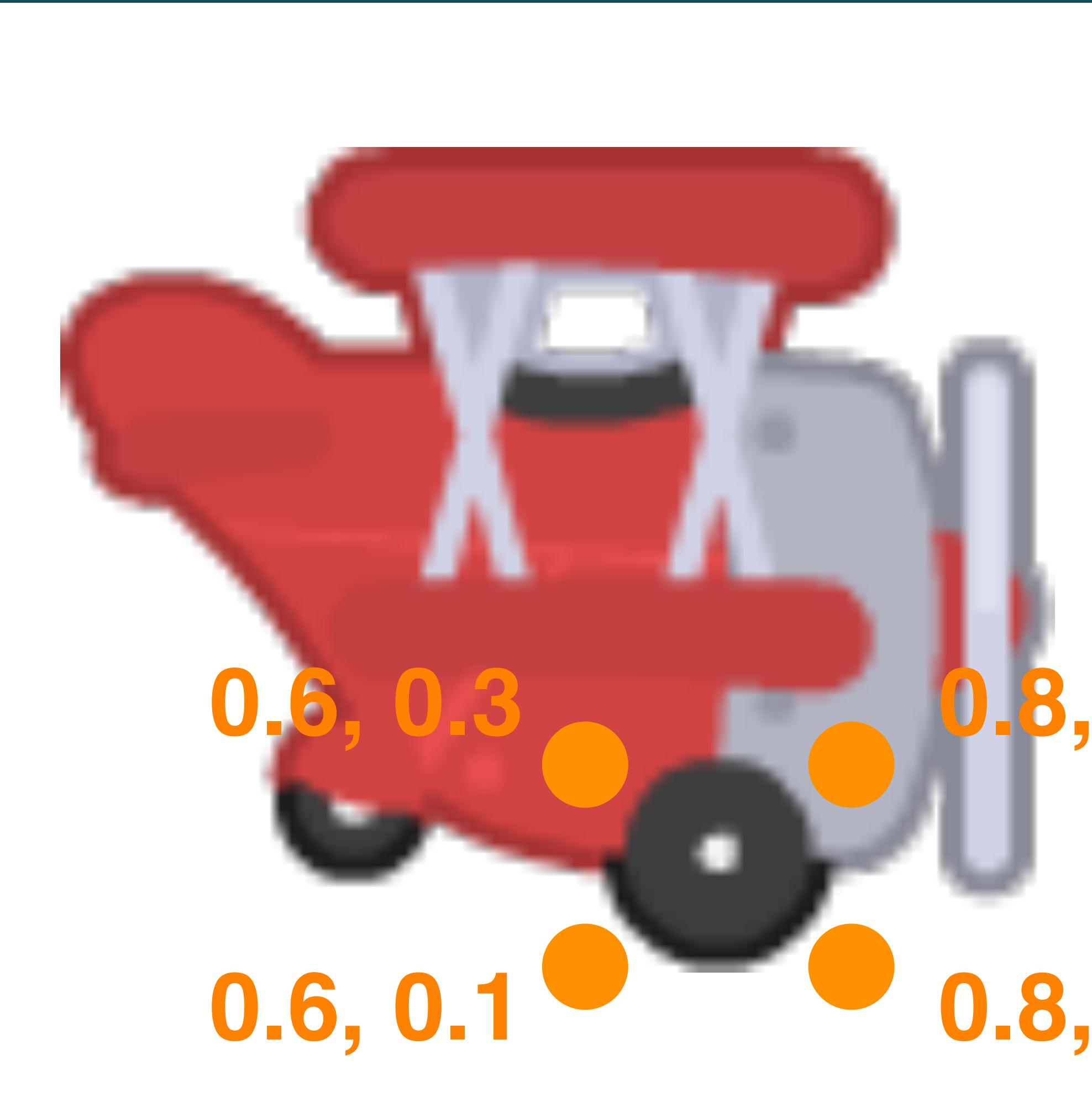


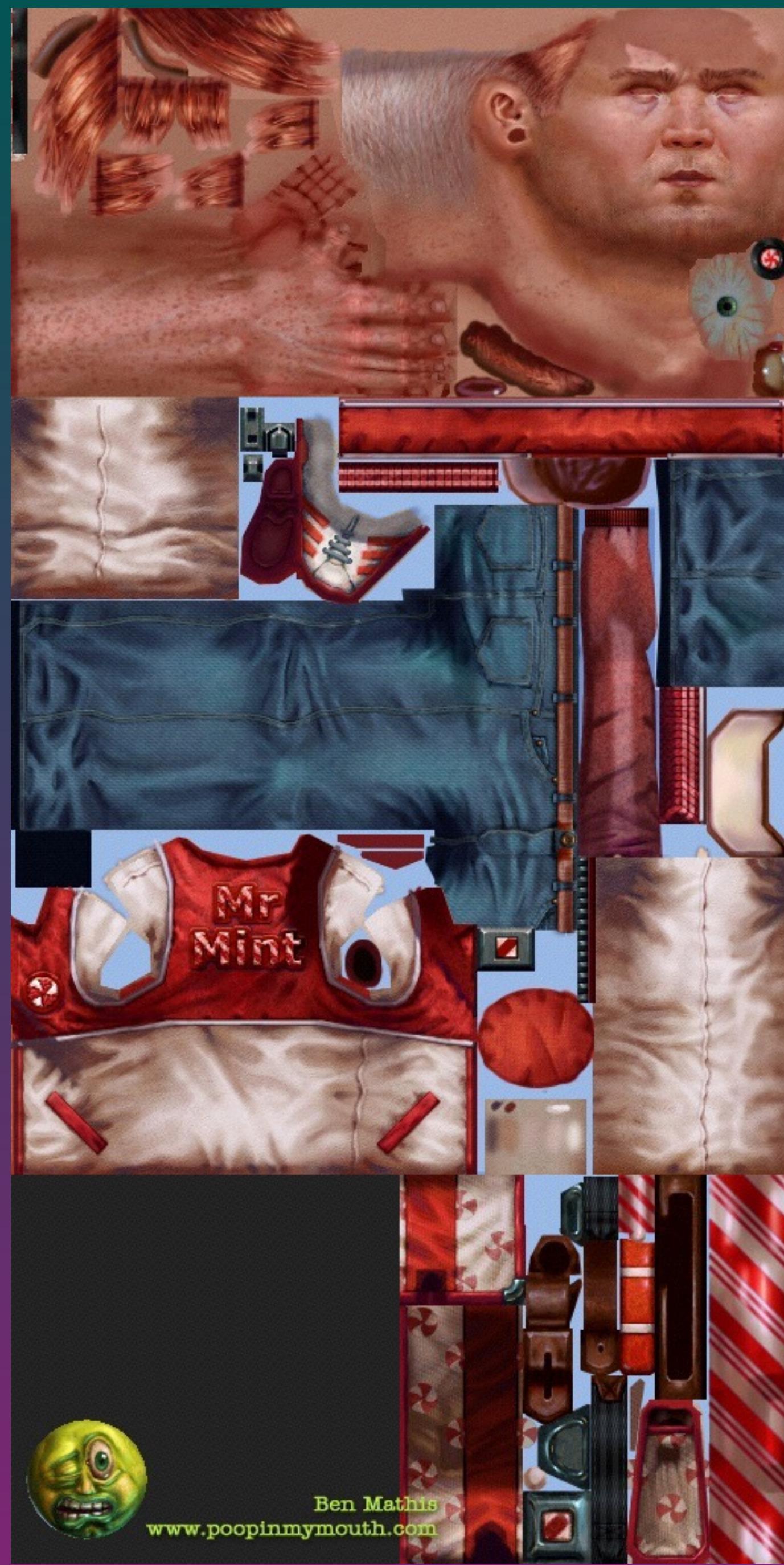
0.0

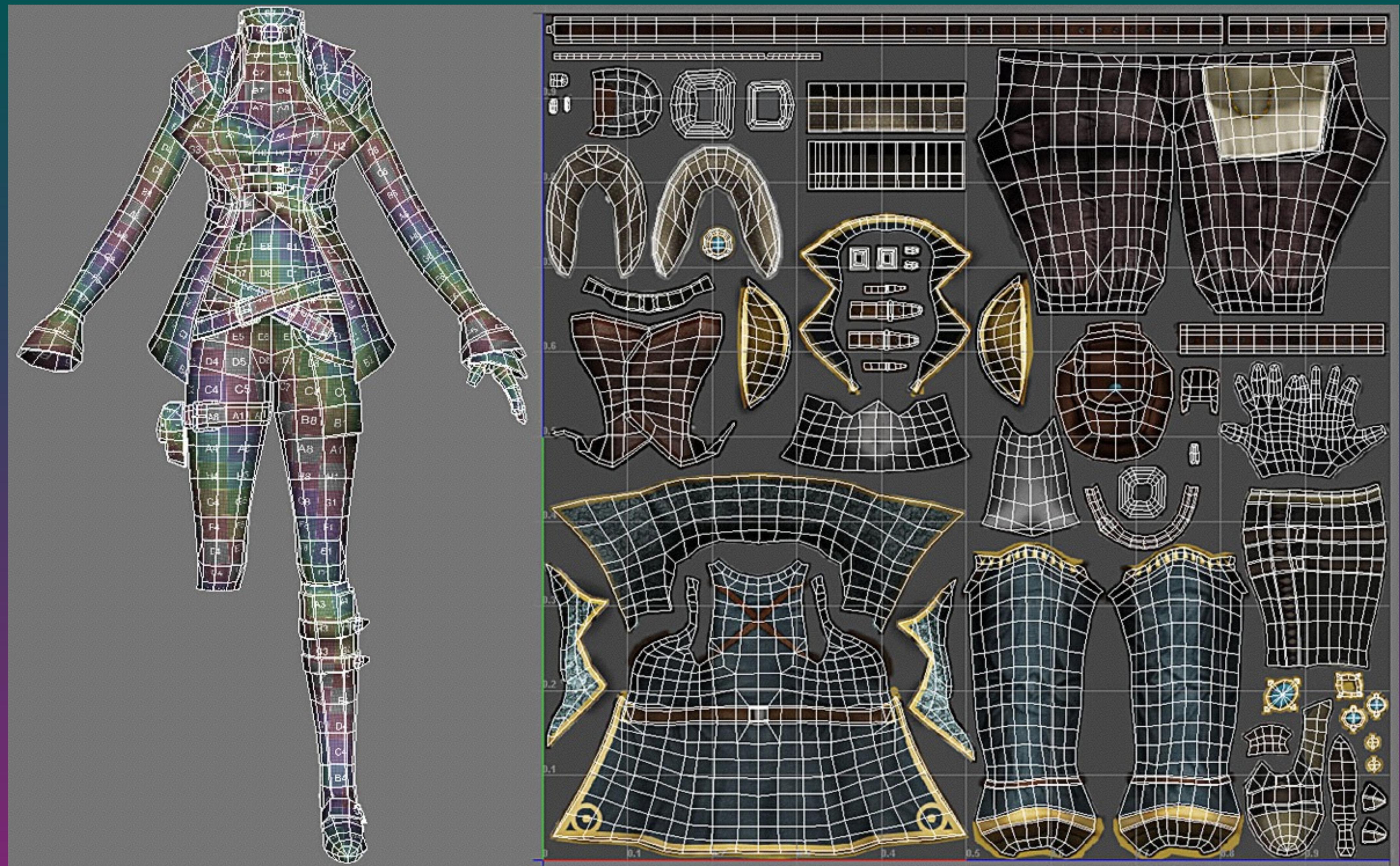
1.0



```
GLfloat quadUVs[] = {0.0, 0.0, 0.0, 1.0, 1.0, 1.0, 1.0, 0.0};  
glTexCoordPointer(2, GL_FLOAT, 0, quadUVs);
```

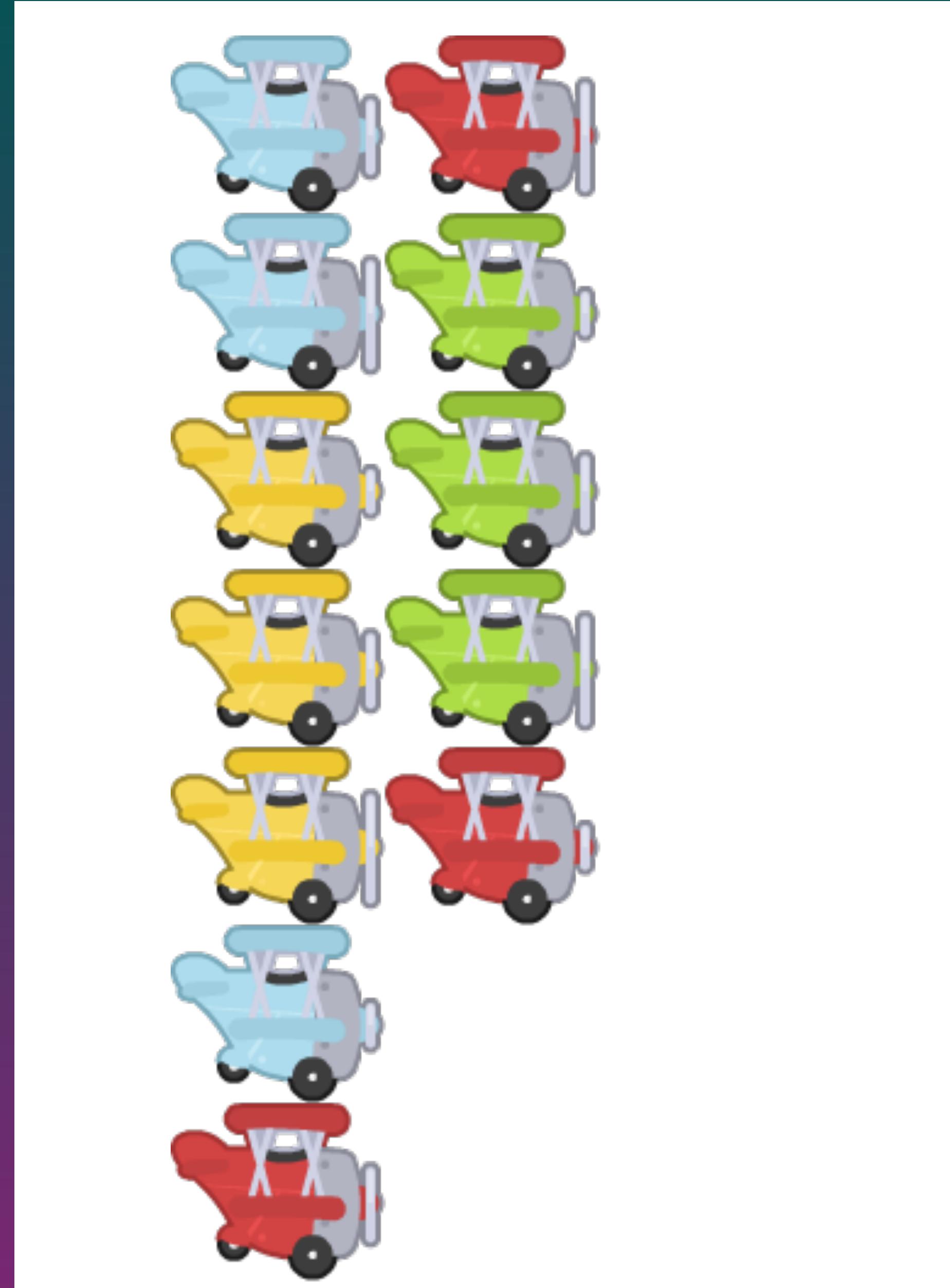




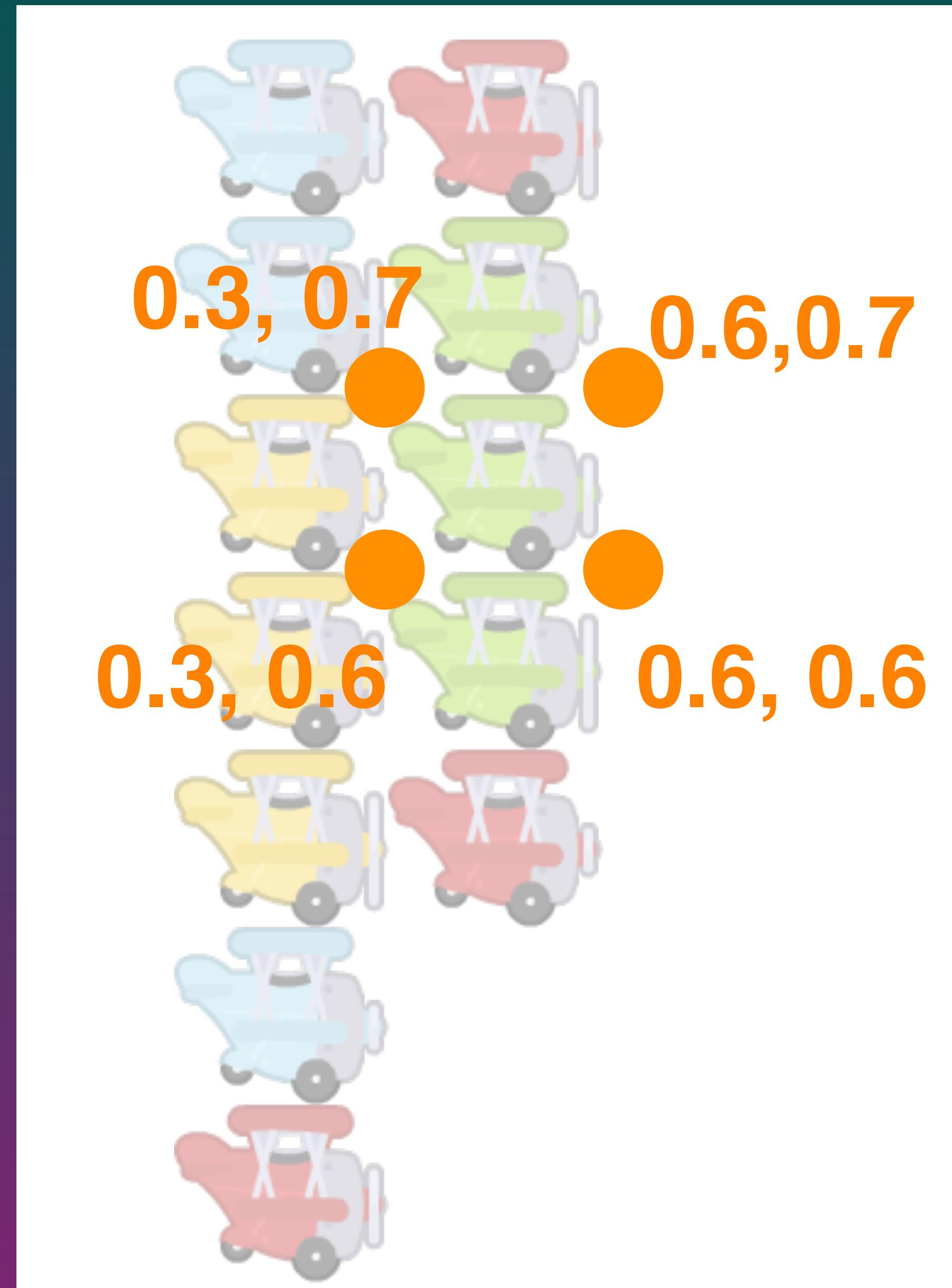


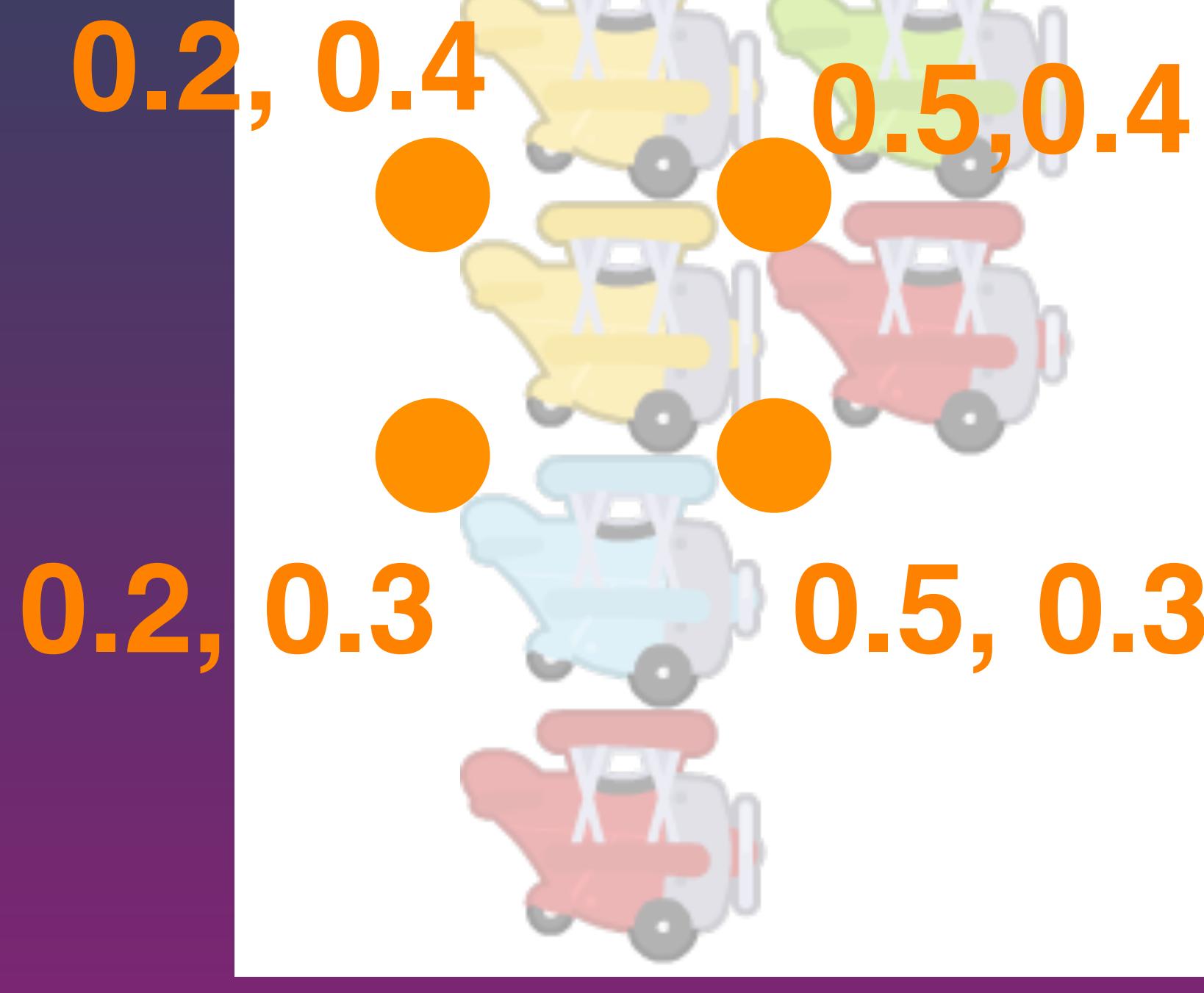
Texture coordinates in 2D graphics.

Texture atlas.

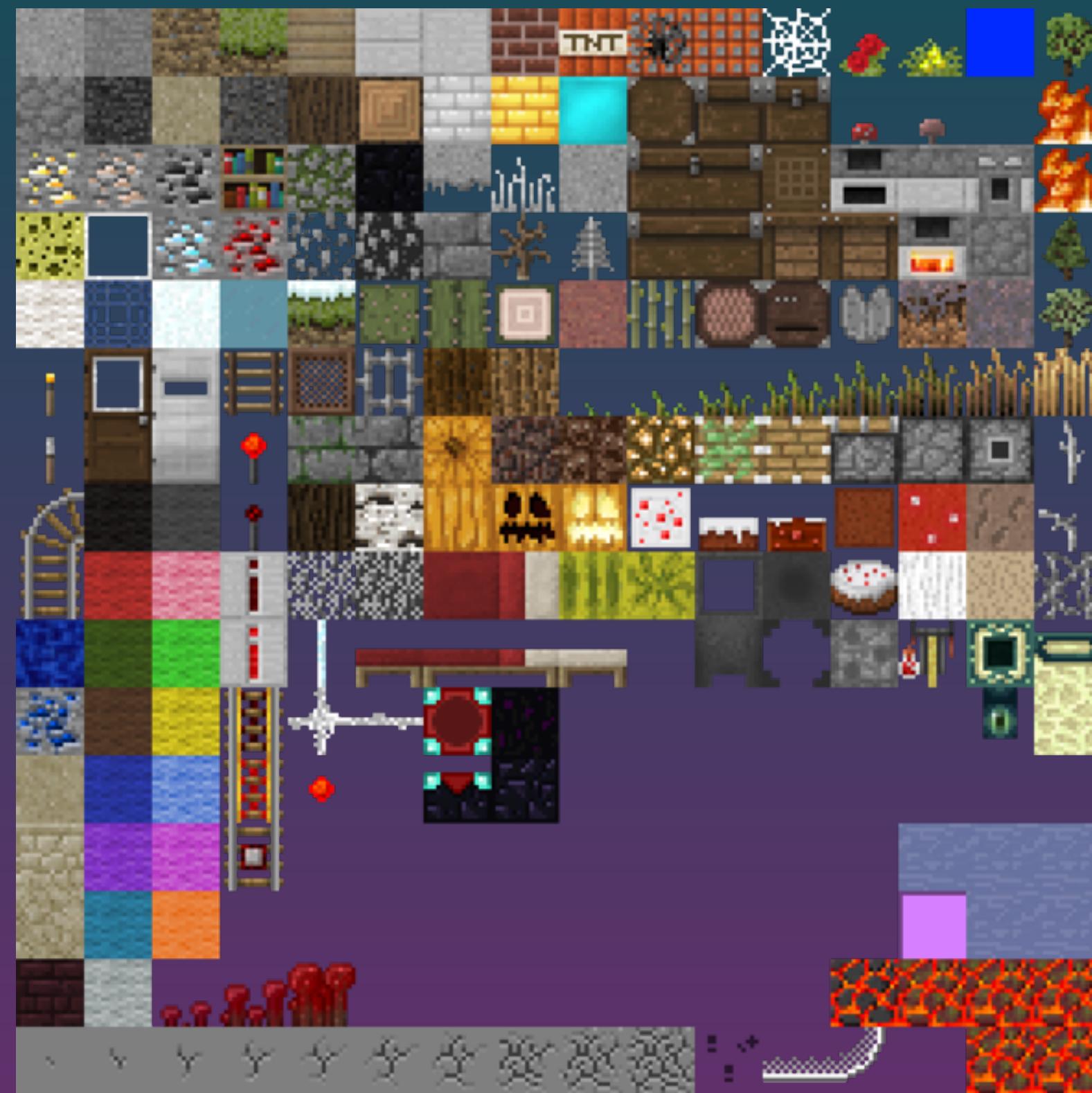


A single texture
that contains
multiple sprites
arranged in a
single image.











□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
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0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?				
@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O				
P	Q	R	S	T	U	V	W	X	Y	Z	[\]	^	-				
‘	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o				
p	q	r	s	t	u	v	w	x	y	z	{		}	~	□				
€	¤	,	f	„	…	†	‡	^	‰	Š	„	Œ	¤	Ž	□				
¤	,	;	“	”	•	—	—	~	™	š	›	œ	¤	ž	ÿ				
°	±	²	³	’	μ	¶	·	„	©	¤	«	¬	-	®	-				
À	Á	Â	Ã	Ä	Å	Æ	Ç	É	É	Ê	Ë	Ì	Í	Î	Ï				
Đ	Ñ	Ò	Ó	Ô	Õ	Ö	×	Ø	Ù	Ú	Û	Ü	Ý	Þ	ß				
à	á	â	ã	ä	å	æ	ç	è	é	ê	ë	ì	í	î	ï				
ð	ñ	ò	ó	ô	õ	ö	÷	ø	ù	ú	û	ü	ý	þ	ÿ				

Evenly spaced sprite sheets









```
int index = 10;
int spriteCountX = 8;
int spriteCountY = 4;
float u = (float)((int)index) % spriteCountX / (float) spriteCountX;
float v = (float)((int)index) / spriteCountX / (float) spriteCountY;
float spriteWidth = 1.0/(float)spriteCountX;
float spriteHeight = 1.0/(float)spriteCountY;

GLfloat quadUVs[] = { u, v,
                      u, v+spriteHeight,
                      u+spriteWidth, v+spriteHeight,
                      u+spriteWidth, v
};
```

```
void DrawSpriteSheetSprite(int spriteTexture, int index, int spriteCountX, int
spriteCountY) {

    // our regular sprite drawing

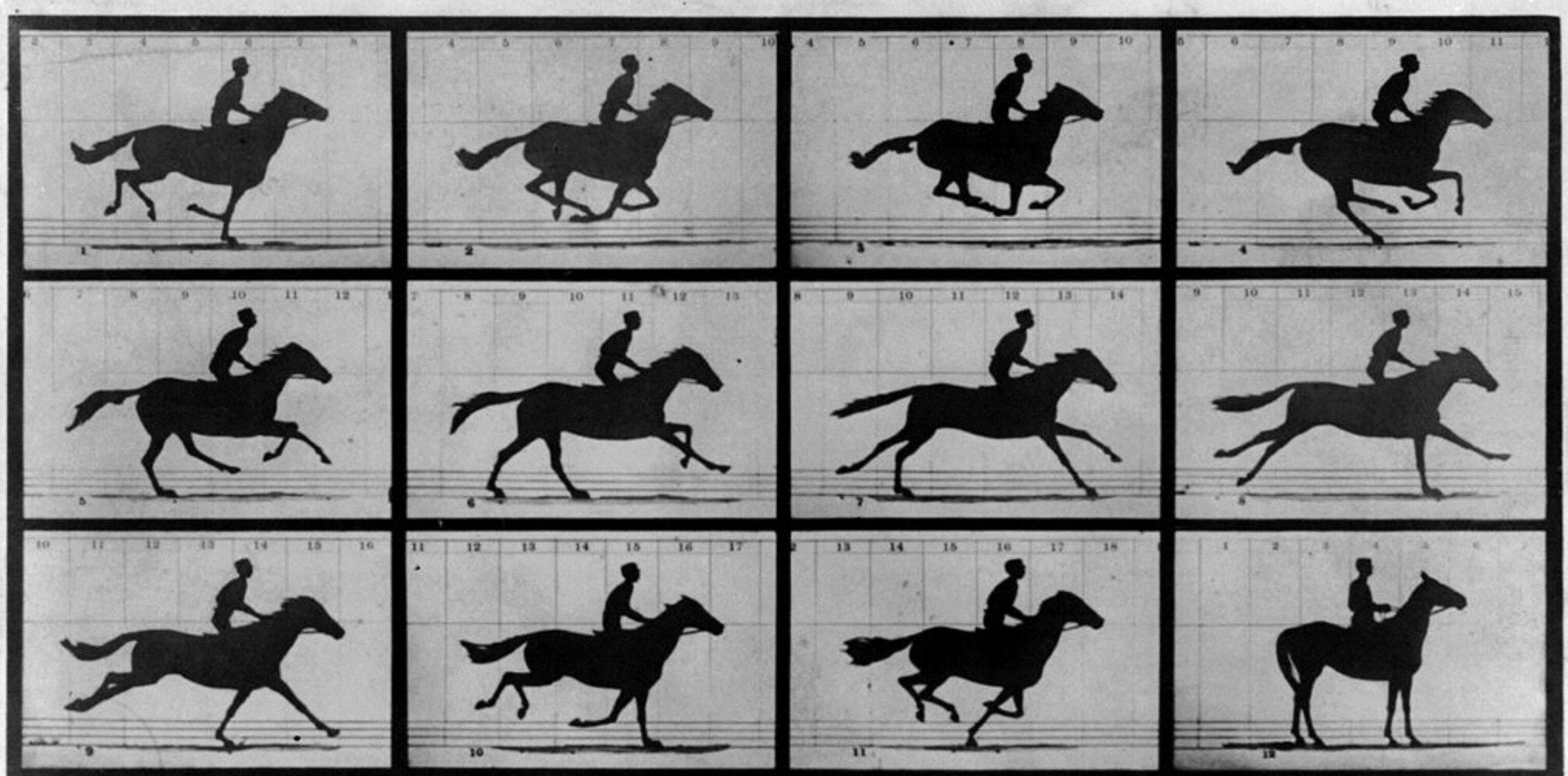
    float u = (float)((int)index) % spriteCountX / (float) spriteCountX;
    float v = (float)((int)index) / spriteCountX / (float) spriteCountY;
    float spriteWidth = 1.0/(float)spriteCountX;
    float spriteHeight = 1.0/(float)spriteCountY;

    GLfloat quadUVs[] = { u, v,
                          u, v+spriteHeight,
                          u+spriteWidth, v+spriteHeight,
                          u+spriteWidth, v
};

    // our regular sprite drawing

}
```

Sprite animation



Copyright, 1878, by MUYBRIDGE.

MORSE'S Gallery, 417 Montgomery St., San Francisco.

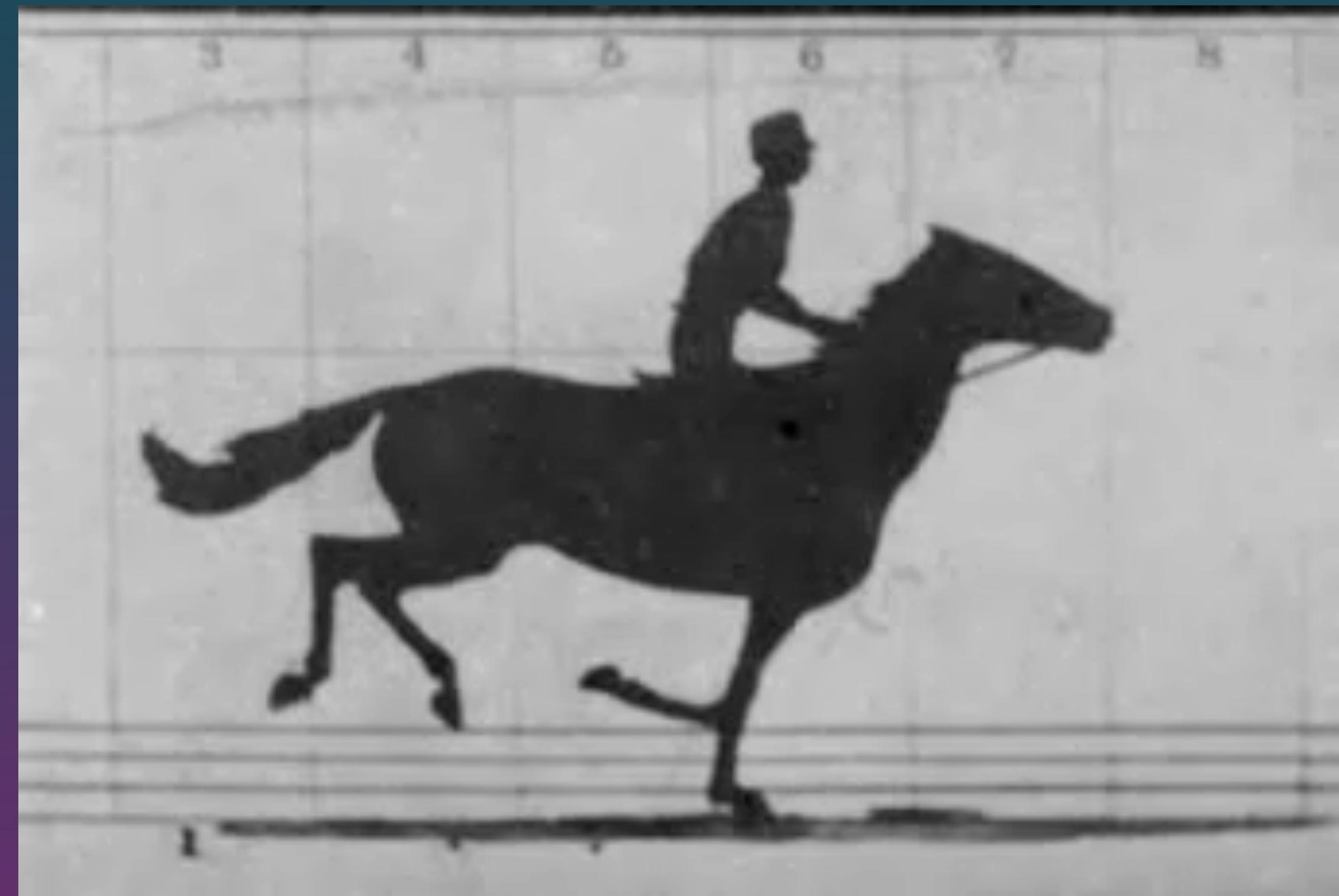
THE HORSE IN MOTION.

Illustrated by
MUYBRIDGE.

AUTOMATIC ELECTRO-PHOTOGRAPHIC.

"SALLIE GARDNER," owned by LELAND STANFORD; running at a 1.40 gait over the Palo Alto track, 19th June, 1878.

The negatives of these photographs were made at intervals of twenty-seven inches of distance, and about the twenty-fifth part of a second of time; they illustrate consecutive positions assumed in each twenty-seven inches of progress during a single stride of the mare. The vertical lines were twenty-seven inches apart; the horizontal lines represent elevations of four inches each. The exposure of each negative was less than the two-thousandth part of a second.





1. Define indices of an animation (e.g. 0-6)
2. Keep a timer
3. Go to next frame when timer hits desired value.
4. If at the last frame, go to first frame (if looped animation).

```
const int runAnimation[] = {9, 10, 11, 12, 13};  
const int numFrames = 5;  
float animationElapsed = 0.0f;  
float framesPerSecond = 30.0f;
```

In our loop:

```
animationElapsed += elapsed;  
  
if(animationElapsed > 1.0/framesPerSecond) {  
    currentIndex++;  
    animationElapsed = 0.0;  
  
    if(currentIndex > numFrames-1) {  
        currentIndex = 0;  
    }  
}  
  
DrawSpriteSheetSprite(spriteTestTexture, runAnimation[currentIndex], 8, 4);
```

Monospaced font rendering.

□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
!	"	#	\$	%	&	'	()	*	+	,	-	.	/					
0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?				
@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O				
P	Q	R	S	T	U	V	W	X	Y	Z	[\]	^	-				
`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o				
p	q	r	s	t	u	v	w	x	y	z	{		}	~	□				
€	¤	,	f	"	"	„	†	‡	^	‰	Š	„	Œ	¤	Ž	¤	ž	ÿ	
¤	,	;	"	"	"	•	-	-	~	™	š	›	œ	¤	ž	ÿ	-		
i	¢	£	¤	¥	₪	₪	₪	₪	₪	₪	₪	₪	₪	₪	₪	₪	₪	₪	₪
°	±	²	³	‘	’	μ	¶	·	·	·	·	·	·	·	·	·	·	·	·
À	Á	Â	Ã	Ä	Å	Æ	Ç	É	É	É	Ê	Ë	Ì	Í	Î	Ï	Ӄ	Ӄ	Ӄ
Đ	Ñ	Ò	Ó	Ô	Õ	Ö	×	Ø	Ù	Ú	Û	Ü	Ý	Þ	Þ	Þ	Þ	Þ	Þ
à	á	â	ã	ä	å	æ	ç	è	é	ê	ë	ì	í	î	ï	Ӄ	Ӄ	Ӄ	Ӄ
ð	ñ	ò	ó	ô	õ	ö	÷	ø	ù	ú	û	ü	ý	þ	þ	þ	þ	þ	þ

□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
!	"	#	\$	%	&	'	()	*	+	,	-	.	/					
0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?				
@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O				
P	Q	R	S	T	U	V	W	X	Y	Z	[\]	^					
`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	ó				
p	q	r	s	t	u	v	w	x	y	z	{	}		~	ø				
€		,	f	"	"	...	†	‡	^	‰	Š	„	Œ	Ž	„				
	'	;	"	"	•	—	—	—	—	™	š	„	œ	ž	„				
i	¢	£	¤	¥	₩		§	“	©	¤	«	„	—	®	—				
°	±	²	³	‘	μ	¶	·	·	¹	º	»	¼	½	¾	¿				
À	Á	Ã	Ä	Å	Æ	Ç	È	É	Ê	Ë	Ì	Í	Î	Ï					
Ð	Ñ	Ò	Ó	Ô	Õ	Ö	×	Ø	Ù	Ú	Û	Ü	Ý	Þ	ß				
à	á	ã	ä	å	æ	ç	è	é	ê	ë	ì	í	î	ï					
ð	ñ	ò	ó	ô	õ	ö	÷	ø	ù	ú	û	ü	ý	þ	ÿ				

To render a string, we must look at it character by character and draw a quad for each letter using the appropriate UV coordinates.

H e l l o

```

string test = "This is a string!";
cout << (int)test[3] << endl; // prints 115, which is 's'

```

Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040	 	Space	64	40	100	@	Ø	96	60	140	`	~
1	1	001	SOH (start of heading)	33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
2	2	002	STX (start of text)	34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
3	3	003	ETX (end of text)	35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
4	4	004	EOT (end of transmission)	36	24	044	$	\$	68	44	104	D	D	100	64	144	d	d
5	5	005	ENQ (enquiry)	37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
6	6	006	ACK (acknowledge)	38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
7	7	007	BEL (bell)	39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
8	8	010	BS (backspace)	40	28	050	((72	48	110	H	H	104	68	150	h	h
9	9	011	TAB (horizontal tab)	41	29	051))	73	49	111	I	I	105	69	151	i	i
10	A	012	LF (NL line feed, new line)	42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11	B	013	VT (vertical tab)	43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12	C	014	FF (NP form feed, new page)	44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
13	D	015	CR (carriage return)	45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
14	E	016	SO (shift out)	46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
15	F	017	SI (shift in)	47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
16	10	020	DLE (data link escape)	48	30	060	0	Ø	80	50	120	P	P	112	70	160	p	p
17	11	021	DC1 (device control 1)	49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
18	12	022	DC2 (device control 2)	50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
19	13	023	DC3 (device control 3)	51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
20	14	024	DC4 (device control 4)	52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
21	15	025	NAK (negative acknowledge)	53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
22	16	026	SYN (synchronous idle)	54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
23	17	027	ETB (end of trans. block)	55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
24	18	030	CAN (cancel)	56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
25	19	031	EM (end of medium)	57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
26	1A	032	SUB (substitute)	58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
27	1B	033	ESC (escape)	59	3B	073	;	:	91	5B	133	[[123	7B	173	{	{
28	1C	034	FS (file separator)	60	3C	074	<	<	92	5C	134	\	\	124	7C	174	|	
29	1D	035	GS (group separator)	61	3D	075	=	=	93	5D	135]]	125	7D	175	}	}
30	1E	036	RS (record separator)	62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
31	1F	037	US (unit separator)	63	3F	077	?	?	95	5F	137	_	_	127	7F	177		DEL

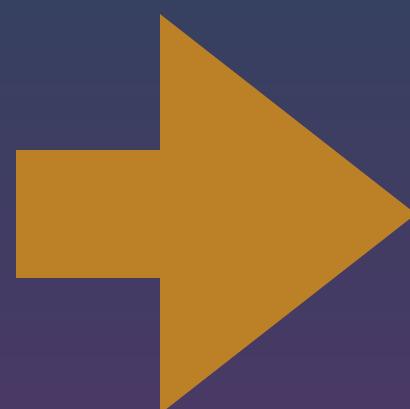
```
void DrawText(int fontTexture, string text, float size, float spacing, float r, float g, float b, float a) {  
    glBindTexture(GL_TEXTURE_2D, fontTexture);  
    glEnable(GL_TEXTURE_2D);  
    glEnable(GL_BLEND);  
    glBlendFunc(GL_SRC_ALPHA, GL_ONE_MINUS_SRC_ALPHA);  
  
    float texture_size = 1.0/16.0f;  
  
    vector<float> vertexData;  
    vector<float> texCoordData;  
    vector<float> colorData;  
  
    for(int i=0; i < text.size(); i++) {  
        float texture_x = (float)((int)text[i]) % 16) / 16.0f;  
        float texture_y = (float)((int)text[i]) / 16) / 16.0f;  
  
        colorData.insert(colorData.end(), {r,g,b,a, r,g,b,a, r,g,b,a, r,g,b,a});  
  
        vertexData.insert(vertexData.end(), {((size+spacing) * i) + (-0.5f * size), 0.5f * size, ((size+spacing) * i) +  
        (-0.5f * size), -0.5f * size, ((size+spacing) * i) + (0.5f * size), -0.5f * size, ((size+spacing) * i) + (0.5f * size), 0.5f  
        * size});  
  
        texCoordData.insert(texCoordData.end(), {texture_x, texture_y, texture_x, texture_y + texture_size, texture_x +  
        texture_size, texture_y + texture_size, texture_x + texture_size, texture_y});  
    }  
  
    glColorPointer(4, GL_FLOAT, 0, colorData.data());  
    glEnableClientState(GL_COLOR_ARRAY);  
    glVertexPointer(2, GL_FLOAT, 0, vertexData.data());  
    glEnableClientState(GL_VERTEX_ARRAY);  
    glTexCoordPointer(2, GL_FLOAT, 0, texCoordData.data());  
    glEnableClientState(GL_TEXTURE_COORD_ARRAY);  
    glDrawArrays(GL_QUADS, 0, text.size() * 4);  
}
```

Texture wrap modes.

0,1



1,1



0,0

1,0

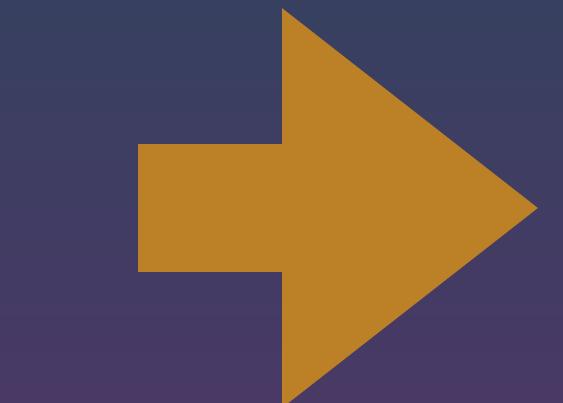
0,2



0,0



2,0

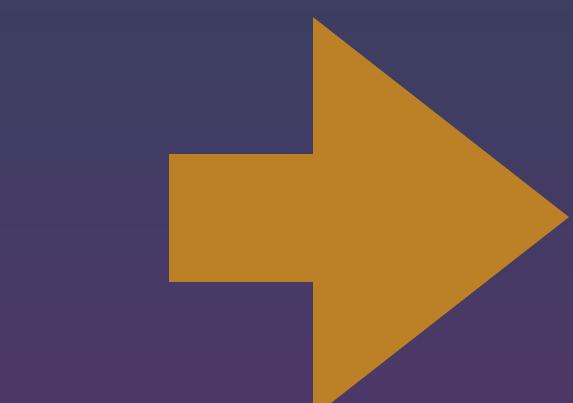


2,2



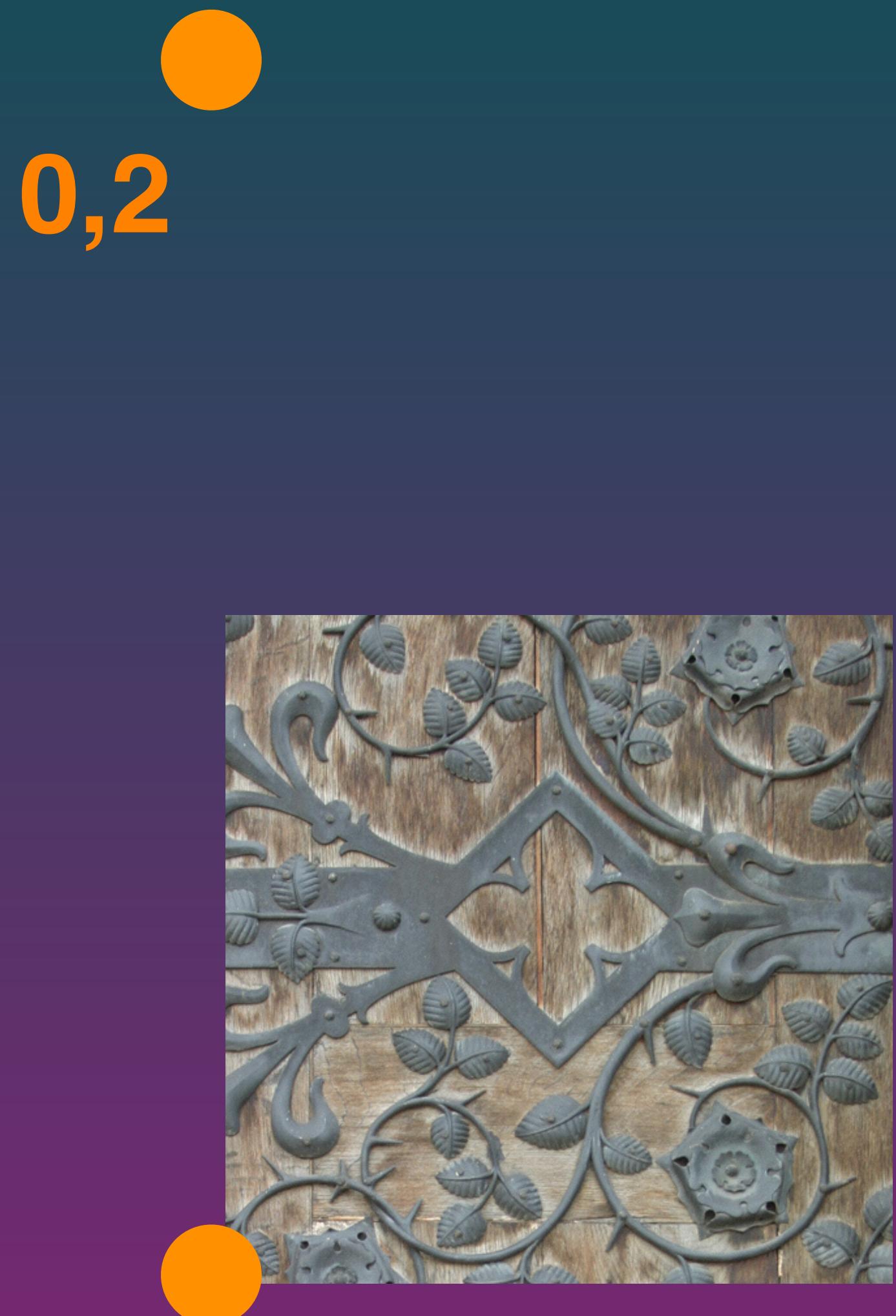
Repeat

0,2
0,0



0,0

Clamp



0,2



2,2



2,0



```
void glTexParameteri (GLenum target, GLenum pname,  
GLint param);
```

Sets a texture parameter of the specified texture target.

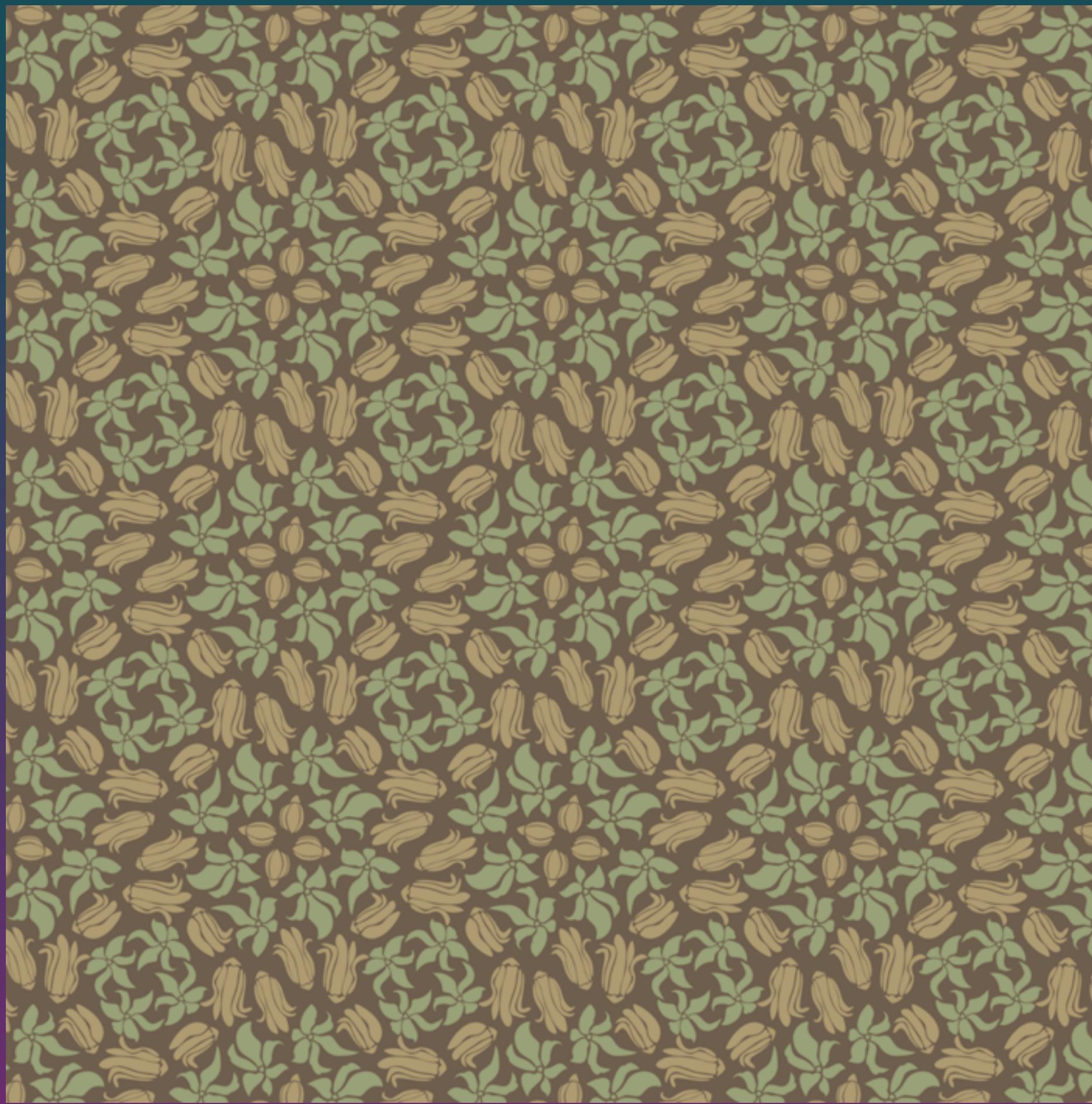
CLAMPING

```
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_S, GL_CLAMP);  
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_T, GL_CLAMP);
```

REPEATING

```
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_S, GL_REPEAT);  
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_T, GL_REPEAT);
```

Use GL_REPEAT for tiled textures like patterns, etc.



Use GL_CLAMP for non-tiled images with alpha.