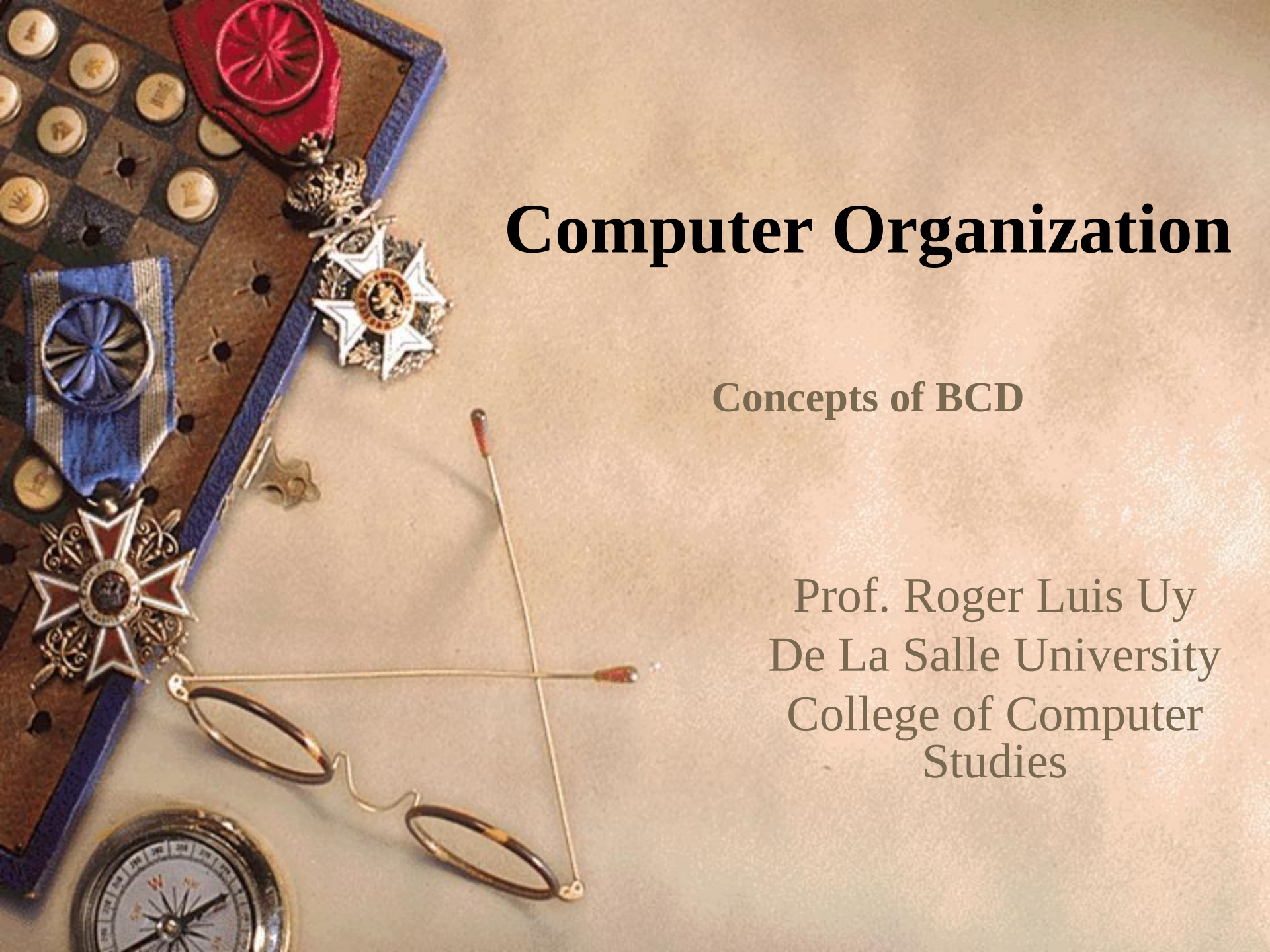

Computer Organization

Concepts of BCD

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BCD – Binary-Coded Decimal

- Binary-coded Decimal (BCD) is a binary encodings of decimal numbers where each decimal digit is represented by a fixed number of bits.

BCD – Binary Coded Decimal

- Three types of representation:
  - Unpacked BCD
  - Packed BCD
  - Densely Packed BCD

Unpacked BCD

- Given an 8-bit binary, only 1 decimal digit can be represented using unpacked BCD
- 0 = 0000 0000
- 1 = 0000 0001
- 5 = 0000 0101
- 9 = 0000 1001

Packed BCD

- Given an 8-bit binary, up to 2 decimal digits can be represented using packed BCD
- 0 = 0000 0000
- 1 = 0000 0001
- 55 = 0101 0101
- 99 = 1001 1001

Packed BCD

- The value 1100 (0C hex) is used as positive sign and 1101 (0D hex) is used as negative sign.
- Based from accounting terms (Credit and Debit)
- Example:

-125: 0001 0010 0101 1101

+45: 0000 0100 0101 1100

Densely Packed Decimal Encoding

- Based on 3-digit BCD
- Originally based on Chen-Ho encoding (1975, Tien Chi Chen & Dr. Irving Ho)
- Later on improved by Mike Cowlishaw (2002)

Example: 555 = 0101 0101 0101

a	b	c	d	e	f	g	h	i	j	k	m
0	1	0	1	0	1	0	1	0	1	0	1

Densely Packed Decimal Encoding

- Compression:

aei	pqr stu v wx y	
000	bcd fgh 0 jk m	all digits are small
001	bcd fgh 1 00 m	right digit is large
010	bcd jkh 1 01 m	middle digit is large
011	bcd 10h 1 11 m	left digit is small*
100	jkd fgh 1 10 m	left digit is large
101	fgd 01h 1 11 m	middle digit is small*
110	jkd 00h 1 11m	right digit is small*
111	00d 11h 1 11 m	all digits are large

* The rest of the digit are large

Densely Packed Decimal Encoding

a	e	i		p	q	r	s	t	u	v	w	x	y
0	0	0		b	c	d	f	g	h	0	j	k	m
0	0	1		b	c	d	f	g	h	1	0	0	m
0	1	0		b	c	d	j	k	h	1	0	1	m
0	1	1		b	c	d	1	0	h	1	1	1	m
1	0	0		j	k	d	f	g	h	1	1	0	m
1	0	1		f	g	d	0	1	h	1	1	1	m
1	1	0		j	k	d	0	0	h	1	1	1	m
1	1	1		0	0	d	1	1	h	1	1	1	m

Densely Packed Decimal Encoding

- Example:

a	b	c	d	e	f	g	h	i	j	k	m

Decimal	BCD	Densely packed
555	0101 0101 0101	101 101 0101
129	0001 0010 1001	001 010 1001
183	0001 1000 0011	001 010 1011
489	0100 1000 1001	100 100 1111

Densely Packed Decimal Encoding

- Example:

a	b	c	d	e	f	g	h	i	j	k	m

Decimal	BCD	Densely packed
967	1000 0110 0111	110 110 1101
928	1001 0010 1000	010 010 1110
987	1001 1000 0111	111 000 1111
999	1001 1001 1001	001 111 1111

Densely Packed Decimal Encoding

- Expansion:

vwxst	abcd efgh ijkm
0….	0pqr 0stu 0wxy
100..	0pqr 0stu 100y
101..	0pqr 100u 0sty
110..	100r 0stu 0pqy
11100	100r 100u 0pqy
11101	100r 0pqu 100y
11110	0pqr 100u 100y
11111	100r 100u 100y