

# HUMAN ACTIVITY CLASSIFICATION USING DEEP LEARNING BASED ON 3D MOTION FEATURE

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## Human activity classification using deep learning based on 3D motion feature

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## ARTICLE INFO

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Human activity  
Motion feature  
Deep learning  
Classification

## ABSTRACT

Human activity classification is needed to support various fields. The health sector, for example, requires the ability to monitor the activities of patients, the elderly, or people with special needs to provide services with fast response as needed. In the traditional classification model, the steps taken to start from the input of data and then proceed with feature extraction, representation, classifier and end with semantic labels. The classification stage uses Convolutional Neural Network (CNN) deep learning to data input, CNN, and semantic labels. This paper proposes a novel method of classifying nine activities based on the movement features of changes in joint distance using Euclidean on the order of frames in each activity segment as input to the CNN model. This study's motion feature extraction technique was tested using various window sizes to obtain the best classification accuracy. The experimental results show that the selection of window size 16 on the motion feature setting will produce an optimal model accuracy of 94.08% in classifying human activities.

## 1. Introduction

The Human Movement Analysis (HMA) research area is an interdisciplinary research area that attracts great interest from the computer vision, machine learning, multimedia, and medical research communities. The implementation of this research is utilized for human-computer interaction, security (intelligent surveillance), health (assisted clinical studies), information technology (content-based video capture), entertainment (special effects in somatosensory film and game production) for all aspects of our daily life (Seidenari et al., 2013). As an essential research series of HMA, Human Activity Recognition (HAR) forms the basis for all the applications mentioned above. Utilization has been widely used in health care applications such as elderly monitoring, exercise monitoring, and rehabilitation monitoring (Huang et al., 2020). HAR is also developing in applications in the fields of robotics, entertainment, biometrics, and multimedia (Bennamoun et al., 2020). An indoor emergency awareness alarm system was also developed using deep neural networks. The system uses mobile devices for people such as the elderly, people with special needs or children who may need help (Kim & Kim, 2020).

In recent years, the development of deep learning has resulted in significant advances in activity recognition. In various research topics, there are two main methods, framework-based activity recognition and sensor-based activity recognition (Goddard, 2021). One of the main

problems of the existing HAR strategy is the relatively low classification accuracy, so it is necessary to increase the accuracy, which requires high computational overhead (Kong et al., 2021). Classification models using deep learning are continuously being developed to improve performance resulting from traditional video classification models.

One of the Deep Learning algorithms to process image or sound data is a Convolutional Neural Network (CNN). CNN in this study was used to classify labelled data using the supervised learning method. Supervised learning work is the presence of target data for data training. Among all types of neural networks, CNN is known as the most successful and is widely used to solve problems of image recognition, object detection/localization, and even text processing (Alpaydin, 2021). CNN (convolutional kernels) combines some local filters with raw input data and generates local translation-invariant features in the convolutional layer. The successive pooling layer extracts fixed-length features via a sliding window from raw input data following some rules like mean, max., etc. (Zhao et al., 2019).

This paper proposes a model for recognizing human activities using deep learning to classify human activities (actions). The preparation of data as input data for the CNN model is the main concern in this paper. Meanwhile, we also pay attention to designing the CNN model that will be trained on the dataset. The source data of the 3D coordinate points of the joints' positions will be processed to detect changes in movement that occur by calculating the distance of the coordinates of the joints

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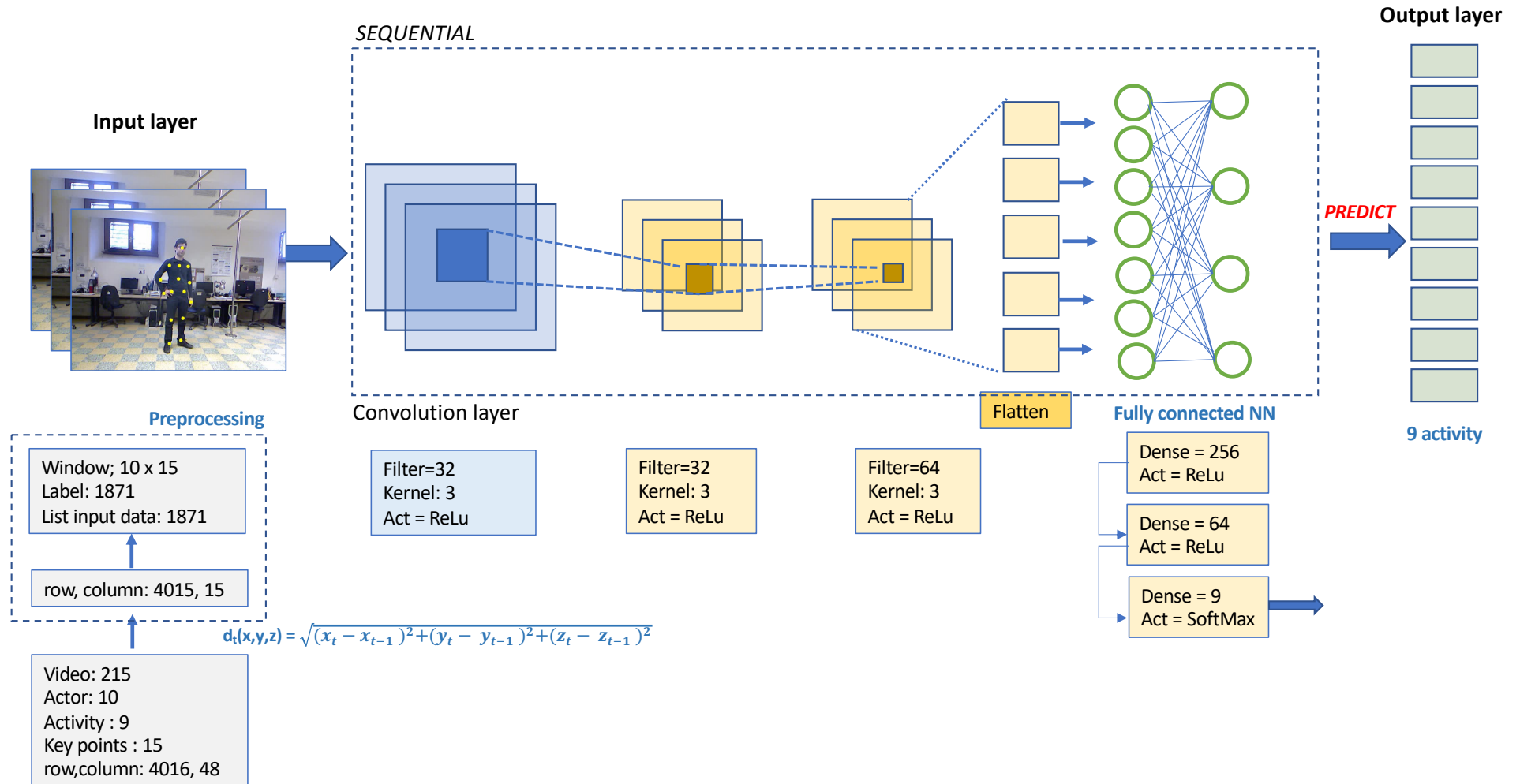
<https://doi.org/10.1016/j.mlwa.2023.100461>

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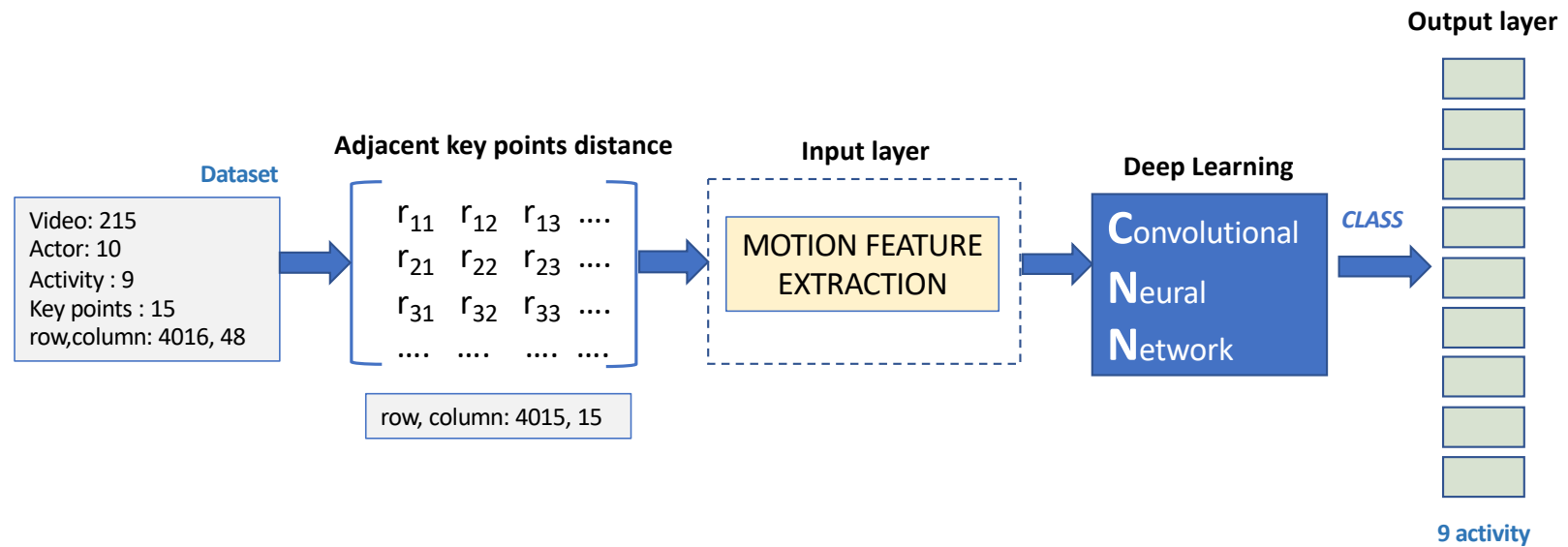
Available online 15 March 2023

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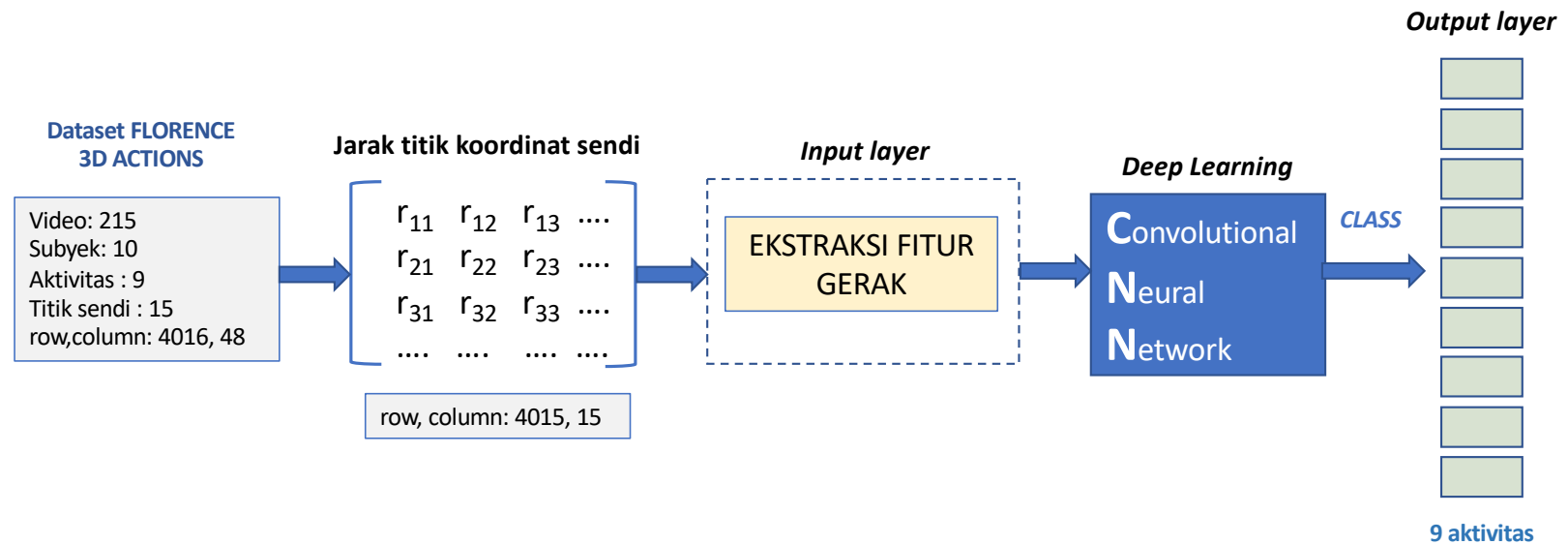
# Arsitektur Model CNN



## Arsitektur Model CNN - paper



## Arsitektur Model CNN – paper - indonesia



# 15 JOINT

| head | neck | spine | l.shoulder | l.elbow | l.wrist | r.shoulder | r.elbow | r.wrist | l.hip | l.knee | l.ankle | r.hip | r.knee | r.ankle |
|------|------|-------|------------|---------|---------|------------|---------|---------|-------|--------|---------|-------|--------|---------|
|------|------|-------|------------|---------|---------|------------|---------|---------|-------|--------|---------|-------|--------|---------|

$$r_n(x,y,z) = \sqrt{(x_n - x_{n-1})^2 + (y_n - y_{n-1})^2 + (z_n - z_{n-1})^2}$$

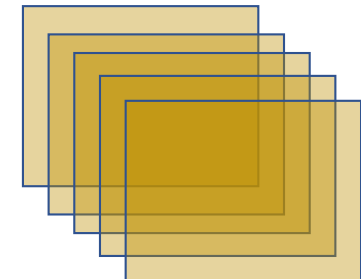
MOTION FEATURE

## DATASET

Video 1

|         | Id Video | Person | Activity | head |   |   | neck |   |   | ... |
|---------|----------|--------|----------|------|---|---|------|---|---|-----|
| frame 1 | 1        | 1      | 1        | x    | y | z | x    | y | z |     |
| frame 2 | 1        | 1      | 1        | x    | y | z | x    | y | z |     |
| frame 3 | 1        | 1      | 1        | x    | y | z | x    | y | z |     |
|         | 1        | 1      | 1        | x    | y | z | x    | y | z |     |
|         | 1        | 1      | 1        | x    | y | z | x    | y | z |     |

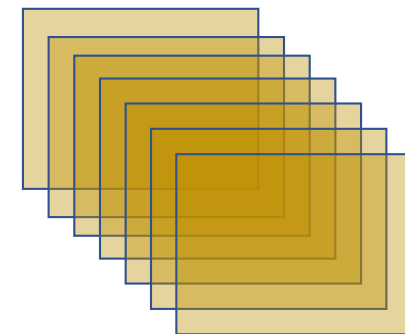
| head | neck | ... |
|------|------|-----|
| r    | r    |     |
| r    | r    |     |
| r    | r    |     |
| r    | r    |     |
| r    | r    |     |



Video 2

|         | Id Video | Person | Activity | x | y | z | x | y | z | ... |
|---------|----------|--------|----------|---|---|---|---|---|---|-----|
| Frame 1 | 2        | 1      | 1        | x | y | z | x | y | z |     |
| Frame 1 | 2        | 1      | 1        | x | y | z | x | y | z |     |
| Frame 3 | 2        | 1      | 1        | x | y | z | x | y | z |     |
|         | 2        | 1      | 1        | x | y | z | x | y | z |     |

|   |   |  |
|---|---|--|
| r | r |  |
| r | r |  |
| r | r |  |
| r | r |  |
| r | r |  |



Video 215



(10 person)  
(9 aktifitas)

(4016, 45)  
(baris, kolom DATASET)



(4015, 15)  
(baris, joint)

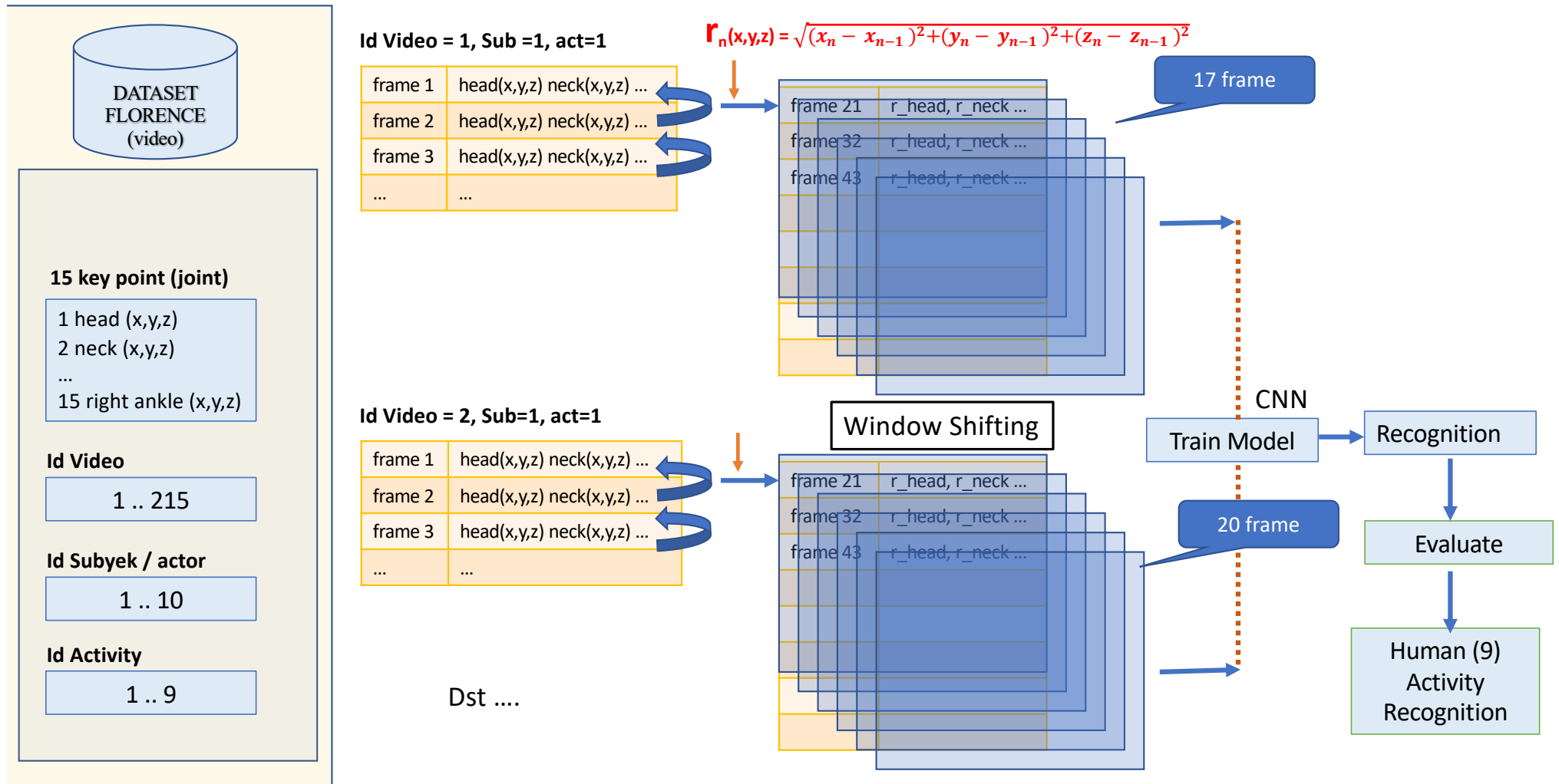
List → (1871 , 10 , 15)  
Label Aktifitas → 1871

window

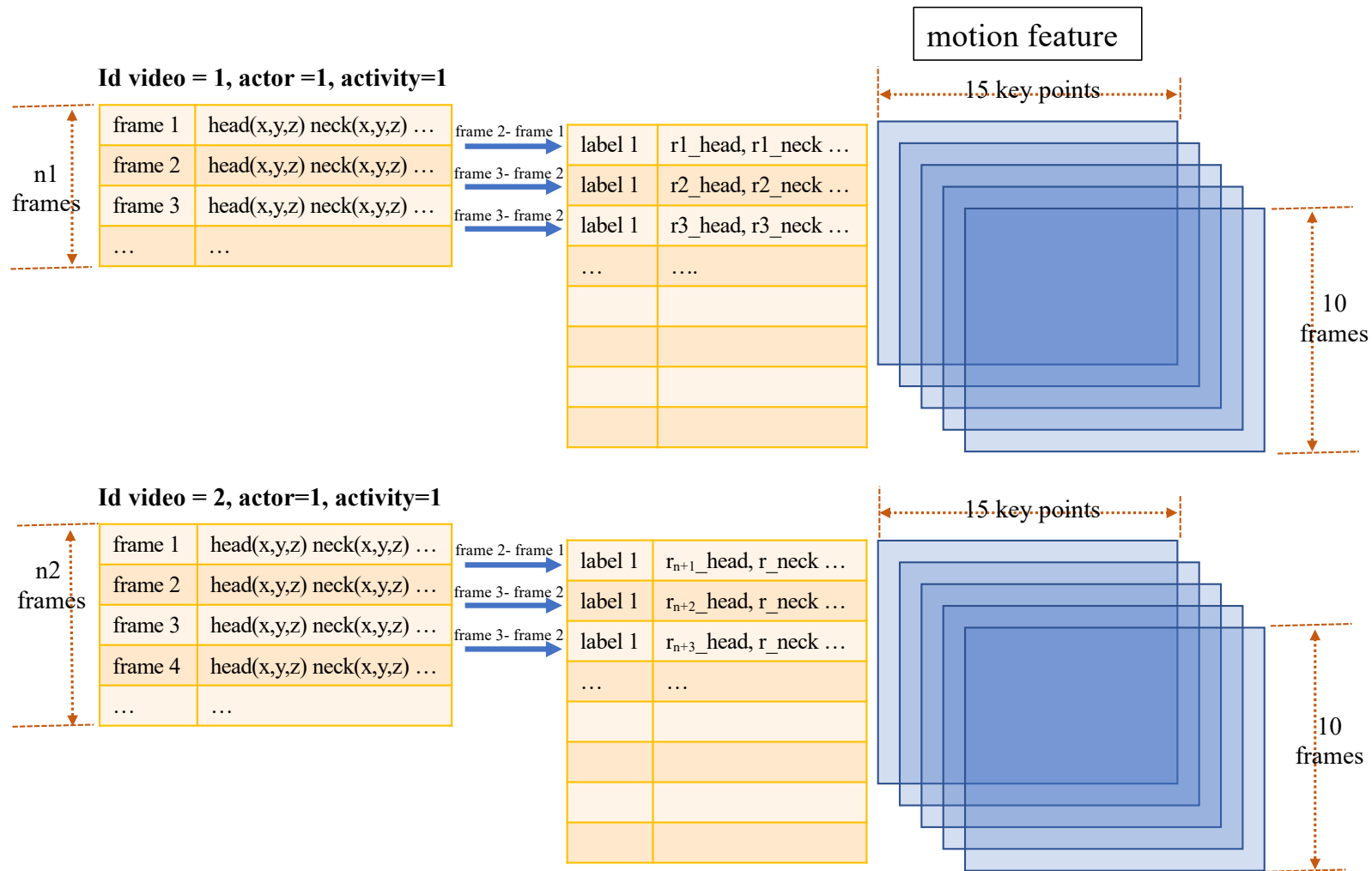
Jml  
frame/  
window

Jml joint

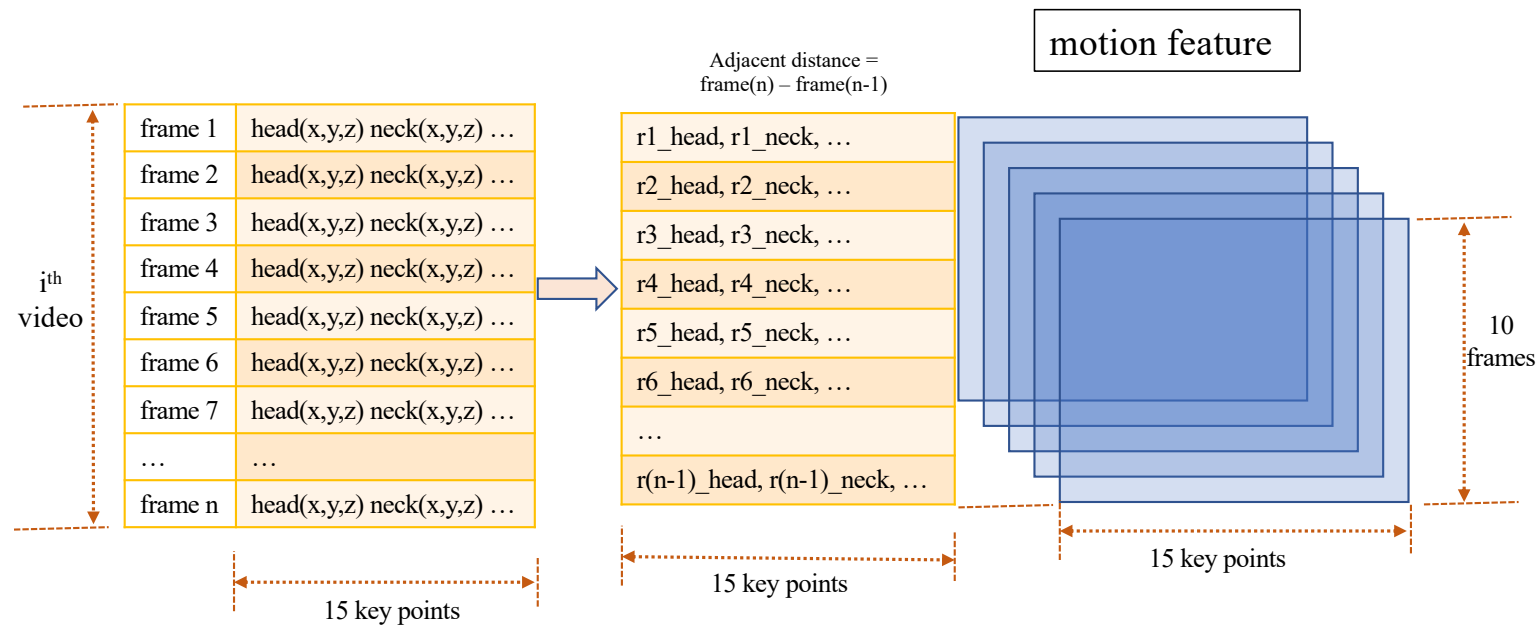
## Data time series – Motion Recognition



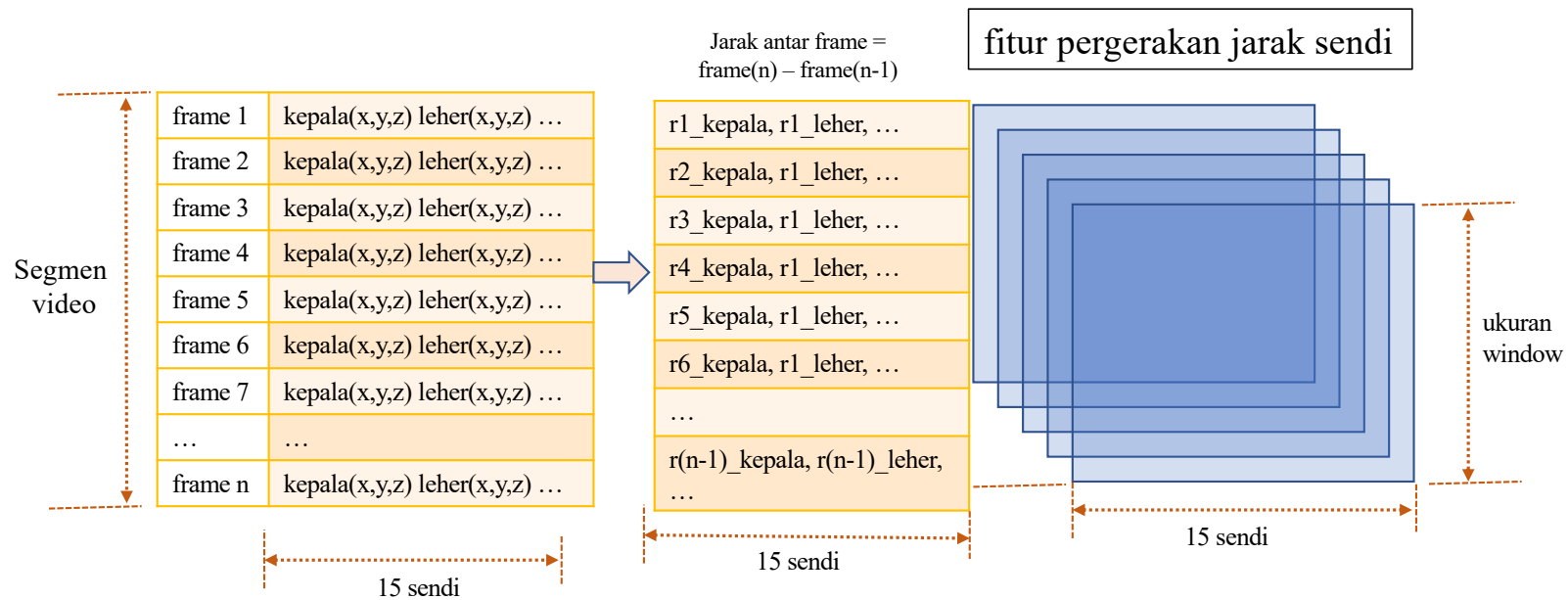
## Data time series – Motion feature – (paper)



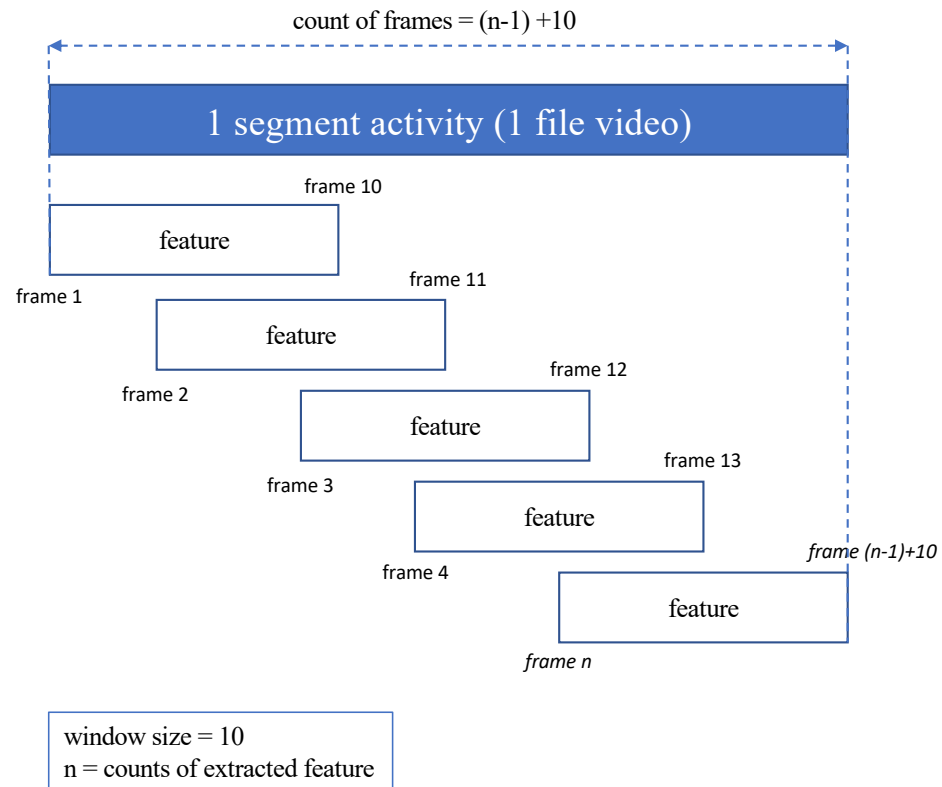
## Data time series – Motion feature – (revisi paper 14 Juli21)



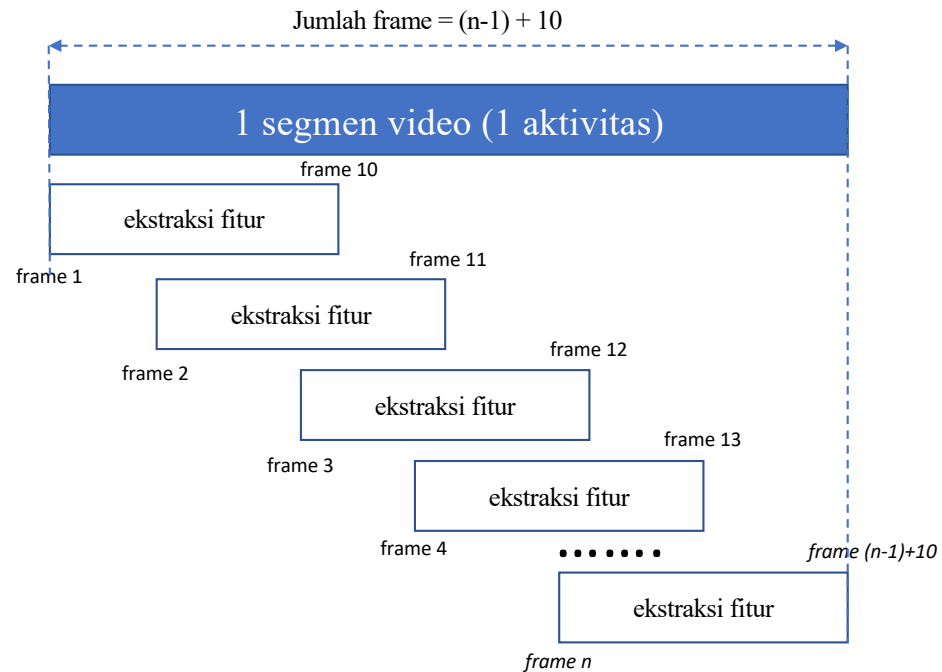
## Data time series – Motion feature – (revisi paper 14 Juli21) - Indonesia



# Motion feature extraction



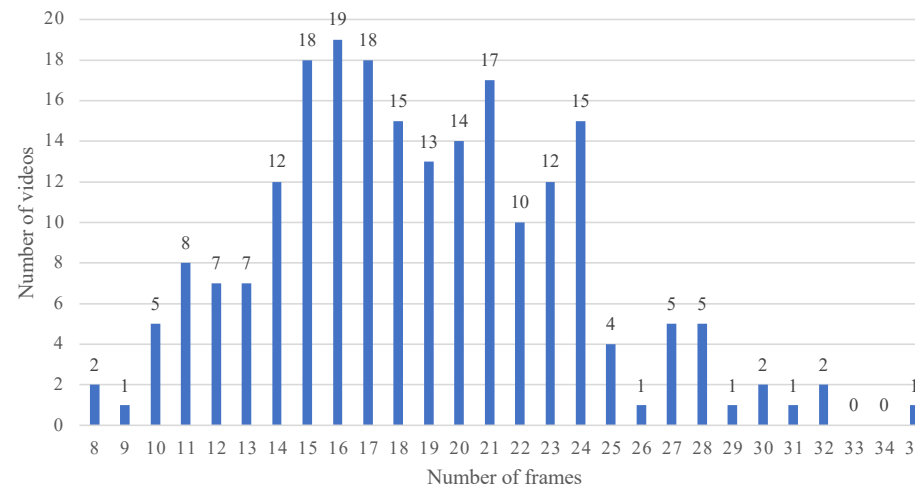
# Motion feature extraction



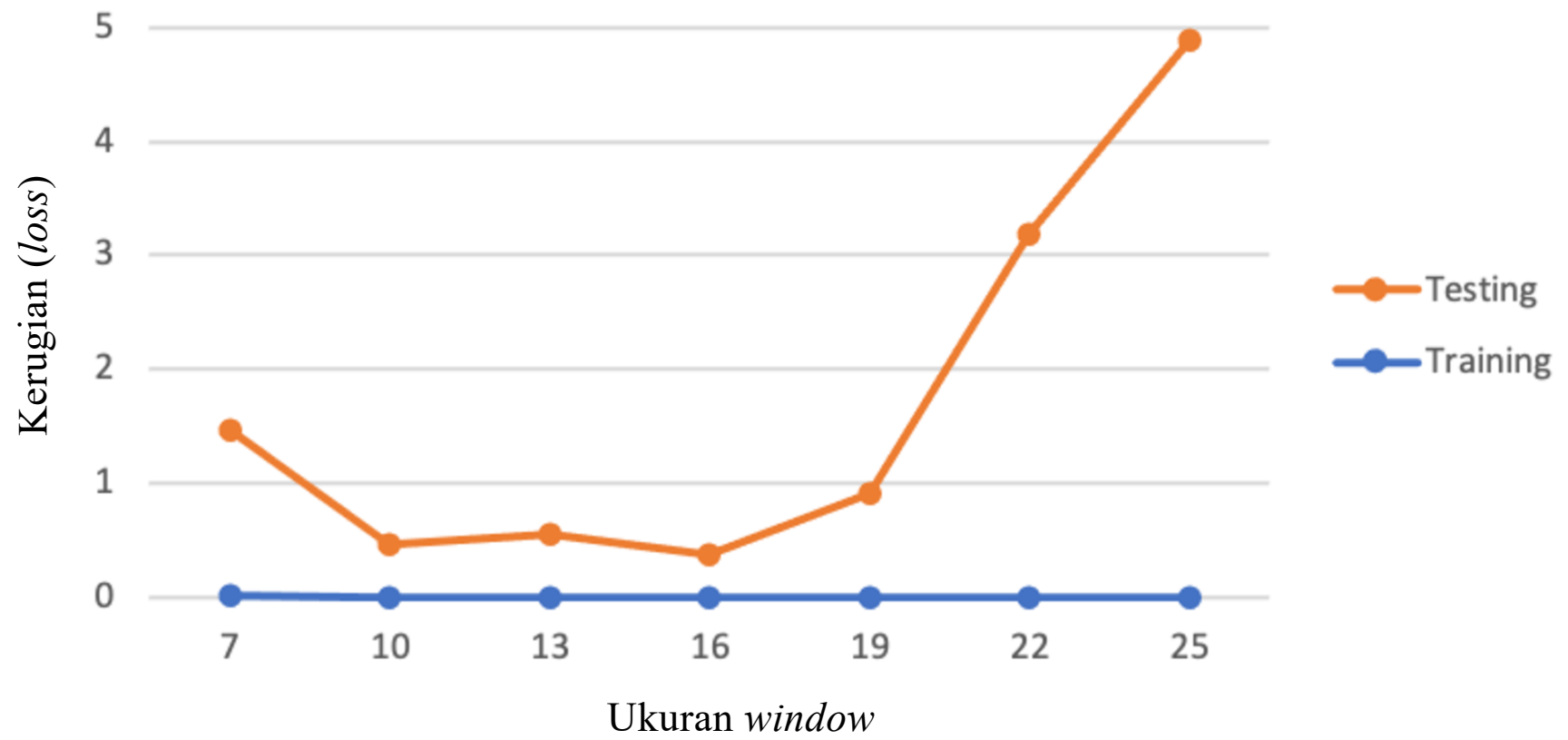
Contoh: ukuran window = 10  
n = jumlah ekstraksi fitur

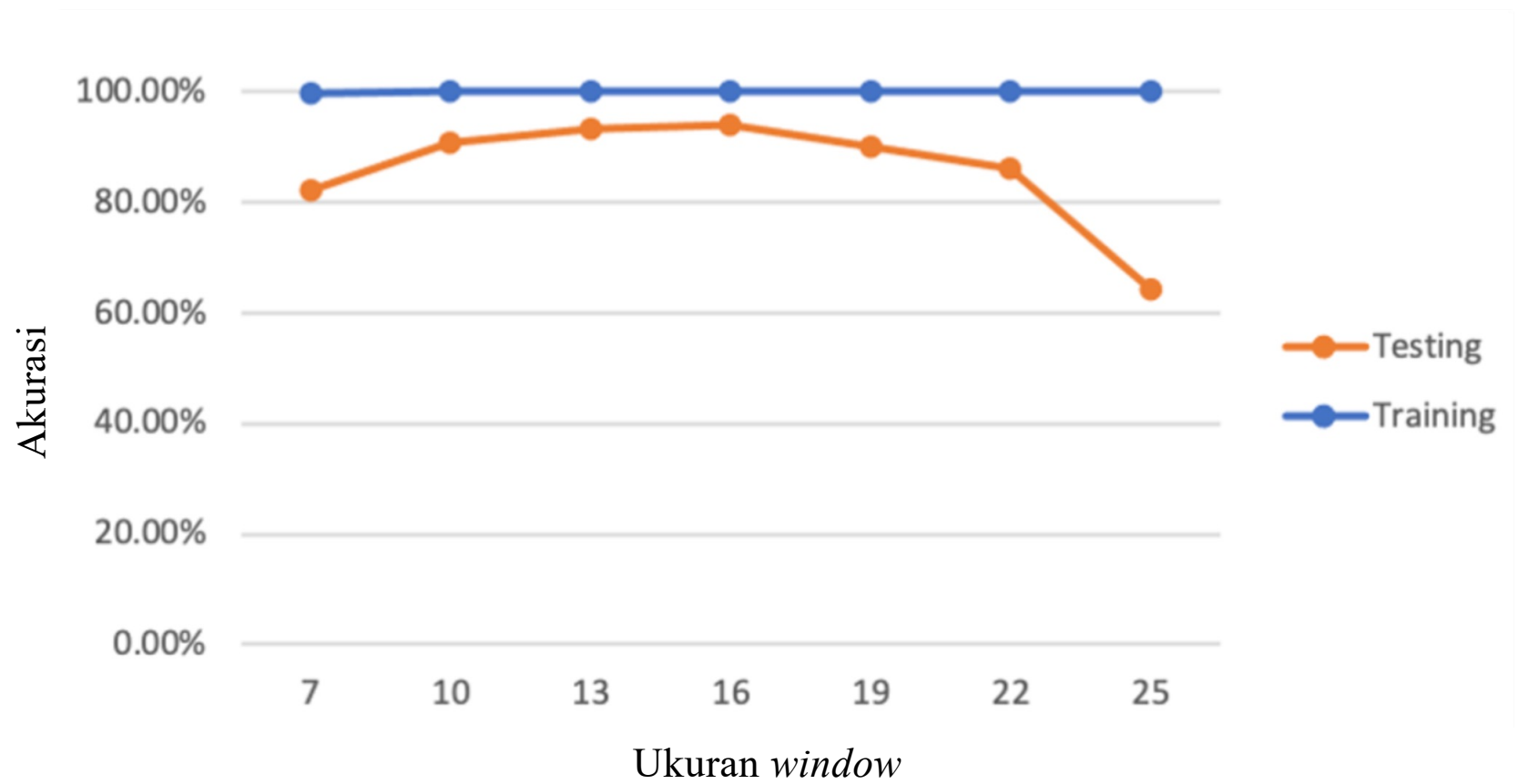
## Count of video segments for each count of frames

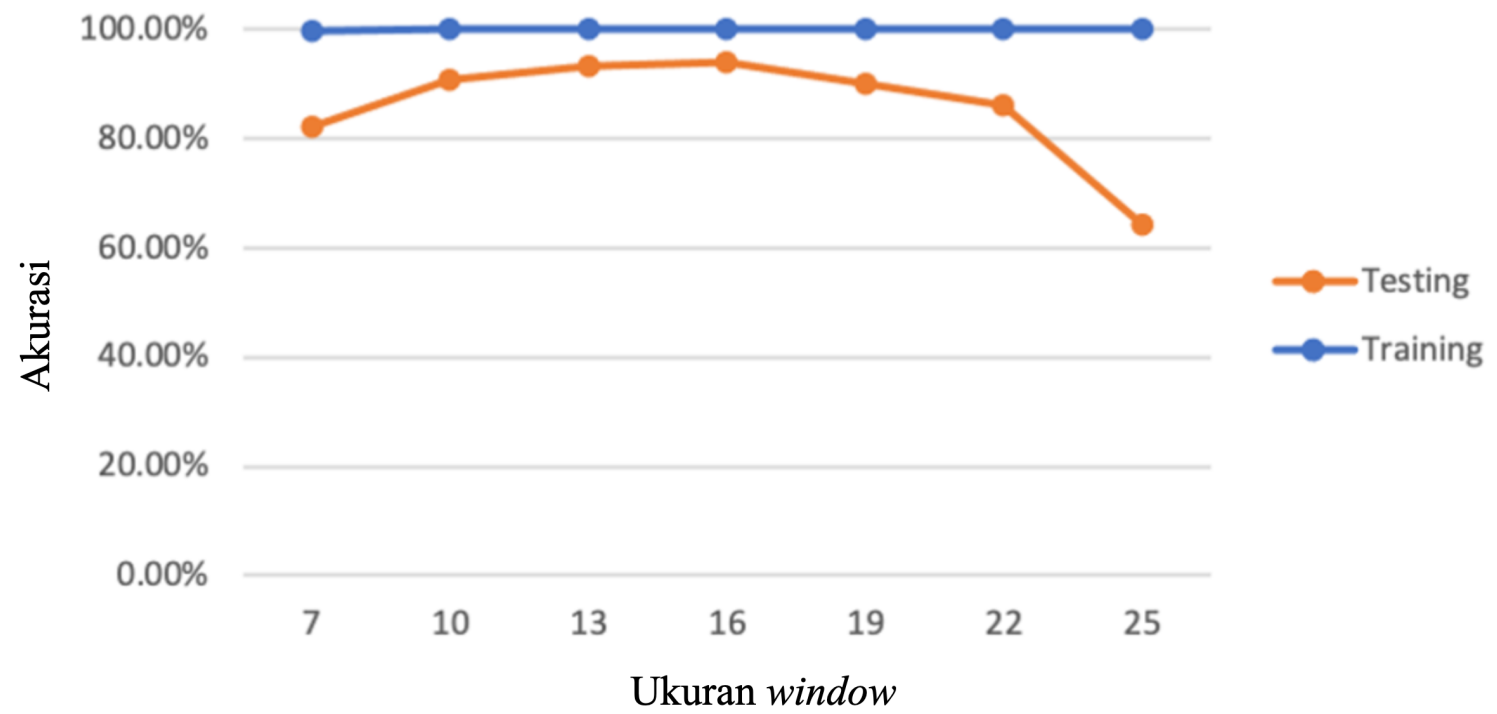
|    |    |
|----|----|
| 8  | 2  |
| 9  | 1  |
| 10 | 5  |
| 11 | 8  |
| 12 | 7  |
| 13 | 7  |
| 14 | 12 |
| 15 | 18 |
| 16 | 19 |
| 17 | 18 |
| 18 | 15 |
| 19 | 13 |
| 20 | 14 |
| 21 | 17 |
| 22 | 10 |
| 23 | 12 |
| 24 | 15 |
| 25 | 4  |
| 26 | 1  |
| 27 | 5  |
| 28 | 5  |
| 29 | 1  |
| 30 | 2  |
| 31 | 1  |
| 32 | 2  |
| 33 | 0  |
| 34 | 0  |
| 35 | 1  |



Count of activity segments for some count of frames used during training

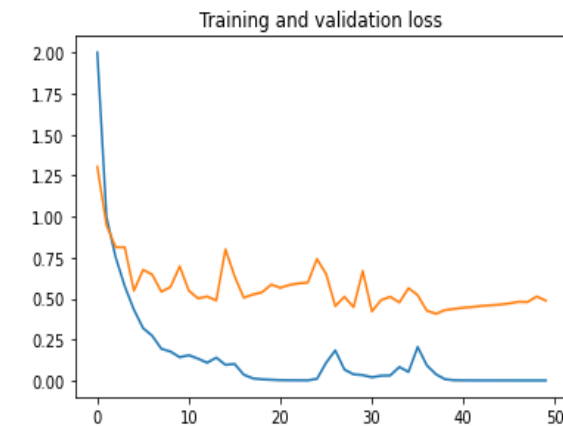
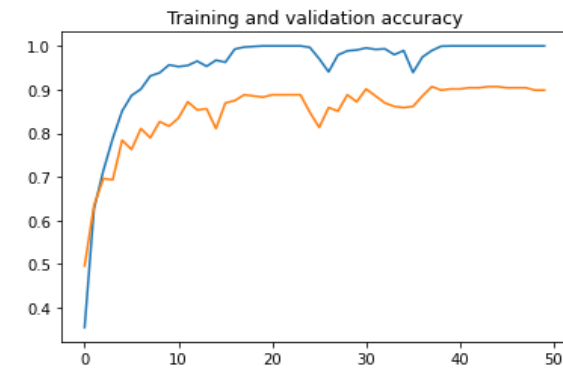
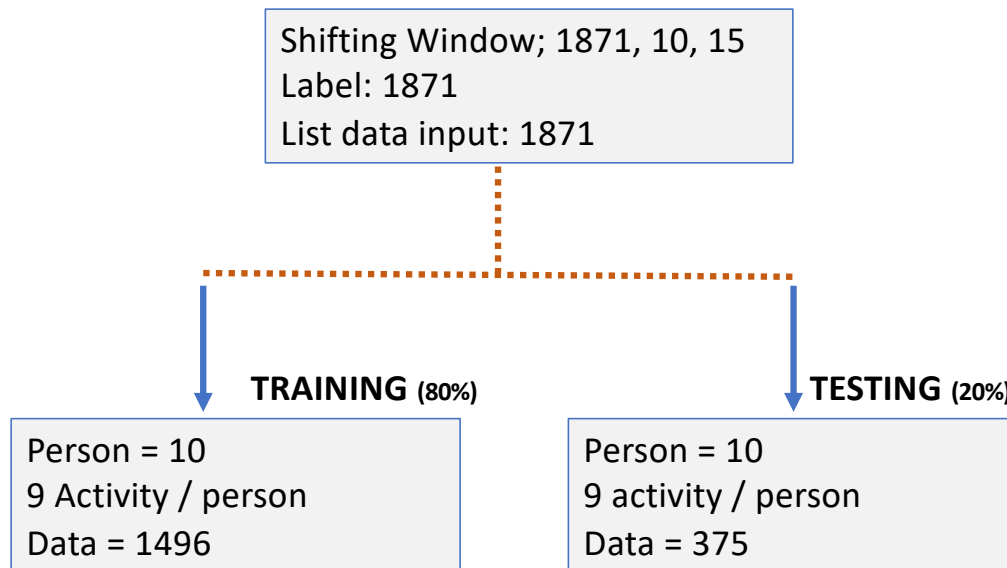


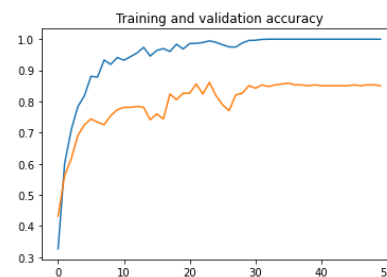
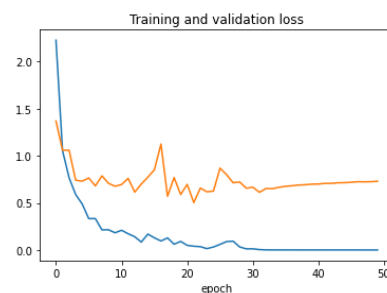
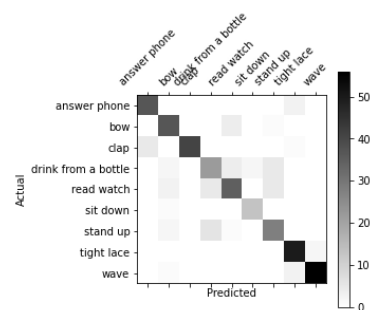




Split data --> training, testing

Hasil eksperimen: deteksi aktifitas (50 epoch)



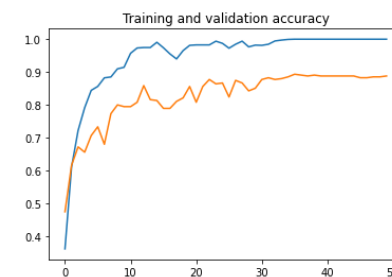
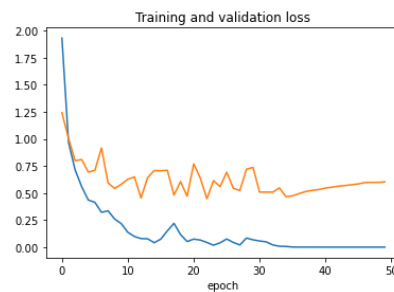
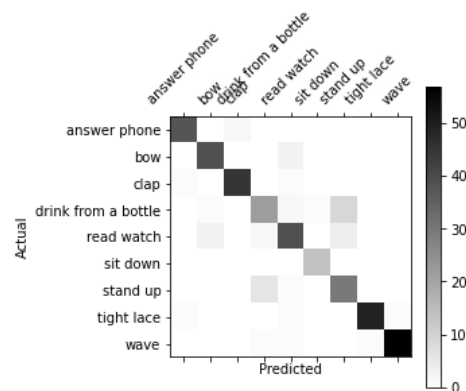


| Actual              | Predicted    |     |      |                     |            |          |          |            |      |
|---------------------|--------------|-----|------|---------------------|------------|----------|----------|------------|------|
|                     | answer phone | bow | clap | drink from a bottle | read watch | sit down | stand up | tight lace | wave |
| answer phone        | 37           | 0   | 0    | 0                   | 0          | 0        | 0        | 3          | 0    |
| bow                 | 0            | 37  | 0    | 0                   | 4          | 0        | 1        | 0          | 0    |
| clap                | 5            | 0   | 41   | 0                   | 0          | 0        | 0        | 1          | 0    |
| drink from a bottle | 0            | 2   | 0    | 22                  | 4          | 2        | 5        | 0          | 0    |
| read watch          | 0            | 3   | 0    | 5                   | 35         | 0        | 5        | 0          | 0    |
| sit down            | 0            | 1   | 0    | 0                   | 0          | 13       | 0        | 0          | 0    |
| stand up            | 0            | 2   | 0    | 6                   | 1          | 0        | 28       | 0          | 0    |
| tight lace          | 0            | 0   | 0    | 0                   | 0          | 0        | 0        | 50         | 2    |
| wave                | 0            | 1   | 0    | 0                   | 0          | 0        | 0        | 3          | 56   |

loss: 1.3547e-04 - accuracy: 1.0000 - val\_loss: 0.7294 - val\_accuracy: 0.8507

loss: 1.2694e-04 - accuracy: 1.0000 - val\_loss: 0.6027 - val\_accuracy: 0.8880

50 epoch

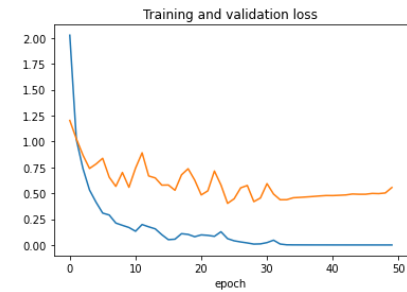
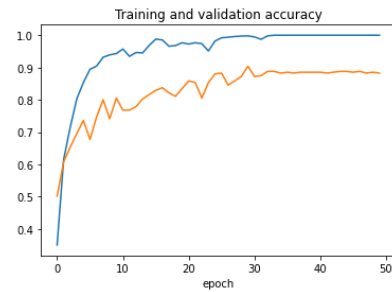


| Actual              | answer phone | bow | clap | drink from a bottle | read watch | sit down | stand up | tight lace | wave |
|---------------------|--------------|-----|------|---------------------|------------|----------|----------|------------|------|
| answer phone        | 38           | 0   | 2    | 0                   | 0          | 0        | 0        | 0          | 0    |
| bow                 | 0            | 39  | 0    | 0                   | 3          | 0        | 0        | 0          | 0    |
| clap                | 1            | 0   | 45   | 0                   | 1          | 0        | 0        | 0          | 0    |
| drink from a bottle | 0            | 1   | 0    | 22                  | 2          | 1        | 9        | 0          | 0    |
| read watch          | 0            | 3   | 0    | 2                   | 39         | 0        | 4        | 0          | 0    |
| sit down            | 0            | 0   | 0    | 0                   | 0          | 14       | 0        | 0          | 0    |
| stand up            | 0            | 0   | 0    | 6                   | 1          | 0        | 30       | 0          | 0    |
| tight lace          | 1            | 0   | 0    | 0                   | 1          | 0        | 0        | 49         | 1    |
| wave                | 0            | 0   | 0    | 1                   | 1          | 0        | 0        | 1          | 57   |



25 Juli 2021

Confusion matrix for the 10-class action recognition task. The matrix shows counts for each combination of actual and predicted actions. The diagonal elements are high, indicating good classification performance. A color bar on the right indicates the count scale from 0 to 60.

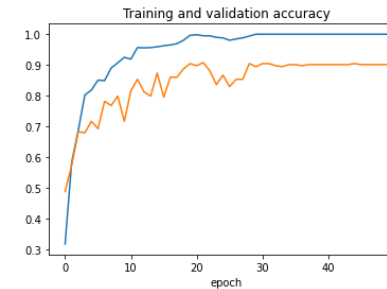
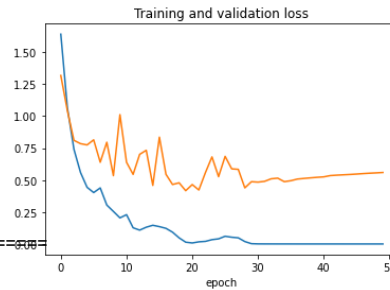
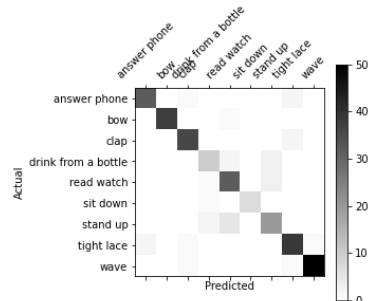
[illegible]

# PROSENTASE

| actual<br>(total<br>act) | prediction |    |    |    |    |     |    |    |    |
|--------------------------|------------|----|----|----|----|-----|----|----|----|
|                          | 1          | 2  | 3  | 4  | 5  | 6   | 7  | 8  | 9  |
| 1 (40)                   | 95         | 0  | 5  | 0  | 0  | 0   | 0  | 0  | 0  |
| 2 (42)                   | 0          | 93 | 0  | 0  | 7  | 0   | 0  | 0  | 0  |
| 3 (47)                   | 2          | 0  | 96 | 0  | 2  | 0   | 0  | 0  | 0  |
| 4 (35)                   | 0          | 3  | 0  | 63 | 6  | 3   | 26 | 0  | 0  |
| 5 (48)                   | 0          | 6  | 0  | 4  | 81 | 0   | 4  | 0  | 0  |
| 6 (14)                   | 0          | 0  | 0  | 0  | 0  | 100 | 0  | 0  | 0  |
| 7 (37)                   | 0          | 0  | 0  | 16 | 3  | 0   | 81 | 0  | 0  |
| 8 (52)                   | 2          | 0  | 0  | 0  | 2  | 0   | 0  | 94 | 2  |
| 9 (60)                   | 0          | 0  | 0  | 2  | 2  | 0   | 0  | 2  | 95 |

loss: 4.3824e-05 - accuracy: 1.0000 - val\_loss: 0.5593 - val\_accuracy: 0.9010

Window = 12



| Layer (type)              | Output Shape       | Param # |
|---------------------------|--------------------|---------|
| conv2d_172 (Conv2D)       | (None, 10, 13, 32) | 320     |
| conv2d_173 (Conv2D)       | (None, 8, 11, 32)  | 9248    |
| dropout_58 (Dropout)      | (None, 8, 11, 32)  | 0       |
| conv2d_174 (Conv2D)       | (None, 6, 9, 32)   | 9248    |
| flatten_49 (Flatten)      | (None, 1728)       | 0       |
| dense_212 (Dense)         | (None, 256)        | 442624  |
| dense_213 (Dense)         | (None, 256)        | 65792   |
| dense_214 (Dense)         | (None, 256)        | 65792   |
| dense_215 (Dense)         | (None, 64)         | 16448   |
| dense_216 (Dense)         | (None, 64)         | 4160    |
| dense_217 (Dense)         | (None, 9)          | 585     |
| Total params: 614,217     |                    |         |
| Trainable params: 614,217 |                    |         |
| Non-trainable params: 0   |                    |         |

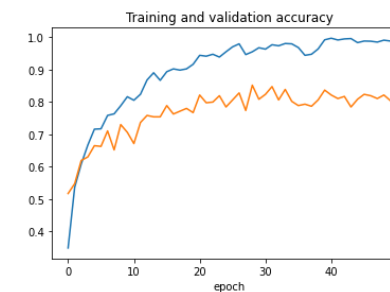
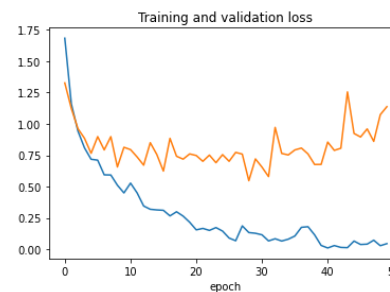
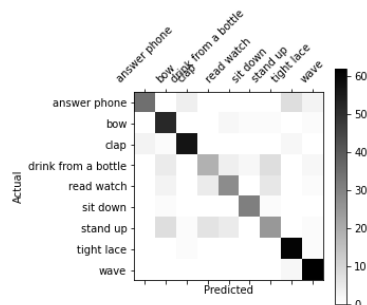
(1465,12,15)

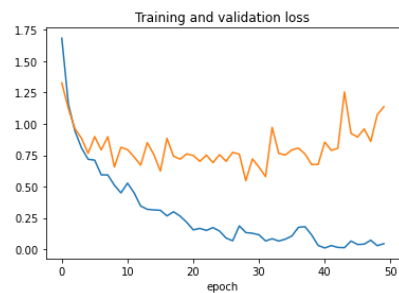
| Actual              | answer phone | bow | clap | drink from a bottle | read watch | sit down | stand up | tight lace | wave |
|---------------------|--------------|-----|------|---------------------|------------|----------|----------|------------|------|
| answer phone        | 32           | 0   | 1    | 0                   | 0          | 0        | 0        | 2          | 0    |
| bow                 | 0            | 38  | 0    | 0                   | 1          | 0        | 0        | 0          | 0    |
| clap                | 0            | 0   | 36   | 0                   | 0          | 0        | 0        | 2          | 0    |
| drink from a bottle | 0            | 0   | 0    | 10                  | 2          | 0        | 3        | 0          | 0    |
| read watch          | 0            | 0   | 0    | 1                   | 32         | 0        | 3        | 0          | 0    |
| sit down            | 0            | 0   | 0    | 1                   | 0          | 7        | 0        | 0          | 0    |
| stand up            | 0            | 0   | 0    | 2                   | 5          | 0        | 20       | 0          | 0    |
| tight lace          | 2            | 0   | 1    | 0                   | 0          | 0        | 0        | 39         | 1    |
| wave                | 0            | 0   | 1    | 0                   | 0          | 0        | 0        | 1          | 50   |



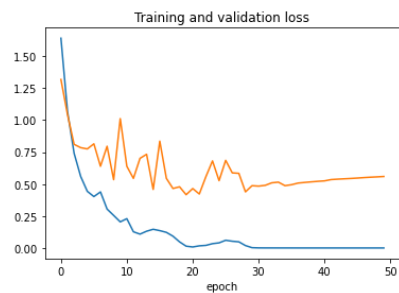
(2296, 8, 15)

| Layer (type)              | Output Shape      | Param # |
|---------------------------|-------------------|---------|
| conv2d_184 (Conv2D)       | (None, 6, 13, 32) | 320     |
| conv2d_185 (Conv2D)       | (None, 4, 11, 32) | 9248    |
| dropout_62 (Dropout)      | (None, 4, 11, 32) | 0       |
| conv2d_186 (Conv2D)       | (None, 2, 9, 32)  | 9248    |
| flatten_53 (Flatten)      | (None, 576)       | 0       |
| dense_236 (Dense)         | (None, 256)       | 147712  |
| dense_237 (Dense)         | (None, 256)       | 65792   |
| dense_238 (Dense)         | (None, 256)       | 65792   |
| dense_239 (Dense)         | (None, 64)        | 16448   |
| dense_240 (Dense)         | (None, 64)        | 4160    |
| dense_241 (Dense)         | (None, 9)         | 585     |
| Total params: 319,305     |                   |         |
| Trainable params: 319,305 |                   |         |
| Non-trainable params: 0   |                   |         |

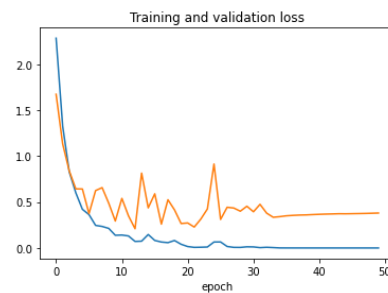
[illegible]



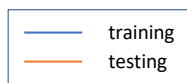
size = 8



size =12



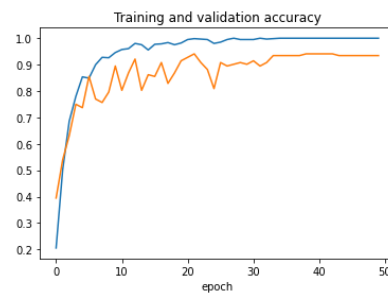
size =16



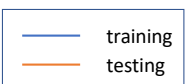
size=8



size = 12



size =16



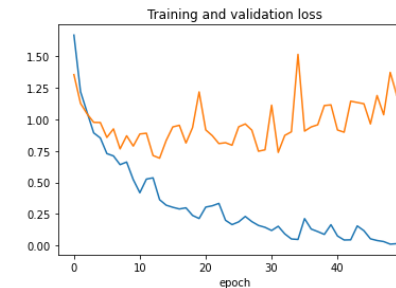
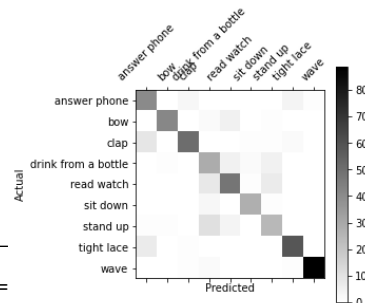
loss: 0.0077 - accuracy: 0.9981 - val\_loss: 1.1904 - val\_accuracy: 0.8191

SIZE WINNDOW = 7

(2511, 7, 15)

Model: "sequential\_1"

| Layer (type)              | Output Shape      | Param # |
|---------------------------|-------------------|---------|
| conv2d_3 (Conv2D)         | (None, 5, 13, 32) | 320     |
| conv2d_4 (Conv2D)         | (None, 3, 11, 32) | 9248    |
| dropout_1 (Dropout)       | (None, 3, 11, 32) | 0       |
| conv2d_5 (Conv2D)         | (None, 1, 9, 32)  | 9248    |
| flatten_1 (Flatten)       | (None, 288)       | 0       |
| dense_6 (Dense)           | (None, 256)       | 73984   |
| dense_7 (Dense)           | (None, 256)       | 65792   |
| dense_8 (Dense)           | (None, 256)       | 65792   |
| dense_9 (Dense)           | (None, 64)        | 16448   |
| dense_10 (Dense)          | (None, 64)        | 4160    |
| dense_11 (Dense)          | (None, 9)         | 585     |
| Total params: 245,577     |                   |         |
| Trainable params: 245,577 |                   |         |
| Non-trainable params: 0   |                   |         |



| Actual              | answer phone | bow | clap | drink from a bottle | read watch | sit down | stand up | tight lace | wave |
|---------------------|--------------|-----|------|---------------------|------------|----------|----------|------------|------|
| answer phone        | 41           | 0   | 3    | 0                   | 0          | 0        | 0        | 4          | 1    |
| bow                 | 0            | 42  | 0    | 2                   | 5          | 0        | 1        | 0          | 0    |
| clap                | 9            | 0   | 51   | 0                   | 0          | 1        | 1        | 2          | 0    |
| drink from a bottle | 0            | 1   | 0    | 29                  | 5          | 2        | 5        | 0          | 0    |
| read watch          | 0            | 0   | 0    | 8                   | 48         | 1        | 7        | 0          | 0    |
| sit down            | 0            | 0   | 0    | 3                   | 0          | 28       | 1        | 0          | 0    |
| stand up            | 1            | 1   | 0    | 11                  | 4          | 0        | 25       | 0          | 0    |
| tight lace          | 7            | 0   | 1    | 0                   | 0          | 0        | 0        | 59         | 0    |
| wave                | 0            | 0   | 1    | 2                   | 0          | 0        | 0        | 1          | 89   |

Update 28 Juli 2021

loss: 8.0974e-05 - accuracy: 1.0000 - val\_loss: 0.6999 - val\_accuracy: 0.8987

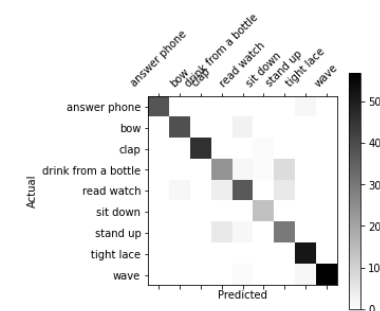
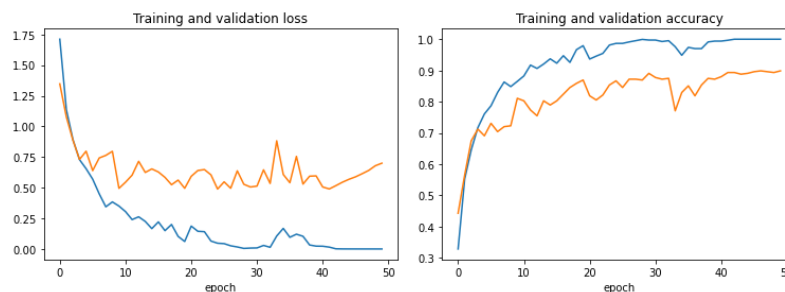
SIZE WINDOW = 10

(1871, 10, 15)

Model: "sequential"

| Layer (type)      | Output Shape      | Param # |
|-------------------|-------------------|---------|
| conv2d (Conv2D)   | (None, 8, 13, 32) | 320     |
| conv2d_1 (Conv2D) | (None, 6, 11, 32) | 9248    |
| dropout (Dropout) | (None, 6, 11, 32) | 0       |
| conv2d_2 (Conv2D) | (None, 4, 9, 32)  | 9248    |
| flatten (Flatten) | (None, 1152)      | 0       |
| dense (Dense)     | (None, 256)       | 295168  |
| dense_1 (Dense)   | (None, 256)       | 65792   |
| dense_2 (Dense)   | (None, 256)       | 65792   |
| dense_3 (Dense)   | (None, 64)        | 16448   |
| dense_4 (Dense)   | (None, 64)        | 4160    |
| dense_5 (Dense)   | (None, 9)         | 585     |

Total params: 466,761  
Trainable params: 466,761  
Non-trainable params: 0



| Actual              | answer phone | bow | clap | drink from a bottle | read watch | sit down | stand up | tight lace | wave |
|---------------------|--------------|-----|------|---------------------|------------|----------|----------|------------|------|
| answer phone        | 38           | 0   | 0    | 0                   | 0          | 0        | 0        | 2          | 0    |
| bow                 | 0            | 39  | 0    | 0                   | 3          | 0        | 0        | 0          | 0    |
| clap                | 0            | 0   | 46   | 0                   | 0          | 1        | 0        | 0          | 0    |
| drink from a bottle | 0            | 0   | 0    | 24                  | 2          | 1        | 8        | 0          | 0    |
| read watch          | 0            | 2   | 0    | 4                   | 37         | 0        | 5        | 0          | 0    |
| sit down            | 0            | 0   | 0    | 0                   | 0          | 14       | 0        | 0          | 0    |
| stand up            | 0            | 0   | 0    | 5                   | 2          | 0        | 30       | 0          | 0    |
| tight lace          | 0            | 0   | 0    | 0                   | 0          | 0        | 0        | 52         | 0    |
| wave                | 0            | 0   | 0    | 0                   | 1          | 0        | 0        | 2          | 57   |





loss: 3.4074e-05 - accuracy: 1.0000 - val\_loss: 0.4479 - val\_accuracy: 0.9136

WINDOW SIZE = 19

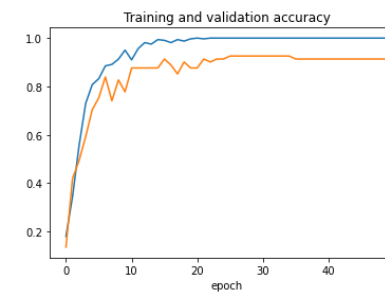
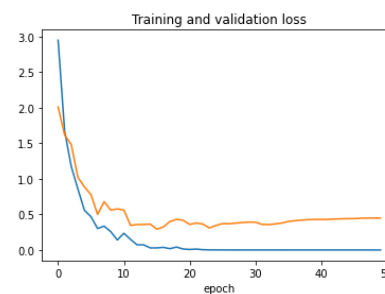
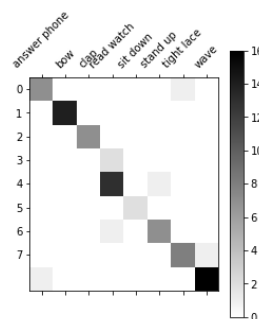
Model: "sequential\_7"

| Layer (type)        | Output Shape       | Param # |
|---------------------|--------------------|---------|
| conv2d_21 (Conv2D)  | (None, 17, 13, 32) | 320     |
| conv2d_22 (Conv2D)  | (None, 15, 11, 32) | 9248    |
| dropout_7 (Dropout) | (None, 15, 11, 32) | 0       |
| conv2d_23 (Conv2D)  | (None, 13, 9, 32)  | 9248    |
| flatten_7 (Flatten) | (None, 3744)       | 0       |
| dense_42 (Dense)    | (None, 256)        | 958720  |
| dense_43 (Dense)    | (None, 256)        | 65792   |
| dense_44 (Dense)    | (None, 256)        | 65792   |
| dense_45 (Dense)    | (None, 64)         | 16448   |
| dense_46 (Dense)    | (None, 64)         | 4160    |
| dense_47 (Dense)    | (None, 9)          | 585     |

Total params: 1,130,313

Trainable params: 1,130,313

Non-trainable params: 0



(403, 19, 15)

| Actual              | answer phone | bow | clap | read watch | sit down | stand up | tight lace | wave |
|---------------------|--------------|-----|------|------------|----------|----------|------------|------|
| answer phone        | 7            | 0   | 0    | 0          | 0        | 0        | 1          | 0    |
| bow                 | 0            | 14  | 0    | 0          | 0        | 0        | 0          | 0    |
| clap                | 0            | 0   | 7    | 0          | 0        | 0        | 0          | 0    |
| drink from a bottle | 0            | 0   | 0    | 2          | 0        | 0        | 0          | 0    |
| read watch          | 0            | 0   | 0    | 13         | 0        | 1        | 0          | 0    |
| sit down            | 0            | 0   | 0    | 0          | 2        | 0        | 0          | 0    |
| stand up            | 0            | 0   | 0    | 1          | 0        | 7        | 0          | 0    |
| tight lace          | 0            | 0   | 0    | 0          | 0        | 0        | 8          | 1    |
| wave                | 1            | 0   | 0    | 0          | 0        | 0        | 0          | 16   |

loss: 4.9678e-05 - accuracy: 1.0000 - val\_loss: 4.1729 - val\_accuracy: 0.7500

WINDOW SIZE = 22

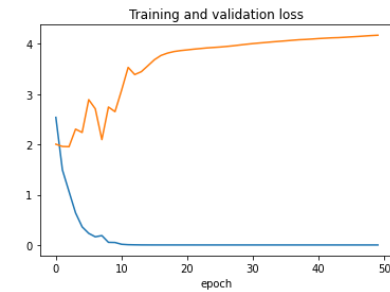
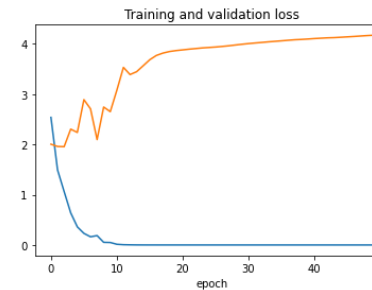
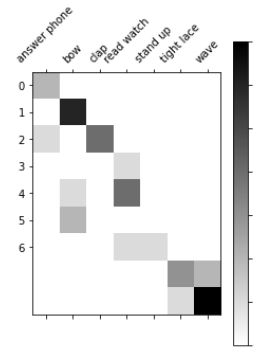
Model: "sequential\_8"

| Layer (type)        | Output Shape       | Param # |
|---------------------|--------------------|---------|
| conv2d_24 (Conv2D)  | (None, 20, 13, 32) | 320     |
| conv2d_25 (Conv2D)  | (None, 18, 11, 32) | 9248    |
| dropout_8 (Dropout) | (None, 18, 11, 32) | 0       |
| conv2d_26 (Conv2D)  | (None, 16, 9, 32)  | 9248    |
| flatten_8 (Flatten) | (None, 4608)       | 0       |
| dense_48 (Dense)    | (None, 256)        | 1179904 |
| dense_49 (Dense)    | (None, 256)        | 65792   |
| dense_50 (Dense)    | (None, 256)        | 65792   |
| dense_51 (Dense)    | (None, 64)         | 16448   |
| dense_52 (Dense)    | (None, 64)         | 4160    |
| dense_53 (Dense)    | (None, 9)          | 585     |

Total params: 1,351,497

Trainable params: 1,351,497

Non-trainable params: 0



(178, 22, 15)

| Actual              | answer phone | bow | clap | read watch | stand up | tight lace | wave |
|---------------------|--------------|-----|------|------------|----------|------------|------|
| answer phone        |              |     |      |            |          |            |      |
| bow                 | 2            | 0   | 0    | 0          | 0        | 0          | 0    |
| clap                | 0            | 6   | 0    | 0          | 0        | 0          | 0    |
| clap                | 1            | 0   | 4    | 0          | 0        | 0          | 0    |
| drink from a bottle | 0            | 0   | 0    | 1          | 0        | 0          | 0    |
| read watch          | 0            | 1   | 0    | 4          | 0        | 0          | 0    |
| sit down            | 0            | 2   | 0    | 0          | 0        | 0          | 0    |
| stand up            | 0            | 0   | 0    | 1          | 1        | 0          | 0    |
| tight lace          | 0            | 0   | 0    | 0          | 0        | 3          | 2    |
| wave                | 0            | 0   | 0    | 0          | 0        | 1          | 7    |

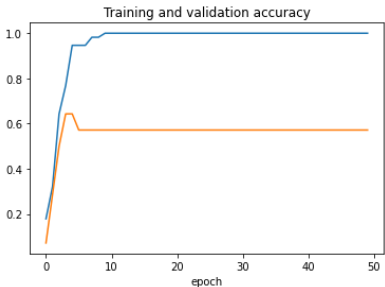
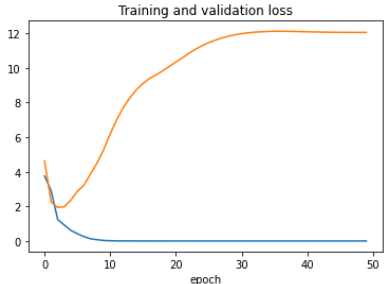
loss: 2.0925e-06 - accuracy: 1.0000 - val\_loss: 12.0550 - val\_accuracy: 0.5714

SIZE WINDOW 25

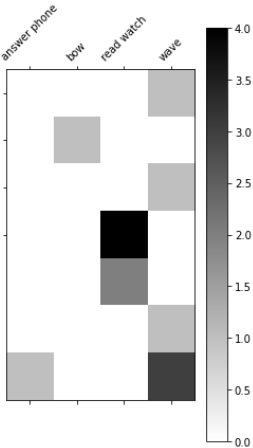
Model: "sequential\_3"

| Layer (type)        | Output Shape       | Param # |
|---------------------|--------------------|---------|
| =====               |                    |         |
| conv2d_9 (Conv2D)   | (None, 23, 13, 32) | 320     |
| conv2d_10 (Conv2D)  | (None, 21, 11, 32) | 9248    |
| dropout_3 (Dropout) | (None, 21, 11, 32) | 0       |
| conv2d_11 (Conv2D)  | (None, 19, 9, 32)  | 9248    |
| flatten_3 (Flatten) | (None, 5472)       | 0       |
| dense_18 (Dense)    | (None, 256)        | 1401088 |
| dense_19 (Dense)    | (None, 256)        | 65792   |
| dense_20 (Dense)    | (None, 256)        | 65792   |
| dense_21 (Dense)    | (None, 64)         | 16448   |
| dense_22 (Dense)    | (None, 64)         | 4160    |
| dense_23 (Dense)    | (None, 9)          | 585     |
| =====               |                    |         |

Total params: 1,572,681  
Trainable params: 1,572,681  
Non-trainable params: 0



| Actual       | answer phone | bow | read watch | wave |
|--------------|--------------|-----|------------|------|
| answer phone | 0            | 0   | 0          | 1    |
| bow          | 0            | 1   | 0          | 0    |
| clap         | 0            | 0   | 0          | 1    |
| read watch   | 0            | 0   | 4          | 0    |
| stand up     | 0            | 0   | 2          | 0    |
| tight lace   | 0            | 0   | 0          | 1    |
| wave         | 1            | 0   | 0          | 3    |



(70, 25, 15)