

Action Recognition Utilizing YGAR Dataset

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Abstract

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Introduction

Action recognition is an important area of research within the field of machine learning. Potential applications of machine recognition and understanding of human actions are endless, ranging from robotics and security surveillance to human-machine interactions. Successful progress in this field would translate to solutions for many real-world problems. Not only are the potentials enormous, diverse distinct research topics exist within the broad category of action recognition. Single action classification[1] is one of the more widely studied topics, and shares many similar techniques to image classification [2]. Moving beyond single actions, localized multiple object action recognition are also possible[3, 4]. Even sequential action recognition has been attempted[5]. Although tremendous progress has been made, much still remains to be done. Some of the obstacles facing the research efforts include: relative scarcity of high quality data[1], high resource requirements for training potential model architectures and difficulty in the processing and modification of input data for analysis.

In this paper, we propose a new method of video actions data generation by means of 3D simulation, where data generation could be customized to facilitate various research goals and specific areas of focus, including single action recognition, action orientation detection and action sequence segmentation, to name a few. Besides the presentation of our novel dataset and data generation process, we also perform several tests of action recognition using classic image classification modeling techniques and deep learning techniques, demonstrating how our dataset could be leveraged to bridge the gap between image classification tasks and 3D action recognition.

Background

Dataset Several data sets exist currently for single action recognition, including UCF101[6] and HMDB[7]. UCF101 dataset is a collection of youtube videos that contains 101 action categories with a total of 13320 videos, averaging 132 videos per category. Some of the categories in the dataset include “Apply Eye Makeup”, “archery” and “Frisbee catch”.

HMDB[7] is another data set that aims to further the progress in understanding action recognition. It contains 51 actions and a total of 7000 video clips. The actions within the videos are broadly categorized into five types: general facial actions, facial actions with object manipulation, general body movements, body movements with object interaction and body movements for human interaction.

Overtime larger data sets have been created for video action recognition tasks such as the kinetics dataset[8], where 700 classes of actions have been categorized, each with an average of 926 sample videos.

More recently, spatio-temporally localized atomic visual actions data sets (AVA)[4] have also been introduced, where actions by multiple objects exist within the same video sample.

Action Recognition As more and more data sets come into existence, models have been built to train and test on these data sets, including convolutional neural network, LSTM[1] based encoder models and 3D neural networks that combines frames and optical flow information [1]. More complex architectures for localized action recognitions have also been proposed[3].

Bottlenecks Although commendable progress has been made in the research of action understanding, many issues still hinder its progress. One of them is the quality of available data sets. The existing data sets are typically collected from video data sources and curated by human judges, this process introduces many variabilities in the quality and comprehensive-

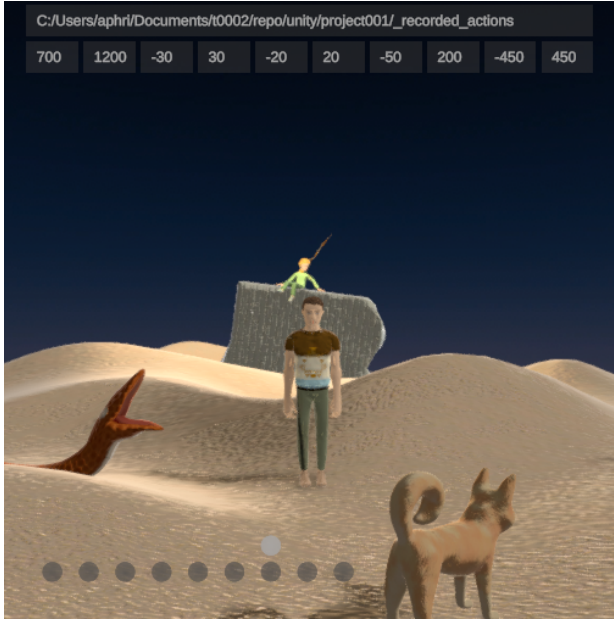


Figure 1: Action simulation engine.

ness of the sample data, and because these data are collected as they are available, often it is impossible to control for characteristics that are desired for particular research objectiveness. For example, it is often difficult to study the specific effects of object variation and orientation separately. Besides targeted research needs, it is often difficult to study hierarchies of categories. As an example, if we would like to conduct a research where we would like to first recognize the person in the image, and then the action performed by the person, then it would be very difficult to conduct such studies with the existing data sets.

The second issue is the quantity of available data, although kinetics data set has attempted to address the issue of volume with larger number of samples, they are still only single action samples of variable qualities, making studies of localized actions and sequential action recognition difficult.

We hope that our new data set could help address some of these issues and contribute to the progress of the study in action recognition.

Data

Data Generation

Our data set is generated by a 3D simulation program(Figure 1) developed in Unity that supports configurations for zoom, center offset, camera angle orientation and avatar styles. The amount of zoom applied to the camera typically varies from 50% to 200%, 100% represents the default zoom amount. An offset could be applied to the x or y direction of the



Figure 2: Various camera angle, offset and zoom configurations.



Figure 3: Appearance styles. First set of 4 figures show possible hairstyles. Second set of 4 figures show possible cloth patterns. Third set of 4 figures shows possible pants patterns.

the camera relative to the target of the camera, the unit of this configuration is based on the simulation world space metric system (meters in world space). The camera could also be rotated about the x and y axis relative to the target avatar, we typically set these configurations between -5 degrees to 90 degrees about the x axis and -90 degrees to 90 degrees about the y axis(Figure 2).

The avatar character in the simulation could be configured with various hair, cloth and pants style. In our current iteration, there are 4 different styles for hair, cloth and pants respectively, for a total of 64 unique combinations(Figure 3).

Our first set of actions include a total of 10 different yoga poses: camel, chair, childs, lord of the dance, lotus, thunderbolt, triangle, upward dog, warrior II and warrior III. Each of the 10 yoga poses have 4 type variations within them, some with more pronounced difference than others, for a total of 40 action and action types(Figure 6). We have decided to choose this set of actions as our first action sets because each pose is distinct and has a defined ending position, which allows us to use image classification techniques to compare classic modeling architecture and deep learning ones.

Our simulation also supports the option to include static background and dynamic background objects which would allow us to adjust the complexity of the sample data.

Data Set

From the actions and configurations available within our simulation program, we generated 3 sets of video actions data of varying difficulties based on the zoom, offset, angle and scene background configurations specified: easy, medium and hard.

The configurations of the three datasets are listed in the Table 1. Each dataset is generated as follows: for each of the 40 action and action types, we sam-

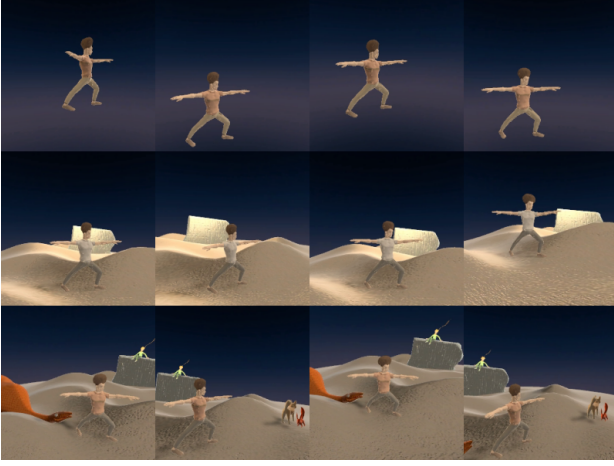


Figure 4: Difficulty levels. First row shows samples from easy level data set. Second row shows samples from medium level data set. Third row shows samples from hard level data set.

Table 1: Data set configurations: zoom in percentage, offset in meters, angle in degrees.

Type	Easy	Medium	Hard
Min. Zoom	80%	80%	70%
Max. Zoom	110%	110%	120%
Min. X Offset	-1.5	-1.5	-3.0
Max. X Offset	1.5	1.5	3.0
Min. Y Offset	-1.5	-1.5	-2.0
Max. Y Offset	1.5	1.5	2.0
Min. X Angle	-5°	-5°	-5°
Max. X Angle	10°	10°	20°
Min. Y Angle	-30°	-30°	-45°
Max. Y Angle	30°	30°	45°
Static Background	Off	On	On
Dynamic Background	Off	Off	On

ple 25 random hair, cloth and pants style combinations to create action scenes for, and for each action scene, we capture the action with 20 cameras of randomly generated offsets and angles based on the constraints specified. Each dataset is therefore consisted of 20,000 videos, every action and action type label combination contains 500 videos and every action label contains 2000 videos. Figure 4 shows samples from each difficulty level.

As we can see from Table 1, the configuration of easy and medium dataset is identical except medium dataset has static background turned on.

Each video is typically about 1 second in length, sampled at 30 FPS. the size of each video is around 80KB and the frame is 351X351 pixels.

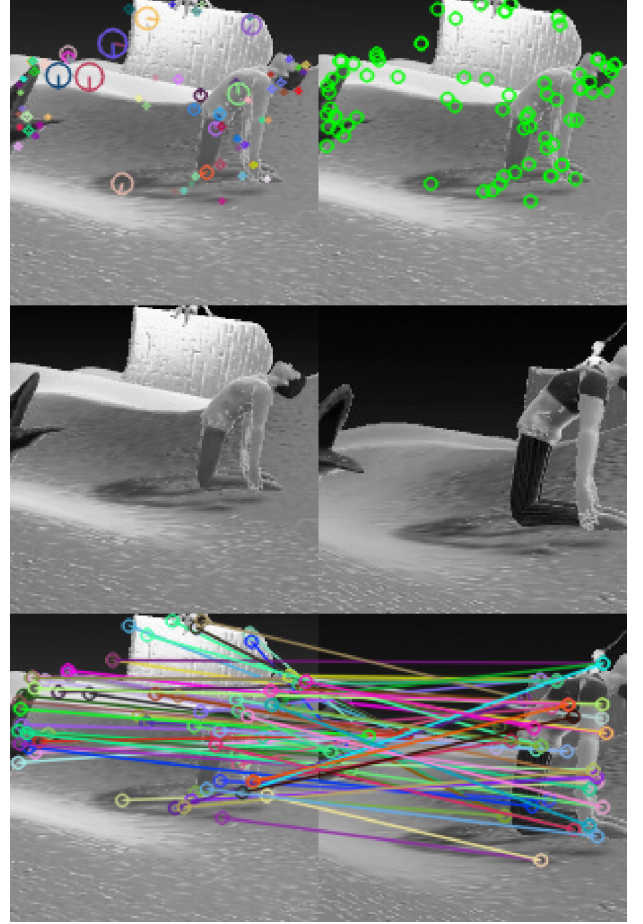


Figure 5: Sift feature mapping. First row shows sift features (with and without size) extracted from train image. Second row shows the train image and test image in gray scale. Third row shows the train image features matched to test image features.

Model

For the modeling section of this research, we have extracted the frame at 50% location of each video as input to our models, since the actions within each video are yoga poses and could be adequately represented by the middle frame. This approach would ideally be enhanced later to use multiple frames within each video, supplemented with temporal information represented by optical flow.

Each frame extracted from the video as 256X256X3 pixel RGB image, then converted to grayscale image of 256X256 pixels. Afterwards, we crop top, bottom, left and right of each grayscale image by 70, 30, 50 and 50 pixels to create 156X156 pixels grayscale image, in order to further reduce the size of input data.

Filter

Principal Component Analysis For computing PCA, we first downsize the input grayscale frame by 50% to 78X78 pixels and flatten the image into an

array of length 6084. Then we apply PCA on the input array, keeping the top 256 principal components. Finally each of the image array is projected onto the top 256 components to create the PCA weights for each image.

Histogram of Oriented Gradients In order to compute the HOG features, we first crop the input grayscale image to 100X100 pixels, due to the amount of time HOG computation requires. Then HOG feature descriptor is computed with 9 orientations, 2x2 pixels per cell and 2x2 cells per block.

Scale-Invariant feature transform & K-Mean Cluster Bag of words is a commonly used technique in image classification. Similar to NLP, image features are used as words. We utilize SIFT features for this purpose. SIFT is one of the important algorithms that detect objects irrelevant to the scale and rotation of the image and the reference. This helps greatly when we are comparing real-world objects to an image because the features extracted are independent of the angle and scale of the image. Figure 5 shows an example of how features from one image could be mapped to another image even when the objects in the image have different orientations. We use OpenCV to extract SIFT descriptors for each image. The descriptors are group into N (N=60) clusters. Then a feature vector $v \in \mathbb{R}^n$ is built where each direction represents a cluster and magnitude represents the count of SIFT descriptors in that cluster for the image.

Classifier

Support Vector Machine We use the support vector classification directly from Scikit-Learn with the default parameters: 1.0 for regularization, radial basis function as kernel and maximum iterations of 50.

Logistic Regression Again we use the logistic regression function from Scikit-Learn with default parameters: "LBFGS" as the solver and maximum iterations of 100.

Gradient Boosting Tree The gradient boosting tree we trained uses 100 estimators, each with a maximum depth of 3 and a learning rate of 0.1.

Convolutional Neural Network Our convolutional neural network model is inspired by the VGG-16 CNN model. The model consists of 10 convolutional layers, where the first two layers extract 32 features and subsequent pairs of layers extract double the number of features from the previous layers. After each pair of layers, a max pooling of size 2X2 is applied to the input features from the previous convolutional layers. Finally, two dense layers followed by a classi-

fication layer is applied to generate the model prediction.

Evaluation

Baseline

Our baseline for evaluation is the SVM model trained on the unfiltered input data scaled down to 20% at the "easy" level. We felt that this model is the most natural starting point to evaluate how effective the various types of filtering and modeling techniques are and how much they contribute to the final accuracy of the models.

Process

We start out by training our baseline models on the "easy" level dataset, which produces a guideline for choosing models for further training. Then combinations of filters and models with the best results are trained on the "medium" level dataset to assess the capabilities of the models. Finally the best performance models are challenged with the "hard" dataset for evaluation.

For every data set and model training, we split the sample data into three sets, training set, validation set and test set, in the ratio of 8:1:1. For classic models, validation data set is not used at all, training set is used to train and optionally validate during training depending on the model in question (GBT), and test data set is used to compute the final accuracy of the models.

Results

Table 2 shows the results from training and testing combinations of 4 models and 3 filters. We start out with the easy level data set, training 3 models (SVM, Logistic, GBT) with no filters except downsizing the input images by a further 80%. The results show that gradient boosting tree generates the best performance out of the three models. However the results of SVM and GBT are comparable with action and action type label combination. Three more sets of models are trained on the easy level data set with the PCA filter, the HOG plus PCA filter combination and the SIFT filter. The results show steady improvements, where HOG plus PCA filter with SVM model achieving the best accuracy for action plus action type labels, although the SIFT filtered models perform better on average.

For the medium set, again we perform the same training and testing for all of the classic models, but this time also including the CNN model. As shown in

Table 2: Model results for each difficulty level and model/filter combination. Action column displays results for using action only as label, A+T column displays results for using action and action type combination as label.

Model	Filter	Easy		Medium		Hard	
		Action	A+T	Action	A+T	Action	A+T
SVM	Downsize	37%	29%	15%	5%	-	-
Logistic	Downsize	43%	16%	21%	6%	-	-
GBT	Downsize	71%	29%	61%	14%	-	-
SVM	PCA	48%	42%	15%	6%	-	-
Logistic	PCA	44%	17%	23%	6%	-	-
GBT	PCA	69%	30%	24%	3%	-	-
SVM	HOG PCA	68%	54%	27%	11%	-	-
Logistic	HOG PCA	55%	21%	34%	10%	-	-
GBT	HOG PCA	85%	46%	30%	5%	-	-
SVM	SIFT KMean	50%	43%	34%	28%	16%	9%
Logistic	SIFT KMean	70%	46%	53%	30%	33%	13%
GBT	SIFT KMean	71%	44%	56%	27%	32%	12%
CNN	-	-	-	100%	98%	95%	92%

the table, the CNN model easily outperforms all other models, achieving 98% accuracy on the action plus action type labels. Second best performing models are the SIFT feature based models, achieving 28% accuracy on average for action plus action type labels. Looking at the data, a general trend appears: SIFT filtered models models general performs better. This is not surprising, because one of the key variations in our samples is the orientation of cameras, SIFT features should be able to reduce the complexity due to these variations to a great extent.

Finally, We take the best performing models on medium data set and apply them to the hard data set(retraining on hard data set). The results show that CNN model still vastly outperform other models, the SIFT feature models perform moderately well on the action only labels, but falters when trying to predict the action plus action type labels.

Model Analysis

Hyperparameter Search

Although CNN model produces superior performance by a large margin, The models with SIFT plus K-Mean clustered features do show great promise. Therefore we perform a hyperparameter search for these models. For this exercise, we use the “hard” level validation data set to optimize the model parameters, Table 3 shows the results. Interesting to note is that SVM performs much better after hyperparameter search, mainly benefiting from gamma parameter change. Logistic Regression results does not change at all, while GBT results become worse, presumably from using a much smaller set of data to

estimate the parameters.

Error Analysis

CNN We perform a detailed analysis of the source of error in the hard level dataset based on the results we obtain from the CNN model.

Discussion

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Future

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References

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Table 3: Best SIFT|KMean filtered model after hyperparameter search.

Model	Filter	Hard		Parameters
		Action	A+T	
SVM	SIFT KMean	40%	16%	C=1 gamma=0.01 kernel=rbf
Logistic	SIFT KMean	33%	13%	C=0.03 penalty=l2 solver=newton-cg
GBT	SIFT KMean	33%	10%	learning_rate=0.1 max_depth=2 n_estimators=50

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Figure 6: 10 yoga poses, each with 4 different variaionts.