

Contents

List of Figures	xv
List of Tables	xvii
Abbreviations	xix
Symbols	xxi
Preface	xxiii
1 INTRODUCTION	1
1.1 Background	1
1.2 Motivation	3
1.3 Problem Statement	6
1.4 Thesis Objective	7
1.5 Outline of the thesis	10
2 THEORETICAL FOUNDATION AND LITERATURE SURVEY	15
2.1 Introduction	16
2.2 Applications	20
2.2.1 Human-Computer Interaction	20
2.2.2 Video Surveillance	22
2.3 Conventional and deep learning based human pose estimation techniques	22
2.3.1 Analysis	24
2.3.2 Input Modality	25
2.3.2.1 RGB Image	25
2.3.2.2 Depth Image	25
2.3.2.3 Infra-red(IR) Image	26
2.3.3 Conventional Approach	26
2.3.3.1 Preprocessing	26
Information calibration	26
Localization	27

	Human Detection	27
	Background Substraction	27
2.3.3.2	Feature Discription	28
	Low-level features:	30
	High-level features:	30
	Motion features:	30
2.3.3.3	Body Modelling	32
2.3.3.4	Methodology	34
	Generative and Discriminative Methods:	35
	I. Discriminative methods:	35
	(i) Mapping and Learning based methods:	36
	(ii) Deep laerning based HPE methods:	37
	Direct prediction:	37
	Indirect prediction:	38
	Single and Multi-stage approaches:	38
	II. Generative based methods:	40
2.3.4	Post-processing:	41
2.4	Deep learning based human activity recognition techniques:	42
2.4.1	Convolutional neural network	43
2.4.2	Autoencoder	43
2.4.3	Recurrent neural network	43
2.5	Benchmark and Evaluation metrics:	44
2.5.1	For human pose estimation method:	44
	2.5.1.1 Evaluation metric:	45
2.5.2	Evaluation metrics and datasets for HAR	47
	Cornell activity datasets (CAD-60)	47
	CAD-120	47
	UTD-MHAD	48
2.6	Comparative analysis of recent state-of-the-art techniques for human pose estimation.	48
2.7	Challenges	49
2.7.1	2D Human Pose Estimation	49
2.7.2	3D Human Pose Estimation	52
2.7.3	Human Activity Recognition	53
2.8	Conclusion	54
3	THE TWO DEEP NETWORKS FOR 2D HUMAN POSE ESTIMATION	55
3.1	Introduction	56
3.2	Literature	61
3.2.1	Multi-stage deep model for 2D human pose estimation	61
	<i>Convolution layer</i>	62
	<i>Feature mapping layer</i>	63

	<i>Pooling Layer</i>	63
3.2.2	2D human pose estimation using detection followed by estimation approach	64
3.3	Methods	64
3.3.1	Multi-stage Deep learning network for 2D HPE	65
3.3.1.1	Feature Extraction	68
3.3.1.2	Feature Refinement	69
3.3.1.3	Fusion	70
3.3.2	Detection followed by estimation Deep learning model for 2D HPE	73
3.3.2.1	Detection module	73
3.3.2.2	Feature Extraction and Classification	73
3.3.2.3	Pre trained CNN based model for making detection accurate	76
3.3.2.4	Deep architecture for HPE	77
3.4	Result and Discussion	78
3.4.1	Multi-stage Deep learning network for 2D HPE	78
3.4.1.1	MPII Dataset	78
3.4.1.2	LSP Dataset	78
3.4.1.3	Training Details	79
3.4.1.4	Evaluation Metric Used	79
3.4.1.5	Preprocessing	81
3.4.1.6	Experiments	82
	Experiment 1:	83
	Experiment 2:	83
3.4.2	Detection followed by estimation Deep learning model for 2D HPE	84
3.4.2.1	Experiments	84
	INIRIA Person dataset:	84
	MPII and LSP Dataset:	85
3.5	Conclusion	86
4	DEEP LEARNING APPROACHES FOR 3D HUMAN POSE ESTIMATION FROM SINGLE VIEW PERSPECTIVE	87
4.1	Introduction	88
4.2	Literature	91
4.3	Methods	95
4.3.1	Two-stage deep network for 3D human pose estimation by exploiting spatial data via its 2D pose	95
4.3.2	Three stage deep network for 3D human pose estimation by exploiting spatial and temporal data	97
4.3.2.1	Frame specific pose estimation(FSPE) 2	97
4.3.2.2	<i>Spatial_{3D}Reconstruction</i>	101
4.3.2.3	Feature Residual connection(FRC) strategy	102

4.3.2.4	<i>Temporal_{3D}Reconstruction</i>	104
4.4	Experiments and Results	105
4.4.1	Two-stage deep network for 3D human pose estimation by exploiting spatial data via its 2D pose	105
4.4.1.1	Dataset and Metrics:	105
MPII Dataset:	. . . . .	105
Human3.6M dataset:	. . . . .	105
HumanEva-I dataset:	. . . . .	106
Evaluation Metric:	. . . . .	106
4.4.1.2	Implementation Details:	107
4.4.1.3	Training Details	107
4.4.1.4	Results and Ablation Analysis:	108
4.4.1.5	MPII Dataset:	108
4.4.1.6	Human3.6M Dataset:	109
4.4.1.7	HumanEva-I	109
4.4.2	Three stage deep network for 3D human pose estimation by exploiting spatial and temporal data	111
4.4.2.1	Dataset and evaluation protocols for 2D pose estimation	111
MPII Dataset.	. . . . .	112
Evaluation Protocol(PCKh)	. . . . .	112
4.4.2.2	Dataset and evaluation protocols for 3D pose estimation	113
Human3.6M Dataset.	. . . . .	113
HumanEva-I.	. . . . .	113
Evaluation Protocols.	. . . . .	114
4.4.2.3	Implementation Details:	115
Training Details.	. . . . .	115
4.4.2.4	Result and Discussion	116
4.4.2.5	Results on MPII	116
4.4.2.6	Results on Human3.6M	117
4.4.2.7	Results on HumanEva-I	118
4.4.2.8	Failure results	118
4.5	Conclusion	118
5	DEEP NETWORK FOR 3D HUMAN POSE ESTIMATION USING MULTI-VIEW DATA	123
5.1	Introduction	123
5.2	Related Work	127
5.3	Proposed Method	130
5.3.1	Enhanced stack-hourglass approach (ESHA)	130
5.4	Multi-view spatial 3D reconstruction approach	132
Convolutional(C)-ReLU(R) layers	. . . . .	133
Batch Normalization(BN) and Dropout(D)	. . . . .	135

	Residual Module	136
	Image/2D joint heatmaps and its fusion	136
	Early Fusion	137
	Late Fusion	137
5.5	Experiments	139
5.5.1	Dataset and Evaluation protocol for ESHA	139
	MPII Dataset.	139
	Evaluation Metric(PCKh)	139
5.5.2	Datasets and Evaluation protocol for 3D HPR	140
	Evaluation Metric for 3D HPR	140
	Human3.6M Dataset.	141
	Evaluation-protocol#1	141
5.5.3	Implementation Details	141
5.5.4	Results and Discussions	142
5.5.4.1	Results and comparison with state-of-the-art	143
	MPII Dataset.	143
	Human3.6M Dataset.	143
5.5.4.2	False Results	144
5.6	Conclusion	145
5.7	conclusion	145
6	ACTIVITY RECOGNITION USING RGB AND SKELETON DATA INPUT	151
6.1	INTRODUCTION	151
6.2	Related Work	155
6.3	Methodology	157
6.3.1	RGB frames	157
6.3.1.1	Motion History Image (MHI) and Motion Energy Image (MEI)	158
6.3.1.2	First Stream	160
6.3.2	Skeleton Joints	162
6.3.2.1	From Skeleton sequences directed to the Images	163
6.3.2.2	Second Stream	168
6.3.3	Cyclic Learning Rate	172
6.3.4	Decision Level Fusion(DLF) approach	173
6.3.4.1	Weighted Product Model (WPM)	173
6.4	Experiments	174
6.4.1	UTD-MHAD Dataset	175
6.4.2	CAD-60	176
6.4.3	NTU-RGB+D120 Dataset	177
6.5	Conclusion and Future scope	179
7	CONCLUSION AND FUTURE WORK	183

Contents

7.1	Conclusions	183
7.2	Future Work	184
	References	187
	List of Publications	219