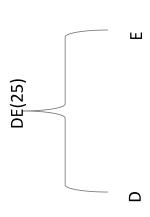
Huffman Coding And Arithmetic Coding

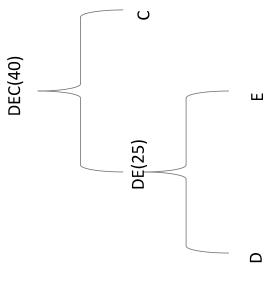
Huffman Coding

Symbol	Frequency
A	30
В	30
U	15
Q	15
Ш	10



Huffman Coding

Symbol A B	Frequency 30 30
	15
	15
	10



Huffman Coding

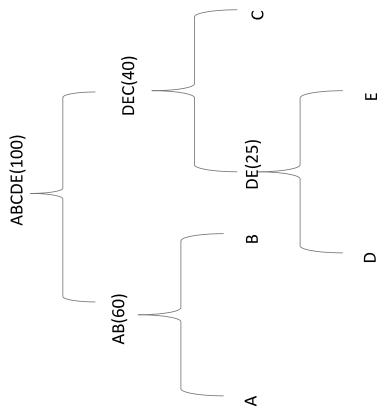
)						DEC(40)		DE(25)	
							AB(60)		B
	Frequency	30	30	15	15	10			٩
	Symbol	A	В	U	Ω	ш			

 \circ

ш

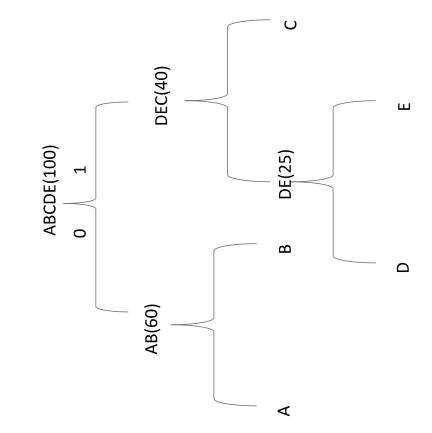
Huffman Coding

Frequency	30	30	15	15	10
Symbol	A	В	U	Q	ш

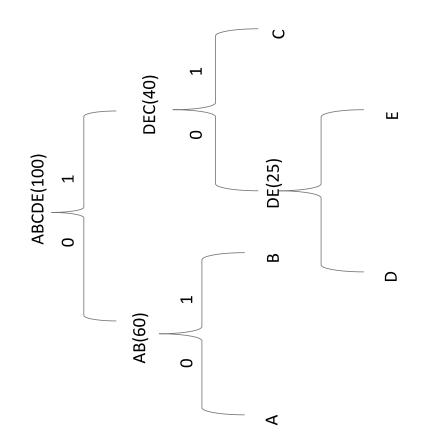


Huffman Coding

>					
Frequency	30	30	15	15	10
Symbol	A	В	C	Q	ш

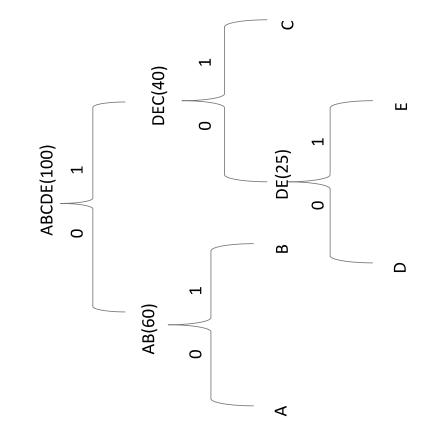


Huffman Coding



Huffman Coding

Code	00	01	11	100	101	
Frequency	30	30	15	15	10	
Symbol	A	В	C	Ω	ш	



Huffman Coding (Example 2)

16 15 15
10
4
2

Huffman Coding (Example 2 solution)

Frequency Code	10	11	000	010	011	0010	00110	00111
Freq	20	18	16	15	15	10	4	2
Symbol	⋖	В	U	D	ш	ட	ŋ	I

Extended Huffman Coding

Symbol	Probability	Huffman Code
A	0.85	0
В	0.10	10
V	0.05	11

Extended Huffman Coding

Symbol	Probability	Huffman Code
A	0.85	0
В	0.10	10
U	0.05	11

Symbol	Probability	Huffman Code
AA	0.85*0.85=0.722	
AB	0.85*0.10=0.085	
AC	0.85*0.05=0.042	
ВА	0.10*0.85=0.085	
BB	0.10*0.10=0.010	
ВС	0.10*0.05=0.005	
CA	0.05*0.85=0.042	
CB	0.05*0.10=0.005	
CC	0.05*0.05=0.0025	

Extended Huffman Coding

Symbol	Probability	Huffman Code
٨	0.85	0
В	0.10	10
O	0.05	11

Symbol	Probability	Huffman Code
AA	0.85*0.85=0.722	0
AB	0.85*0.10=0.085	100
AC	0.85*0.05=0.042	111
ВА	0.10*0.85=0.085	101
BB	0.10*0.10=0.010	11011
BC	0.10*0.05=0.005	110101
CA	0.05*0.85=0.042	1110
CB	0.05*0.10=0.005	1101000
သ	0.05*0.05=0.0025	1101001

Arithmetic Coding

oability Range From Range To	0.0 0.1	0.1 0.3	0.3 0.4	0.4 0.5	0.5 0.6	0.6 0.7	0.7 0.8	0.8 0.9	0
Probability Ran	0.1 0.0	0.2 0.1	0.1 0.3	0.1 0.4	0.1 0.5	0.1 0.6	0.1 0.7	0.1 0.8	0.0
SYMBOL	>	ш	~	ŋ	Z	Σ	۷	щ	Ĺ

Arithmetic Coding

SYMBOL	Probability	Range From	Range To
>	0.1	0.0	0.1
ш	0.2	0.1	0.3
~	0.1	0.3	0.4
9	0.1	0.4	0.5
Z	0.1	0.5	9.0
Σ	0.1	9.0	0.7
⋖	0.1	0.7	0.8
ш	0.1	0.8	6.0
S	0.1	6.0	1.0

Arithmetic Code for GERMAN

Arithmetic Code for **GERMAN**

SYMBOL	Probability	Range From	Range To
>	0.1	0.0	0.1
ш	0.2	0.1	0.3
~	0.1	0.3	0.4
9	0.1	0.4	0.5
Z	0.1	0.5	9.0
Σ	0.1	9.0	0.7
٨	0.1	0.7	0.8
Œ.	0.1	0.8	6.0
O	0.1	6.0	1.0

LV=0 HV=1 DIFF=1 For every symbol in input { LV=LV+DIFF*RANGE_FROM(SYMBOL)	HV=LV+DIFF*RANGE_TO(SYMBOL) DIFF=HV-LV INT LV
---	---

Arithmetic **Coding** for **GERMAN**

```
LV_OLD=0
HV=1
DIFF=1
For every symbol in input
{
LV=LV_OLD+DIFF*RANGE_FROM(SYMBOL)
HV=LV_OLD+DIFF*RANGE_TO(SYMBOL)
DIFF=HV-LV
LV_OLD=LV
}
PRINT LV
```

SYMBOL LV		H	DIFF
-	0	1	1
ŋ	0+1*0.4= 0.4	0+1*0.5=0.5	0.1
ш	0.4+0.1*0.1=0.41	0.4+0.1*0.3=0.43	0.02
~	0.41+0.02*0.3=0.416	0.41+0.02*0.4=0.418	0.002
Σ	0.416+0.002*0.6=0.4172	0.416+0.002*0.7=0.4174	0.0002
⋖	0.4172 + 0.0002 * 0.7 = 0.41734	0.4172+0.0002*0.8=0.41736	0.00002
z	0.41734+0.00002*0.5=0.417350	34+0.00002*0.5=0.417350 0.41734+0.00002*0.6=0.417352	0.000002

EXAMPLE 2

Range To	0.1	0.3	0.4	0.5	9.0	0.7	0.8	6.0	1.0
Range From	0.0	0.1	0.3	0.4	0.5	9.0	0.7	0.8	6.0
Probability	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
SYMBOL	>	ш	~	Ð	z	Σ	A	ш	v

Arithmetic Code for FRANCE

EXAMPLE 3

Range To	0.3	0.5	1.0
Range From Range To	0.0	0.3	0.5
Probability	0.3	0.2	0.5
SYMBOL	4	В	O

Arithmetic Code for AACBC

Arithmetic Decoding GERMAN

While (Code I= 0)	(o	Output the symbol corresponding to Range	Code – Range From(symbol)	Code== =	Range_To(symbol)- Range_From(symbol)	~ -			
Range To	0.1	0.3	0.4	0.5	9.0	0.7	0.8	6.0	1.0
Range From Range To	0.0	0.1	0.3	0.4	0.5	9.0	0.7	0.8	6.0
Probability	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
SYMBOL	>-	ш	~	ŋ	z	Σ	4	ш	U

Here Code for **GERMAN** is 0.417350 which falls in the range from 0.4 to 0.5 Output Symbol 'G'

Code = (0.417350 - 0.4) / (0.5 - 0.4) = 0.17350

Arithmetic Decoding GERMAN

While (Code I= 0)		Output the symbol corresponding to Range	Code – Range From(symbol)	Code=Code=	Range_To(symbol)- Range_From(symbol)					
Range To	0.1	0.3	0.4	0.5	9.0	0.7	0.8	6.0	1.0	
Range From Range To	0.0	0.1	0.3	0.4	0.5	9.0	0.7	0.8	6.0	
Probability	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
SYMBOL	>	Е	~	9	z	Σ	A	F	C	

Here Code for German is 0.17350 which falls in the range from 0.1 to 0.3 Output Symbol 'E'

Code = (0.17350 - 0.1) / (0.3 - 0.1) = 0.3675

Arithmetic Decoding GERMAN

W/bile (Code I- 0)	(o = : = o) {	Output the symbol corresponding to Range	Code – Range From(symbol)	Code== = Code=	Range_To(symbol)- Range_From(symbol)	~~			
Range To	0.1	0.3	0.4	0.5	9.0	0.7	0.8	6.0	1.0
Probability Range From Range To	0.0	0.1	0.3	0.4	0.5	9.0	0.7	0.8	6.0
Probability	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
SYMBOL	>	ш	&	Ŋ	z	Σ	⋖	ш	U

Here Code for German is 0.3675 which falls in the range from 0.3 to 0.4 Output Symbol 'R'

Code = (0.3675 - 0.3) / (0.4 - 0.3) = 0.675

Arithmetic Decoding GERMAN

While (Code I= 0)		Output the symbol corresponding to Range	Code – Range From(symbol)	Code= = Code= =	Range_To(symbol)- Range_From(symbol)					
Range To	0.1	0.3	0.4	0.5	9.0	0.7	0.8	6.0	1.0	
Probability Range From Range To	0.0	0.1	0.3	0.4	0.5	9.0	0.7	0.8	6.0	
Probability	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
SYMBOL	>	Е	~	9	Z	Σ	⋖	щ	C	

Here Code for German is 0.675 which falls in the range from 0.6 to 0.7 Output Symbol 'M'

Code =
$$(0.675 - 0.6) / (0.7 - 0.6) = 0.75$$

Arithmetic Decoding GERMAN

While (Code I= 0)	(O = : DOO : O) }	Output the symbol corresponding to Range	Code – Range From(symbol)	Code=	Range_To(symbol)- Range_From(symbol)	~ -			
Range To	0.1	0.3	0.4	0.5	9.0	0.7	0.8	6.0	1.0
ity Range From Range To	0.0	0.1	0.3	0.4	0.5	9.0	0.7	0.8	6.0
Probability	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
SYMBOL	>-	ш	~	Ŋ	z	Σ	⋖	ш	U

Here Code for German is 0.75 which falls in the range from 0.7 to 0.8 Output Symbol 'A'

Code = (0.75 - 0.7) / (0.8 - 0.7) = 0.5

Arithmetic Decoding GERMAN

While (Code I= 0)	\(\tau_{\tau} \)	Output the symbol corresponding to Range	Code – Range From(symbol)	Code================================	Range_To(symbol)- Range_From(symbol)	•			
Range To	0.1	0.3	0.4	0.5	9.0	0.7	0.8	6.0	1.0
Range From Range To	0.0	0.1	0.3	0.4	0.5	9.0	0.7	0.8	6.0
Probability	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
SYMBOL	>-	Е	~	Ŋ	z	Σ	⋖	¥	O

Here Code for German is 0.5 which falls in the range from 0.5 to 0.6 Output Symbol 'N'

Code =
$$(0.5 - 0.5) / (0.6 - 0.5) = 0$$

EXAMPLE 2

SYMBOL	Probability	Range From	Range To
>	0.1	0.0	0.1
ш	0.2	0.1	0.3
~	0.1	0.3	0.4
Ŋ	0.1	0.4	0.5
z	0.1	0.5	9.0
Σ	0.1	9.0	0.7
٥	0.1	0.7	0.8
L.	0.1	0.8	6.0
C	0.1	6.0	1.0

Arithmetic Decoding for 0.837591

EXAMPLE 3

nge To		10	0
Ra	0.3	0.5	1.0
Range From Range To	0.0	0.3	0.5
Probability	0.3	0.2	0.5
SYMBOL	4	В	O

Arithmetic Decoding for 0.0630

Dictionary based Coding

• LZ77

• LZ78

• LZW

Assume that there is an initial dictionary of 256 characters.

Symbol	Address to Dictionary
	0
*	15
9	47
S	59
W	63
>-	65
	255

LZW Coding

NARY	Address to Dictionary	256						
DICTIONARY	SYMBOL	WY						
	Output Code	63						
	Symbol	M						

INPUT:

WYS*WYGWYS*WYSWYSG

RY	Address to Dictionary	10	,					
DICTIONARY	Add	256	257					
DIC								
	SYMBOL	ΛΛ	YS					
		-						
	Output Code							
	Outp	63	65					
	Symbol							

LZW Coding

NARY	Address to Dictionary	256	257	258					
DICTIONARY									
	SYMBOL	W	YS	*\$					
	Code								
	Output Code	63	65	59					
	Symbol	>	>	S					

INPUT:

WYS*WYGWYS*WYSWYSG

		DICTIONARY	NARY
symbol	Output Code	SYMBOL	Address to Dictionary
	63	WY	256
	65	YS	257
	59	*\$	258
	15	% *	259

LZW Coding

		DICTIONARY	NARY
Symbol	Output Code	SYMBOL	Address to Dictionary
>	63	WY	256
>	65	YS	257
S	59	*\$	258
*	15	*	259

INPUT:

WYS*WYGWYS*WYSWYSG

d		DICTIONARY	NARY
Output Code		SYMBOL	Address to Dictionary
63		WY	256
65		YS	257
59	O,	*5	258
15	•	% *	259
256		WYG	260

LZW Coding

		DICTIONARY	NARY
Symbol	Output Code	SYMBOL	Address to Dictionary
>	63	WY	256
>	65	YS	257
S	59	*\$	258
*	15	% *	259
WY	256	WYG	260
g	47	GW	261

INPUT:

WYS*WYGWYS*WYSGG

\	DICTIONARY	Address to Dictionary	256	257	258	259	260	261	262			
j	חכוו	SYMBOL	WY	YS	*5	*	WYG	GW	WYS			
		Output Code	63	65	59	15	256	47	256			
		Symbol	M	>	S	*	WY	9	WY			

LZW Coding

		DICTIC	DICTIONARY
Symbol	Output Code	SYMBOL	Address to Dictionary
*	63	WY	256
>	65	YS	257
S	59	*\$	258
*	15	*	259
WY	256	WYG	260
_U	47	GW	261
WY	256	WYS	262
*\$	258	N*S	263

INPUT:

WYS*WYGWYS*WYSGG

		DICTIC	DICTIONARY
Symbol	Output Code	SYMBOL	Address to Dictionary
*	63	WY	256
>	65	YS	257
S	59	*\$	258
*	15	% *	259
WY	256	WYG	260
Ŋ	47	GW	261
WY	256	WYS	262
*\$	258	N*S	263
WYS	262	WYSW	264

LZW Coding

		DICTIO	DICTIONARY
Symbol	Output Code	SYMBOL	Address to Dictionary
%	63	WY	256
>	65	YS	257
S	59	*\$	258
*	15	% *	259
WY	256	WYG	260
ŋ	47	GW	261
WY	256	WYS	262
*5	258	N*S	263
WYS	262	WYSW	264
WYS	262	WYSG	265

INPUT:

WYS*WYGWYS*WYSGG

	0. ^												
NARY	Address to Dictionary	256	257	258	259	260	261	262	263	264	265		
DICTIONARY													
	SYMBOL	₩	YS	* S	*	WYG	QW	WYS	N*S	WYSW	WYSG		
	Code												
	Output Code	63	65	59	15	256	47	256	258	262	262	47	
	Symbol	>	>	S	*	ΥΥ	ŋ	ΛM	*>	WYS	WYS	9	

LZW Coding

		DICTIO	DICTIONARY
Symbol	Output Code	SYMBOL	Address to Dictionary
>	63	WY	256
,	65	YS	257
(0	59	*\$	258
*	15	*	259
٧٧	256	WYG	260
(ŋ	47	GW	261
٨٨	256	WYS	262
*0	258	N*S	263
WYS	262	WYSW	264
WYS	262	WYSG	265
(1)	47		
eof			

LZW Coding (Ex. 2)

ABACACBDACBDBDACBDAACD

INPUT:

NARY	Address to Dictionary	256	257	258	259				
DICTIONARY	SYMBOL	AB	ВА	AC	CA				
	Output Code								
	Symbol	A	В	A	C				

LZW Coding (Ex. 2)

ABACACBDACBDBDACBDAACD

INPUT:

NARY	Address to Dictionary	256	257	258	259	260	261	262	263		
DICTIONARY	SYMBOL	AB	ВА	AC	5	ACB	ВD	DA	ACBD		
	Output Code					258			260		
	Symbol	4	В	⋖	U	AC	В	Q	ACB		

LZW Coding (Ex. 2)

ABACACBDACBDBDACBDAACD

INPUT:

		DICTIC	DICTIONARY
Symbol	Output Code	SYMBOL	Address to Dictionary
٨		AB	256
а		ВА	257
٨		AC	258
U		CA	259
AC	258	ACB	260
а		BD	261
Q		DA	262
ACB	260	ACBD	263
Q		DB	264
ВD	261	BDA	265
ACBD	263	ACBDA	266

LZW Coding (Ex. 2) ABACACBDACBDBDACBDAACD INPUT:

			DICTIONARY
Symbol	Output Code	SYMBOL	Address to Dictionary
A		AB	256
В		ВА	257
A		AC	258
U		8	259
AC	258	ACB	260
В		BD	261
D		DA	262
ACB	260	ACBD	263
D		DB	264
BD	261	BDA	265
ACBD	263	ACBDA	266
A		AA	267
AC	258	ACD	268
D			
- Oof			