

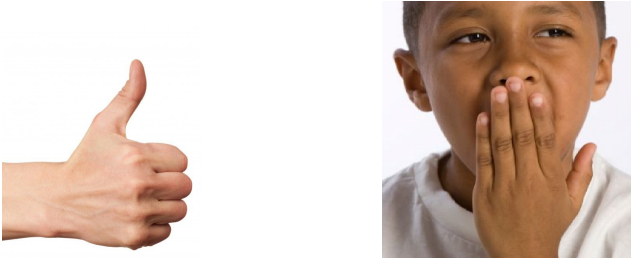
A Hierarchical Deep Temporal Model for Group Activity Recognition

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Simon Fraser University

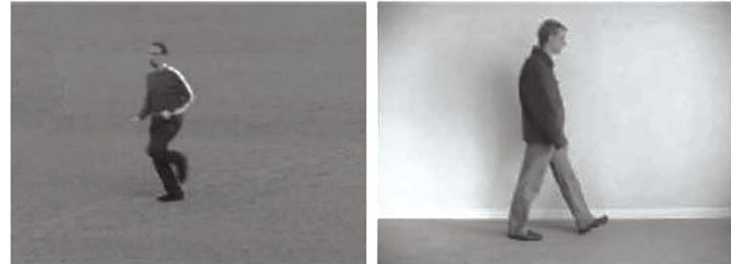
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Human Activities



Gestures



Actions



Interactions



Group Activity

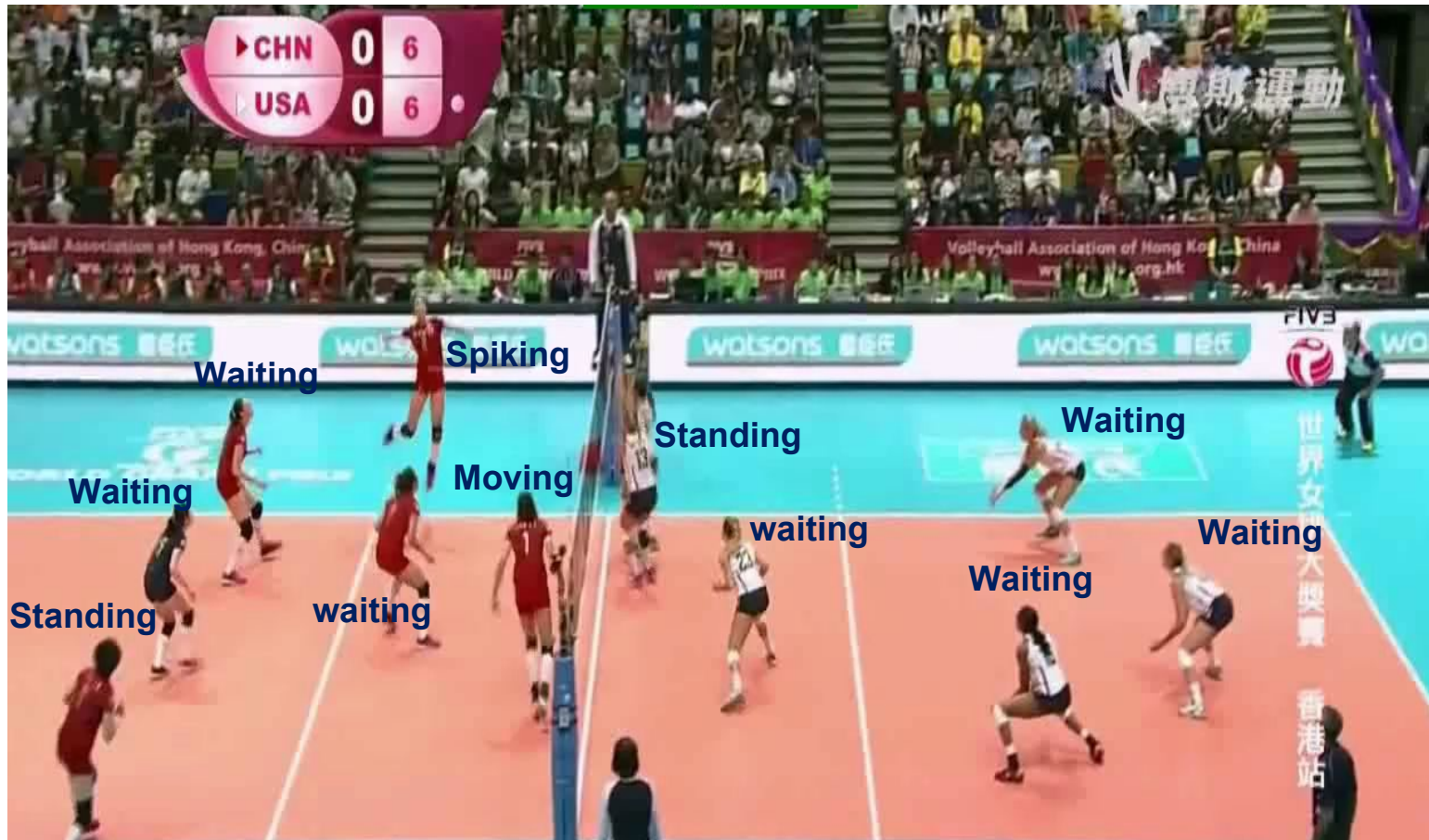
Group Activity Recognition

Major Activity = Walking scene.

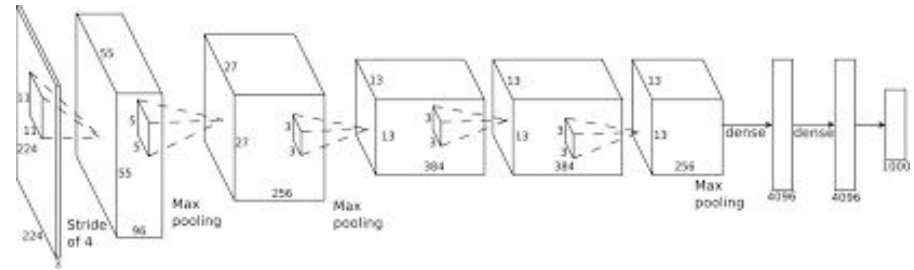


Group Activity Recognition

Main Activity = Left Spike



Naive Approach: Image Classifier



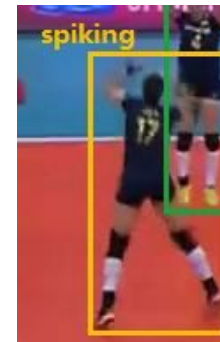
Walking

Background?!
Person's Actions?!

Hierarchical Modeling Approach

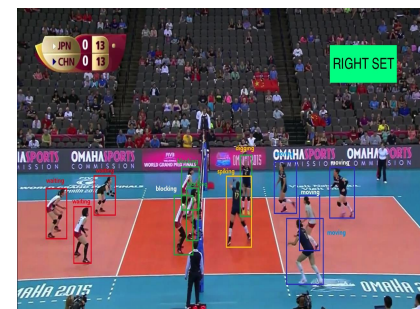
Understand
person action

- Track people in the scene
- Learn **action** classifier
- <Bounding Box, Person Action> inputs
- Extract person's representation

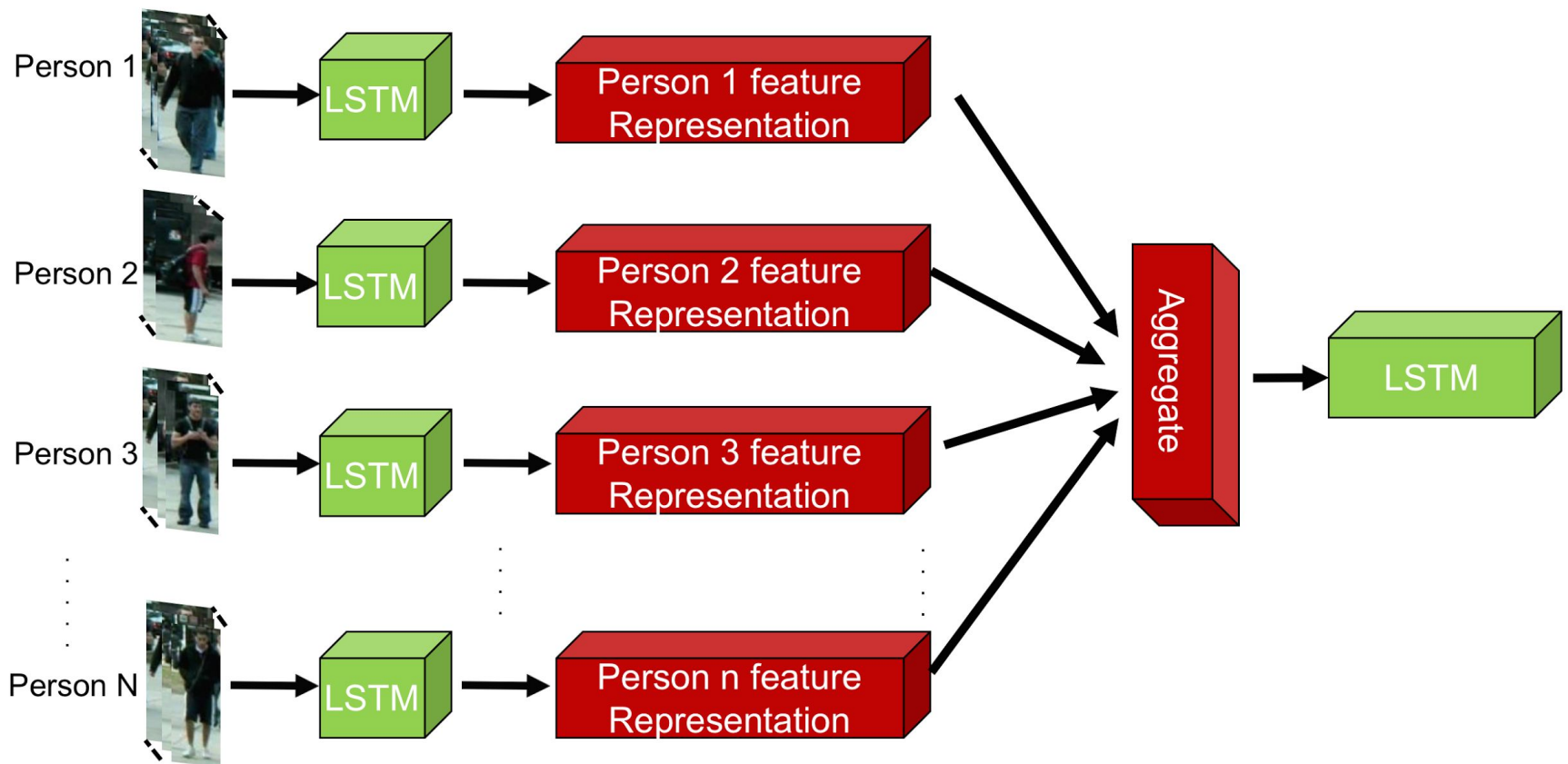


Understand
group activity

- Aggregate the people's representations
- Learn **activity** classifier
- <Scene Representation, Scene Activity>



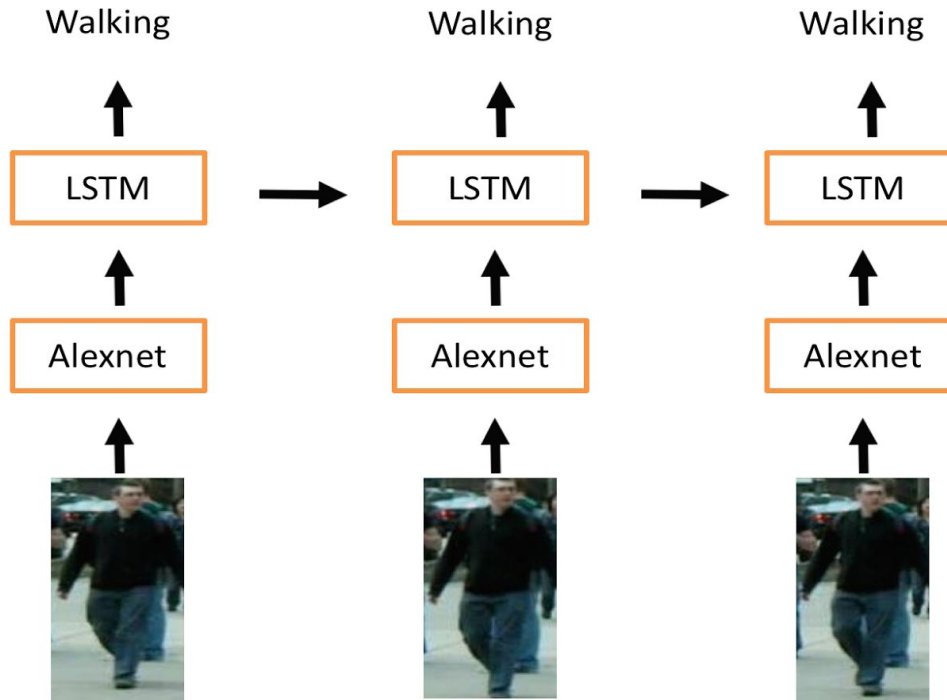
Hierarchical Deep Temporal Model



Person Action Classifier

- Build a **spatio-temporal** representation for **person's actions**.
- **Track** a manually annotated bounding box for each person for a fixed temporal window
- **Extract** deep visual representation for each tracked person using **Alexnet's fc7** features,
- Feed fc7 to a person **LSTM** to model the **temporal** dimension.
- **Extract spatio-temporal** features per person from its LSTM

Person Action Classifier



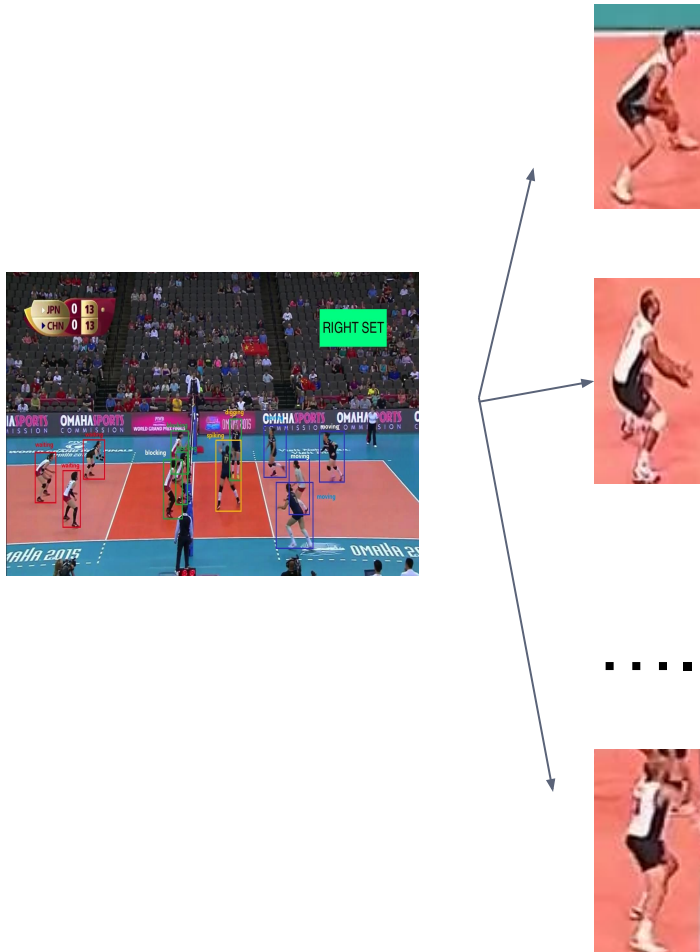
$$\begin{aligned} i_t &= \sigma(W_{xi}x_t + W_{hi}h_{t-1} + b_i) \\ f_t &= \sigma(W_{xf}x_t + W_{hf}h_{t-1} + b_f) \\ o_t &= \sigma(W_{xo}x_t + W_{ho}h_{t-1} + b_o) \\ g_t &= \phi(W_{xc}x_t + W_{hc}h_{t-1} + b_c) \\ c_t &= f_t \odot c_{t-1} + i_t \odot g_t \\ h_t &= o_t \odot \phi(c_t) \end{aligned}$$

h_t is the extracted features from lstm layer representing spatio-temporal features of a person at time t

Group Activity Classifier

- Build a **spatio-temporal** representation for the **group activity** of a given frame
- **Aggregate** all individual person representations for every temporal step.
 - Standard pooling operators (e.g. max/avg pooling) are experimented
- Feed aggregated representation to a **group level LSTM**
- Extract spatio-temporal representation for the group activity from the top-level LSTM
- Learn a soft-max **classifier** on top of the **group activity** representation.

Pooling Persons' representations



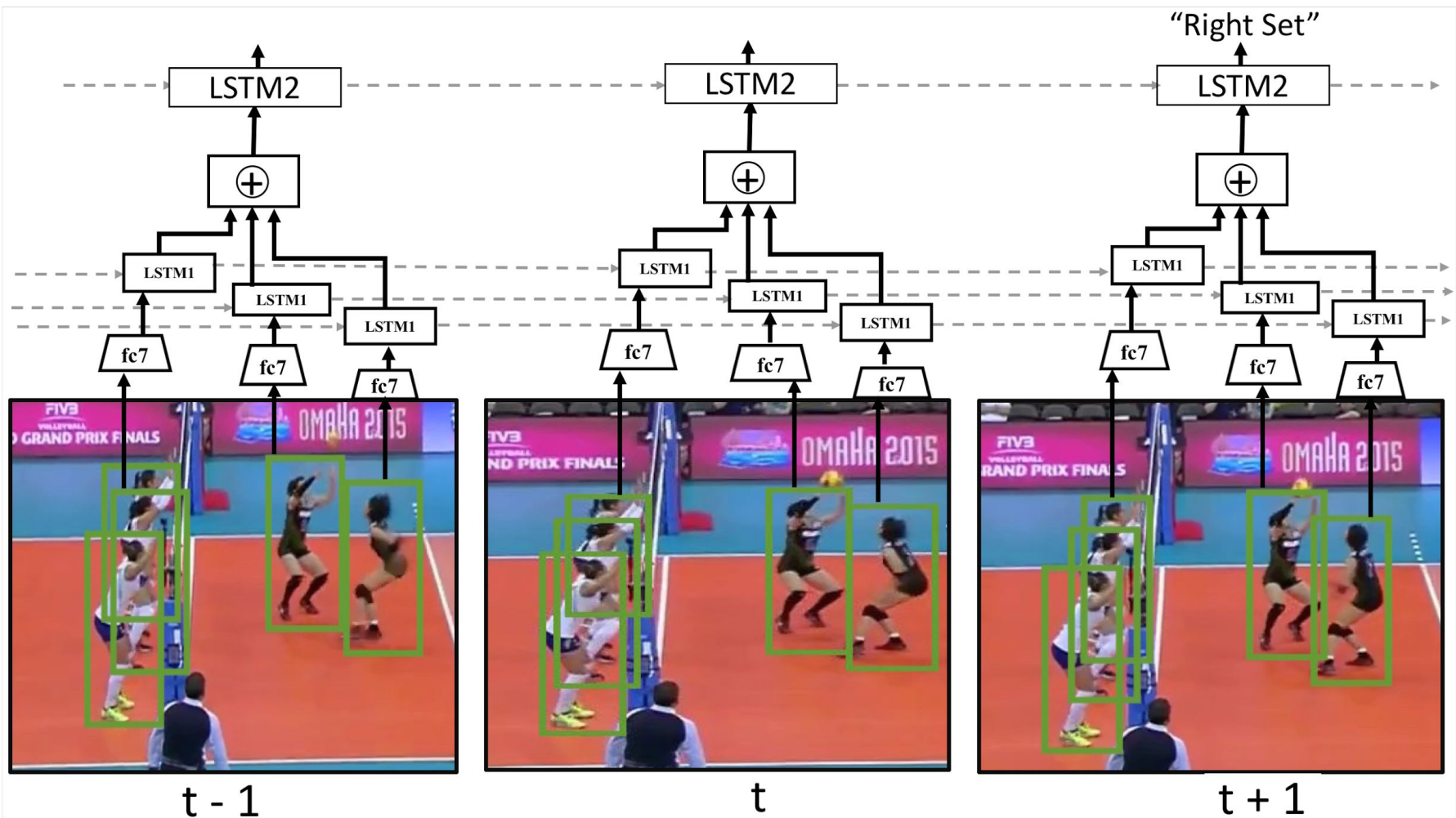
$$P_{tk} = x_{tk} \oplus h_{tk}$$

$$Z_t = P_{t1} \diamond P_{t2} \dots \diamond P_{tk}$$

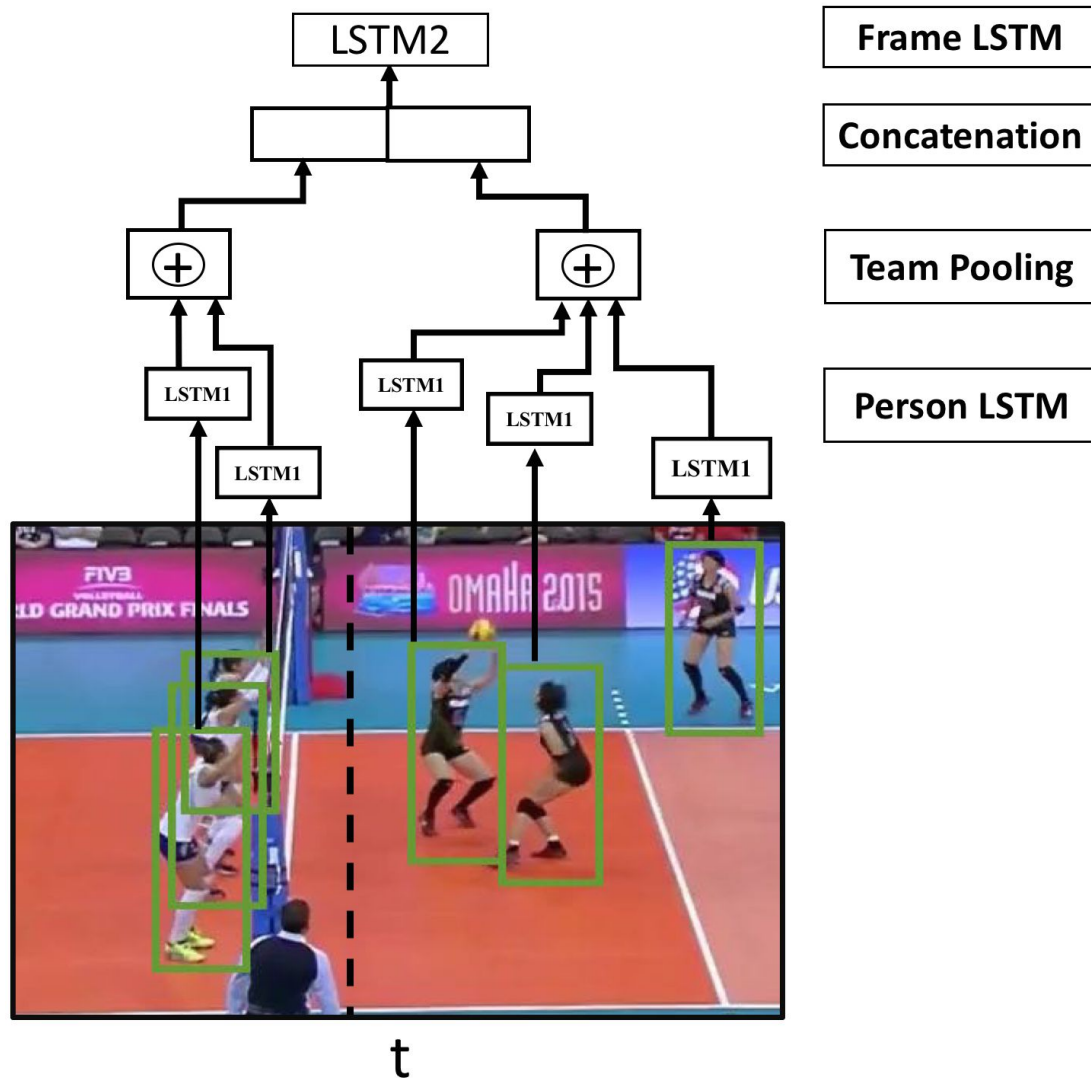
P_{tk} = kth Person representation

Z_t = Scene representation at time t

Overall model



Overall model - more spatial





Experiments

Collective Activity Dataset

- Same label set for people and group activities
- 1925 video clips for training, 638 clips for test

1. Crossing



2. Queueing



3. Talking



4. Waiting



5. Walking



Collective Activity Dataset

Method	Accuracy
B1-Image Classification	63.0
B2-Person Classification	61.8
B3-Fine-tuned Person Classification	66.3
B4-Temporal Model with Image Features	64.2
B5-Temporal Model with Person Features	64.0
B6-Two-stage Model without LSTM 1	70.1
B7-Two-stage Model without LSTM 2	76.8
Two-stage Hierarchical Model	81.5

Method	Accuracy
Contextual Model [Lan NIPS'10]	79.1
Deep Structured Model [Deng BMVC'15]	80.6
Our Model	81.5
Cardinality Kernel [Hajimirsadeghi CVPR'15]	83.4

crossing	61.54	4.27	0.85	33.33	0.00
waiting	11.41	66.44	0.00	22.15	0.00
queuing	0.00	0.00	96.77	3.23	0.00
walking	16.49	3.09	0.00	80.41	0.00
talking	0.00	0.00	0.00	0.55	99.45
	crossing	waiting	queuing	walking	talking

New Volleyball Dataset

- 4830 annotated frames from 55 YouTube videos.
- 9 person level labels, and 8 group activity labels.

Waiting



Digging



Setting



Spiking



Falling



Jumping



Moving



Standing



Blocking



Spiking



Setting



Passing



Win point



Left/right team variants

Volleyball Dataset

Method	Accuracy
B1-Image Classification	66.7
B2-Person Classification	64.6
B3-Fine-tuned Person Classification	68.1
B4-Temporal Model with Image Features	63.1
B5-Temporal Model with Person Features	67.6
B6-Two-stage Model without LSTM 1	74.7
B7-Two-stage Model without LSTM 2	80.2
Our Two-stage Hierarchical Model	81.9
IDTF (Improved Dense Trajectories)	73.4
IDTF - 1 group-box trajectories	71.7
IDTF - 2 groups-box trajectories	78.7

lpass	77.88	4.87	11.06	0.44	2.65	2.21	0.00	0.88
rpass	2.86	81.43	0.00	10.48	2.86	1.90	0.48	0.00
lset	8.93	1.19	84.52	0.60	2.98	1.19	0.60	0.00
rset	4.17	19.79	1.04	68.75	0.00	4.69	1.56	0.00
lspike	3.35	2.23	4.47	0.00	89.39	0.56	0.00	0.00
rspike	1.16	2.89	1.73	5.78	1.73	85.55	1.16	0.00
lwin	1.96	1.96	1.96	0.00	0.00	0.00	88.24	5.88
rwin	2.30	1.15	1.15	0.00	0.00	0.00	8.05	87.36
	lpass	rpass	lset	rset	lspike	rspike	lwin	rwin

Spatial Model

lpass	65.49	13.72	10.18	2.65	1.77	5.75	0.44	0.00
rpass	18.10	61.90	2.86	9.52	4.29	1.43	1.90	0.00
lset	11.90	1.19	76.79	4.76	3.57	1.79	0.00	0.00
rset	6.77	19.27	5.21	61.46	1.04	4.17	1.56	0.52
lspike	3.91	1.68	3.91	0.56	83.80	6.15	0.00	0.00
rspike	3.47	1.16	0.58	5.78	4.62	83.24	1.16	0.00
lwin	0.98	1.96	0.98	0.00	0.00	0.00	79.41	16.67
rwin	1.15	1.15	0.00	0.00	1.15	0.00	78.16	18.39
	lpass	rpass	lset	rset	lspike	rspike	lwin	rwin

Non Spatial Model

Volleyball Dataset: Success/Failure



Summary

- A two stage hierarchical model for group activity recognition
- LSTMs as a highly effective temporal model and temporal feature source
- Decent people-relation modeling with simple pooling
- Code & Dataset [Link](#)

