



```
/*  
 * convolve.c  
 */
```

```
/* Standard includes */  
#include <assert.h>  
#include <math.h>  
#include <stdlib.h> /* malloc(), realloc() */
```

```
/* Our includes */  
#include "base.h"  
#include "error.h"  
#include "convolve.h"  
#include "klt_util.h" /* printing */
```

```
#define MAX_KERNEL_WIDTH 71
```

```
typedef struct {  
  int width;  
  float data[MAX_KERNEL_WIDTH];  
} ConvolutionKernel;
```

```
/* Kernels */
```

Fundamentals of Programming

lecture 13

Characters and Strings

How to represent characters?

How to represent characters?

- BCD: Binary Coded Decimal
- EBCDIC: Extended Binary Coded Decimal Interchange Code
- ASCII: American Standard Code for Information Interchange
- Unicode (UTF-8, UTF-16, UTF-32, etc.)

ASCII Table <https://commons.wikimedia.org/wiki/File%3AAscii-proper-color.svg>

Dec	Hex	Oct	Char	Dec	Hex	Oct	Char	Dec	Hex	Oct	Char	Dec	Hex	Oct	Char
0	0	0		32	20	40	[space]	64	40	100	@	96	60	140	`
1	1	1		33	21	41	!	65	41	101	A	97	61	141	a
2	2	2		34	22	42	"	66	42	102	B	98	62	142	b
3	3	3		35	23	43	#	67	43	103	C	99	63	143	c
4	4	4		36	24	44	\$	68	44	104	D	100	64	144	d
5	5	5		37	25	45	%	69	45	105	E	101	65	145	e
6	6	6		38	26	46	&	70	46	106	F	102	66	146	f
7	7	7		39	27	47	'	71	47	107	G	103	67	147	g
8	8	10		40	28	50	(	72	48	110	H	104	68	150	h
9	9	11		41	29	51	)	73	49	111	I	105	69	151	i
10	A	12		42	2A	52	*	74	4A	112	J	106	6A	152	j
11	B	13		43	2B	53	+	75	4B	113	K	107	6B	153	k
12	C	14		44	2C	54	,	76	4C	114	L	108	6C	154	l
13	D	15		45	2D	55	-	77	4D	115	M	109	6D	155	m
14	E	16		46	2E	56	.	78	4E	116	N	110	6E	156	n
15	F	17		47	2F	57	/	79	4F	117	O	111	6F	157	o
16	10	20		48	30	60	0	80	50	120	P	112	70	160	p
17	11	21		49	31	61	1	81	51	121	Q	113	71	161	q
18	12	22		50	32	62	2	82	52	122	R	114	72	162	r
19	13	23		51	33	63	3	83	53	123	S	115	73	163	s
20	14	24		52	34	64	4	84	54	124	T	116	74	164	t
21	15	25		53	35	65	5	85	55	125	U	117	75	165	u
22	16	26		54	36	66	6	86	56	126	V	118	76	166	v
23	17	27		55	37	67	7	87	57	127	W	119	77	167	w
24	18	30		56	38	70	8	88	58	130	X	120	78	170	x
25	19	31		57	39	71	9	89	59	131	Y	121	79	171	y
26	1A	32		58	3A	72	:	90	5A	132	Z	122	7A	172	z
27	1B	33		59	3B	73	;	91	5B	133	[	123	7B	173	{
28	1C	34		60	3C	74	<	92	5C	134	\	124	7C	174	|
29	1D	35		61	3D	75	=	93	5D	135	]	125	7D	175	}
30	1E	36		62	3E	76	>	94	5E	136	^	126	7E	176	~
31	1F	37		63	3F	77	?	95	5F	137	_	127	7F	177	

<https://ascii.cl/>

ASCII Hex Symbol			ASCII Hex Symbol			ASCII Hex Symbol			ASCII Hex Symbol		
0	0	NUL	16	10	DLE	32	20	(space)	48	30	0
1	1	SOH	17	11	DC1	33	21	!	49	31	1
2	2	STX	18	12	DC2	34	22	"	50	32	2
3	3	ETX	19	13	DC3	35	23	#	51	33	3
4	4	EOT	20	14	DC4	36	24	\$	52	34	4
5	5	ENQ	21	15	NAK	37	25	%	53	35	5
6	6	ACK	22	16	SYN	38	26	&	54	36	6
7	7	BEL	23	17	ETB	39	27	'	55	37	7
8	8	BS	24	18	CAN	40	28	(	56	38	8
9	9	TAB	25	19	EM	41	29	)	57	39	9
10	A	LF	26	1A	SUB	42	2A	*	58	3A	:
11	B	VT	27	1B	ESC	43	2B	+	59	3B	;
12	C	FF	28	1C	FS	44	2C	,	60	3C	<
13	D	CR	29	1D	GS	45	2D	-	61	3D	=
14	E	SO	30	1E	RS	46	2E	.	62	3E	>
15	F	SI	31	1F	US	47	2F	/	63	3F	?

ASCII Hex Symbol			ASCII Hex Symbol			ASCII Hex Symbol			ASCII Hex Symbol		
64	40	@	80	50	P	96	60	`	112	70	p
65	41	A	81	51	Q	97	61	a	113	71	q
66	42	B	82	52	R	98	62	b	114	72	r
67	43	C	83	53	S	99	63	c	115	73	s
68	44	D	84	54	T	100	64	d	116	74	t
69	45	E	85	55	U	101	65	e	117	75	u
70	46	F	86	56	V	102	66	f	118	76	v
71	47	G	87	57	W	103	67	g	119	77	w
72	48	H	88	58	X	104	68	h	120	78	x
73	49	I	89	59	Y	105	69	i	121	79	y
74	4A	J	90	5A	Z	106	6A	j	122	7A	z
75	4B	K	91	5B	[	107	6B	k	123	7B	{
76	4C	L	92	5C	\	108	6C	l	124	7C	|
77	4D	M	93	5D	]	109	6D	m	125	7D	}
78	4E	N	94	5E	^	110	6E	n	126	7E	~
79	4F	O	95	5F	_	111	6F	o	127	7F	␣

ASCII Hex Symbol			ASCII Hex Symbol			ASCII Hex Symbol			ASCII Hex Symbol		
0	0	NUL	16	10	DLE	32	20	(space)	48	30	0
1	1	SOH	17	11	DC1	33	21	!	49	31	1
2	2	STX	18	12	DC2	34	22	"	50	32	2
3	3	ETX	19	13	DC3	35	23	#	51	33	3
4	4	EOT	20	14	DC4	36	24	\$	52	34	4
5	5	ENQ	21	15	NAK	37	25	%	53	35	5
6	6	ACK	22	16	SYN	38	26	&	54	36	6
7	7	BEL	23	17	ETB	39	27	'	55	37	7
8	8	BS	24	18	CAN	40	28	(	56	38	8
9	9	TAB	25	19	EM	41	29	)	57	39	9
10	A	LF	26	1A	SUB	42	2A	*	58	3A	:
11	B	VT	27	1B	ESC	43	2B	+	59	3B	;
12	C	FF	28	1C	FS	44	2C	,	60	3C	<
13	D	CR	29	1D	GS	45	2D	-	61	3D	=
14	E	SO	30	1E	RS	46	2E	.	62	3E	>
15	F	SI	31	1F	US	47	2F	/	63	3F	?

ASCII Hex Symbol			ASCII Hex Symbol			ASCII Hex Symbol			ASCII Hex Symbol		
64	40	@	80	50	P	96	60	`	112	70	p
65	41	A	81	51	Q	97	61	a	113	71	q
66	42	B	82	52	R	98	62	b	114	72	r
67	43	C	83	53	S	99	63	c	115	73	s
68	44	D	84	54	T	100	64	d	116	74	t
69	45	E	85	55	U	101	65	e	117	75	u
70	46	F	86	56	V	102	66	f	118	76	v
71	47	G	87	57	W	103	67	g	119	77	w
72	48	H	88	58	X	104	68	h	120	78	x
73	49	I	89	59	Y	105	69	i	121	79	y
74	4A	J	90	5A	Z	106	6A	j	122	7A	z
75	4B	K	91	5B	[	107	6B	k	123	7B	{
76	4C	L	92	5C	\	108	6C	l	124	7C	|
77	4D	M	93	5D	]	109	6D	m	125	7D	}
78	4E	N	94	5E	^	110	6E	n	126	7E	~
79	4F	O	95	5F	_	111	6F	o	127	7F	À

putchar

NAME

fputc, fputs, putc, putchar, puts - output of characters and strings

SYNOPSIS

```
#include <stdio.h>
```

```
int fputc(int c, FILE *stream);
```

```
int fputs(const char *s, FILE *stream);
```

```
int putc(int c, FILE *stream);
```

```
int putchar(int c);
```

```
int puts(const char *s);
```

DESCRIPTION

fputc() writes the character c, cast to an unsigned char, to stream.

fputs() writes the string s to stream, without its terminating null ('\0').

putc() is equivalent to **fputc()** except that it may be implemented macro which evaluates stream more than once.

putchar(c) is equivalent to **putc(c, stdout)**.

putchar

ASCII Hex Symbol	ASCII Hex Symbol	ASCII Hex Symbol	ASCII Hex Symbol
64 40 @	80 50 P	96 60 `	112 70 p
65 41 A	81 51 Q	97 61 a	113 71 q
66 42 B	82 52 R	98 62 b	114 72 r
67 43 C	83 53 S	99 63 c	115 73 s
68 44 D	84 54 T	100 64 d	116 74 t
69 45 E	85 55 U	101 65 e	117 75 u
70 46 F	86 56 V	102 66 f	118 76 v
71 47 G	87 57 W	103 67 g	119 77 w
72 48 H	88 58 X	104 68 h	120 78 x
73 49 I	89 59 Y	105 69 i	121 79 y
74 4A J	90 5A Z	106 6A j	122 7A z
75 4B K	91 5B [	107 6B k	123 7B {
76 4C L	92 5C \	108 6C l	124 7C |
77 4D M	93 5D]	109 6D m	125 7D ~
78 4E N	94 5E ^	110 6E n	126 7E
79 4F O	95 5F _	111 6F o	127 7F

```
#include <stdio.h>

int main() {
    putchar(65);

    return 0;
}
```

putchar.c

putchar

ASCII Hex Symbol	ASCII Hex Symbol	ASCII Hex Symbol	ASCII Hex Symbol
64 40 @	80 50 P	96 60 `	112 70 p
65 41 A	81 51 Q	97 61 a	113 71 q
66 42 B	82 52 R	98 62 b	114 72 r
67 43 C	83 53 S	99 63 c	115 73 s
68 44 D	84 54 T	100 64 d	116 74 t
69 45 E	85 55 U	101 65 e	117 75 u
70 46 F	86 56 V	102 66 f	118 76 v
71 47 G	87 57 W	103 67 g	119 77 w
72 48 H	88 58 X	104 68 h	120 78 x
73 49 I	89 59 Y	105 69 i	121 79 y
74 4A J	90 5A Z	106 6A j	122 7A z
75 4B K	91 5B [	107 6B k	123 7B {
76 4C L	92 5C \	108 6C l	124 7C |
77 4D M	93 5D]	109 6D m	125 7D ~
78 4E N	94 5E ^	110 6E n	126 7E ¨
79 4F O	95 5F _	111 6F o	127 7F ¨

```
#include <stdio.h>
```

```
int main() {  
    putchar(65);  
    putchar(10);  
  
    return 0;  
}
```

putchar2.c

<https://ascii.cl/>

putchar

ASCII Hex Symbol			ASCII Hex Symbol		
64	40	@	80	50	P
65	41	A	81	51	Q
66	42	B	82	52	R
67	43	C	83	53	S
68	44	D	84	54	T
69	45	E	85	55	U
70	46	F	86	56	V
71	47	G	87	57	W
72	48	H	88	58	X
73	49	I	89	59	Y
74	4A	J	90	5A	Z
75	4B	K	91	5B	[
76	4C	L	92	5C	\
77	4D	M	93	5D]
78	4E	N	94	5E	^
79	4F	O	95	5F	_

```
#include <stdio.h>

int main() {
    char c = 65;

    for (int i = 0; i < 26; i++) {
        putchar(c);
        putchar(10);
        c++;
    }

    return 0;
}
```

putchar3.c

putchar

ASCII Hex Symbol			ASCII Hex Symbol		
64	40	@	80	50	P
65	41	A	81	51	Q
66	42	B	82	52	R
67	43	C	83	53	S
68	44	D	84	54	T
69	45	E	85	55	U
70	46	F	86	56	V
71	47	G	87	57	W
72	48	H	88	58	X
73	49	I	89	59	Y
74	4A	J	90	5A	Z
75	4B	K	91	5B	[
76	4C	L	92	5C	\
77	4D	M	93	5D]
78	4E	N	94	5E	^
79	4F	O	95	5F	_

```
#include <stdio.h>

int main() {
    char c = 65;

    char s[] = {83, 65, 76, 65, 77, 10};

    for (int i = 0; i < 6; i++) {
        putchar(s[i]);
    }

    return 0;
}
```

putchar4.c

putchar

ASCII Hex Symbol			ASCII Hex Symbol		
64	40	@	80	50	P
65	41	A	81	51	Q
66	42	B	82	52	R
67	43	C	83	53	S
68	44	D	84	54	T
69	45	E	85	55	U
70	46	F	86	56	V
71	47	G	87	57	W
72	48	H	88	58	X
73	49	I	89	59	Y
74	4A	J	90	5A	Z
75	4B	K	91	5B	[
76	4C	L	92	5C	\
77	4D	M	93	5D]
78	4E	N	94	5E	^
79	4F	O	95	5F	_

```
#include <stdio.h>

int main() {

    printf("%d\n", 'A');

    return 0;

}
```

putchar5.c

<https://ascii.cl/>

putchar

ASCII Hex Symbol			ASCII Hex Symbol		
64	40	@	80	50	P
65	41	A	81	51	Q
66	42	B	82	52	R
67	43	C	83	53	S
68	44	D	84	54	T
69	45	E	85	55	U
70	46	F	86	56	V
71	47	G	87	57	W
72	48	H	88	58	X
73	49	I	89	59	Y
74	4A	J	90	5A	Z
75	4B	K	91	5B	[
76	4C	L	92	5C	\
77	4D	M	93	5D]
78	4E	N	94	5E	^
79	4F	O	95	5F	_

<https://ascii.cl/>

```
#include <stdio.h>

int main() {
    printf("%d\n", 'A');
    return 0;
}
```

putchar5.c

putchar

ASCII Hex Symbol			ASCII Hex Symbol		
64	40	@	80	50	P
65	41	A	81	51	Q
66	42	B	82	52	R
67	43	C	83	53	S
68	44	D	84	54	T
69	45	E	85	55	U
70	46	F	86	56	V
71	47	G	87	57	W
72	48	H	88	58	X
73	49	I	89	59	Y
74	4A	J	90	5A	Z
75	4B	K	91	5B	[
76	4C	L	92	5C	\
77	4D	M	93	5D]
78	4E	N	94	5E	^
79	4F	O	95	5F	_

<https://ascii.cl/>

```
#include <stdio.h>

int main() {

    printf("%d\n", 'A');

    return 0;

}
```

putchar5.c

putchar

ASCII Hex Symbol			ASCII Hex Symbol		
64	40	@	80	50	P
65	41	A	81	51	Q
66	42	B	82	52	R
67	43	C	83	53	S
68	44	D	84	54	T
69	45	E	85	55	U
70	46	F	86	56	V
71	47	G	87	57	W
72	48	H	88	58	X
73	49	I	89	59	Y
74	4A	J	90	5A	Z
75	4B	K	91	5B	[
76	4C	L	92	5C	\
77	4D	M	93	5D]
78	4E	N	94	5E	^
79	4F	O	95	5F	_

<https://ascii.cl/>

```
#include <stdio.h>

int main() {
    char j = 'A';

    for (int i = 0; i < 26; i++)
        putchar(j+i);

    putchar('\n');

    return 0;
}
```

putchar6.c

putchar

ASCII Hex Symbol			ASCII Hex Symbol		
64	40	@	80	50	P
65	41	A	81	51	Q
66	42	B	82	52	R
67	43	C	83	53	S
68	44	D	84	54	T
69	45	E	85	55	U
70	46	F	86	56	V
71	47	G	87	57	W
72	48	H	88	58	X
73	49	I	89	59	Y
74	4A	J	90	5A	Z
75	4B	K	91	5B	[
76	4C	L	92	5C	\
77	4D	M	93	5D]
78	4E	N	94	5E	^
79	4F	O	95	5F	_

<https://ascii.cl/>

```
#include <stdio.h>

int main() {
    int n;

    char s[7] = {'S', 'a', 'l', 'a', 'm', '!', '\n'};

    for (int i = 0; i < 7; i++)
        putchar(s[i]);

    return 0;
}
```

putchar7.c

Introduction to strings

ASCII Hex Symbol

64	40	@
65	41	A
66	42	B
67	43	C
68	44	D
69	45	E
70	46	F
71	47	G
72	48	H
73	49	I
74	4A	J
75	4B	K
76	4C	L
77	4D	M
78	4E	N
79	4F	O

ASCII Hex Symbol

80	50	P
81	51	Q
82	52	R
83	53	S
84	54	T
85	55	U
86	56	V
87	57	W
88	58	X
89	59	Y
90	5A	Z
91	5B	[
92	5C	\
93	5D]
94	5E	^
95	5F	_

```
#include <stdio.h>

int main() {
    char s[] = {'S', 'a', 'l', 'a', 'm', '!', '\n', 0};

    for (int i = 0; s[i] != 0; i++)
        putchar(s[i]);

    return 0;
}
```

putchar8.c

Different between 0 and '0'

ASCII Hex Symbol			ASCII Hex Symbol		
32	20	(space)	48	30	0
33	21	!	49	31	1
34	22	"	50	32	2
35	23	#	51	33	3
36	24	\$	52	34	4
37	25	%	53	35	5
38	26	&	54	36	6
39	27	'	55	37	7
40	28	(	56	38	8
41	29	)	57	39	9
42	2A	*	58	3A	:
43	2B	+	59	3B	;
44	2C	,	60	3C	<
45	2D	-	61	3D	=
46	2E	.	62	3E	>
47	2F	/	63	3F	?

<https://ascii.cl/>

```
#include <stdio.h>

int main() {

    printf("%d, %d, %d\n", 0, '0', '\0');

    return 0;
}
```

putchar9.c

Introduction to strings

ASCII Hex Symbol			ASCII Hex Symbol		
64	40	@	80	50	P
65	41	A	81	51	Q
66	42	B	82	52	R
67	43	C	83	53	S
68	44	D	84	54	T
69	45	E	85	55	U
70	46	F	86	56	V
71	47	G	87	57	W
72	48	H	88	58	X
73	49	I	89	59	Y
74	4A	J	90	5A	Z
75	4B	K	91	5B	[
76	4C	L	92	5C	\
77	4D	M	93	5D]
78	4E	N	94	5E	^
79	4F	O	95	5F	_

```
#include <stdio.h>

int main() {
    int n;

    char s[7] = {'S', 'a', 'l', 'a', 'm', '!', '\n'};

    for (int i = 0; i < 7; i++)
        putchar(s[i]);

    return 0;
}
```

putchar8.c

<https://ascii.cl/>

Introduction to strings

ASCII Hex Symbol

64	40	@
65	41	A
66	42	B
67	43	C
68	44	D
69	45	E
70	46	F
71	47	G
72	48	H
73	49	I
74	4A	J
75	4B	K
76	4C	L
77	4D	M
78	4E	N
79	4F	O

ASCII Hex Symbol

80	50	P
81	51	Q
82	52	R
83	53	S
84	54	T
85	55	U
86	56	V
87	57	W
88	58	X
89	59	Y
90	5A	Z
91	5B	[
92	5C	\
93	5D]
94	5E	^
95	5F	_

```
#include <stdio.h>

int main() {
    char s[] = {'S', 'a', 'l', 'a', 'm', '!', '\n', 0};

    printf(s);

    return 0;
}
```

putchar10.c

Introduction to strings

ASCII Hex Symbol

64	40	@
65	41	A
66	42	B
67	43	C
68	44	D
69	45	E
70	46	F
71	47	G
72	48	H
73	49	I
74	4A	J
75	4B	K
76	4C	L
77	4D	M
78	4E	N
79	4F	O

ASCII Hex Symbol

80	50	P
81	51	Q
82	52	R
83	53	S
84	54	T
85	55	U
86	56	V
87	57	W
88	58	X
89	59	Y
90	5A	Z
91	5B	[
92	5C	\
93	5D]
94	5E	^
95	5F	_

```
#include <stdio.h>

int main() {
    char s[] = {'S', 'a', 'l', 'a', 'm', '!', '\n', 0};

    printf("%s", s);

    return 0;
}
```

putchar11.c

Introduction to strings

ASCII Hex Symbol

64	40	@
65	41	A
66	42	B
67	43	C
68	44	D
69	45	E
70	46	F
71	47	G
72	48	H
73	49	I
74	4A	J
75	4B	K
76	4C	L
77	4D	M
78	4E	N
79	4F	O

ASCII Hex Symbol

80	50	P
81	51	Q
82	52	R
83	53	S
84	54	T
85	55	U
86	56	V
87	57	W
88	58	X
89	59	Y
90	5A	Z
91	5B	[
92	5C	\
93	5D]
94	5E	^
95	5F	_

```
#include <stdio.h>

int main() {
    char s1[] = {'S', 'a', 'l', 'a', 'm', '!', '\n', 0};
    char s2[] = "Salam!\n";

    printf("%s",s1);
    printf("%s",s2);

    return 0;
}
```

putchar12.c

Introduction to strings

ASCII Hex Symbol			ASCII Hex Symbol		
64	40	@	80	50	P
65	41	A	81	51	Q
66	42	B	82	52	R
67	43	C	83	53	S
68	44	D	84	54	T
69	45	E	85	55	U
70	46	F	86	56	V
71	47	G	87	57	W
72	48	H	88	58	X
73	49	I	89	59	Y
74	4A	J	90	5A	Z
75	4B	K	91	5B	[
76	4C	L	92	5C	\
77	4D	M	93	5D]
78	4E	N	94	5E	^
79	4F	O	95	5F	_

<https://ascii.cl/>

```
#include <stdio.h>

int main() {
    char s[] = "Miam Barata! Kako!!!";
    int i = 0;

    while (s[i] != 0)
        i++;

    printf("%d\n", i);

    return 0;
}
```

string1.c

Reading strings

```
#include <stdio.h>

int main() {
    char s[100];

    scanf("%s", s);

    int i = 0;
    while (s[i] != 0)
        i++;

    while (i > 0) {
        i--;
        putchar(s[i]);
    }

    putchar('\n');

    return 0;
}
```

string2.c

Reading strings

```
#include <stdio.h>

int main() {
    char s[100];

    scanf("%s", s);

    int i = 0;
    while (s[i] != 0)
        i++;

    while (i > 0) {
        i--;
        putchar(s[i]);
    }

    putchar('\n');

    return 0;
}
```

string2.c