

Fig. 1

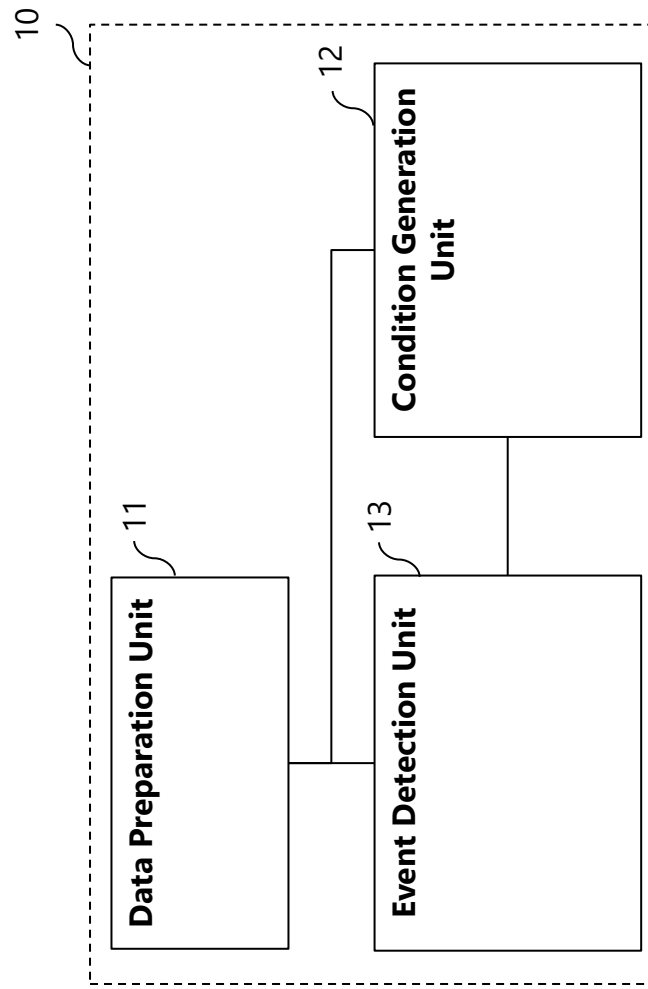


Fig. 2

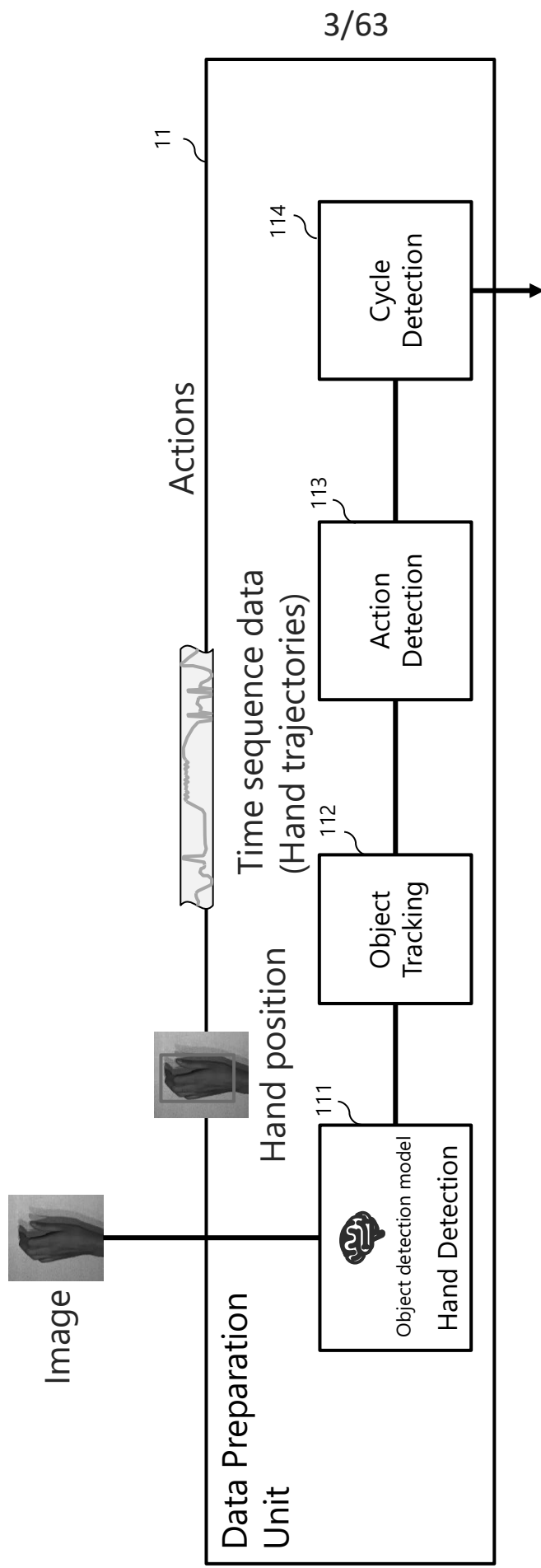


Fig. 3

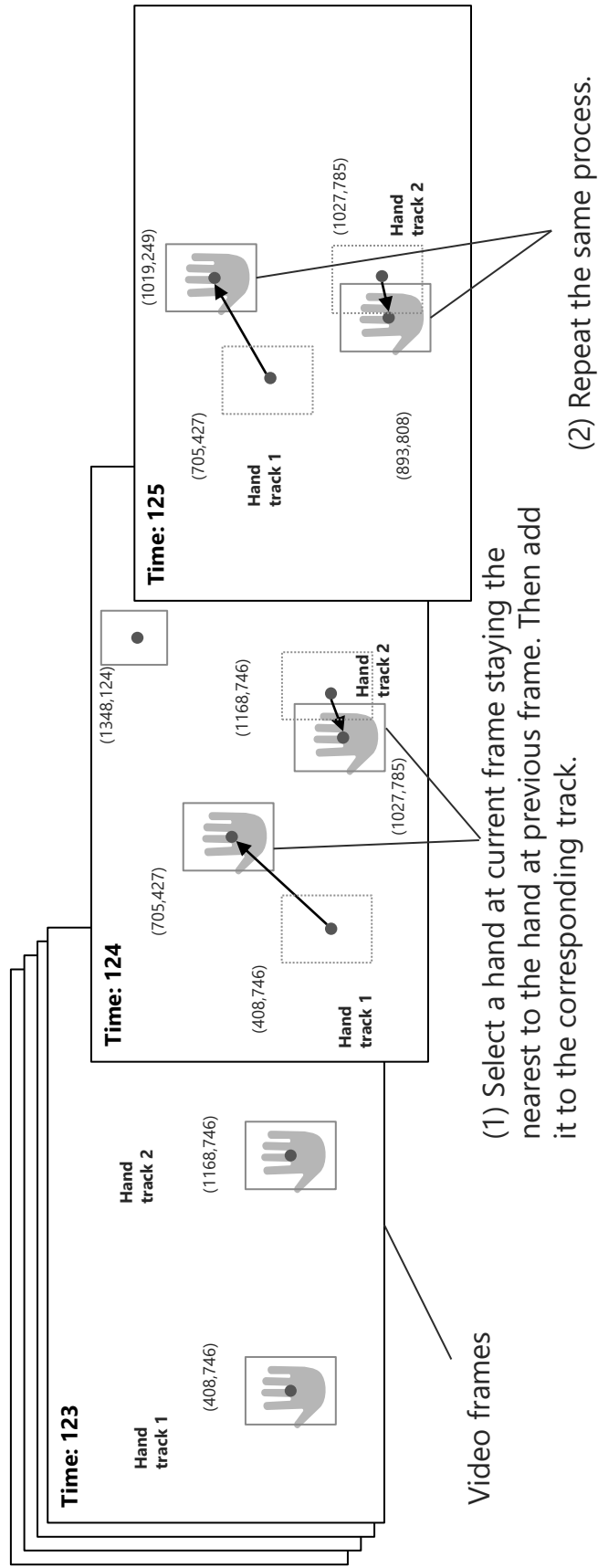


Fig. 4

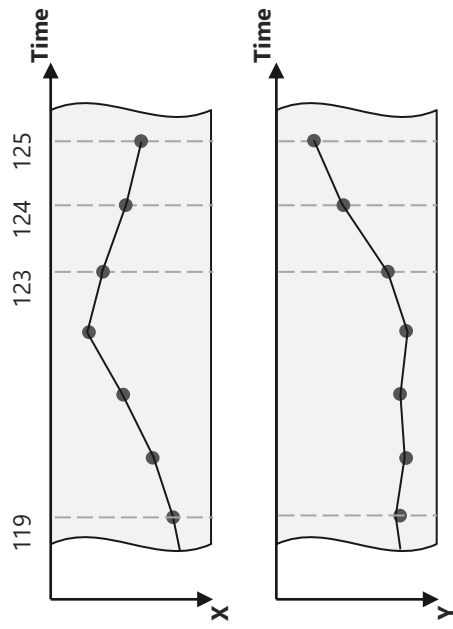


Fig. 5

Action	Sample of hand trajectory
A1 - Start of cycle	T1
A2 - End of cycle	T2
A3 - Picking up parts X	T3
A4 - Picking up parts Y and Z	T4

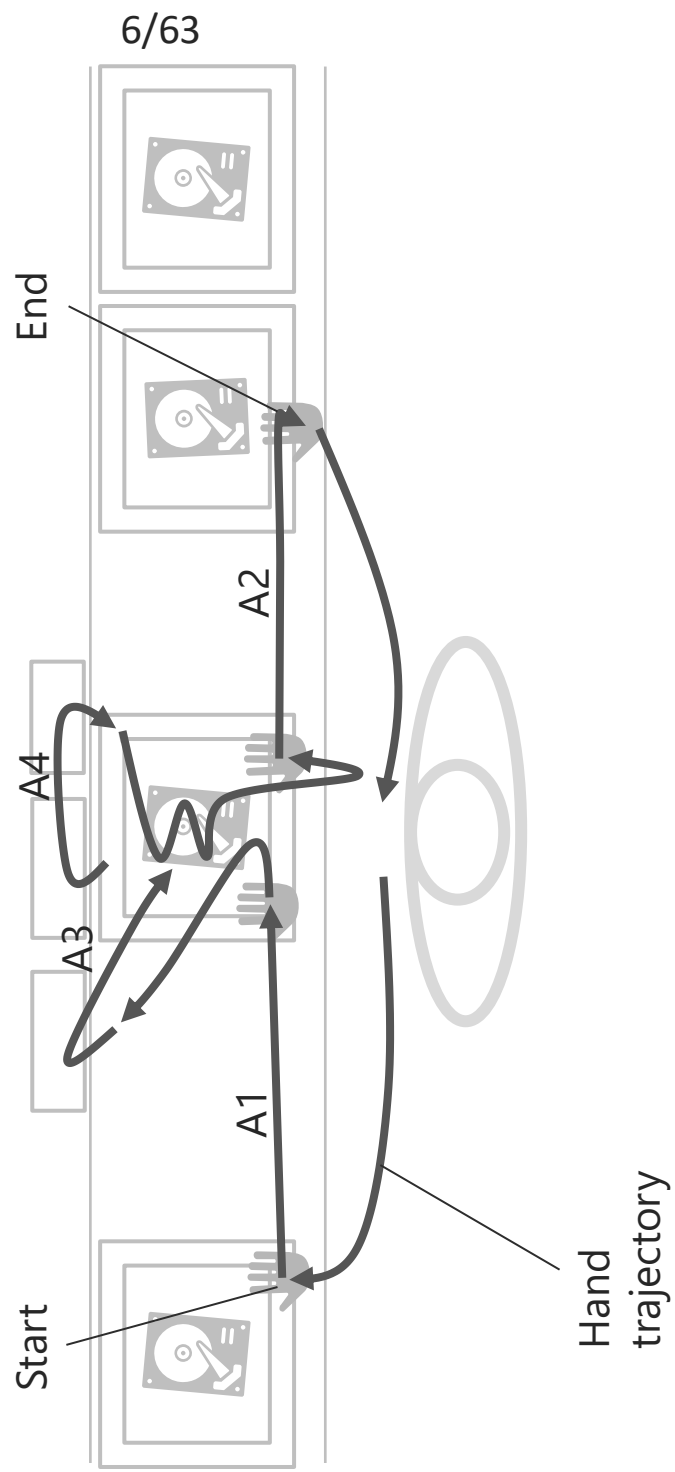


Fig. 6

Query	Threshold	Action
Q1	10.0	A1
Q2	8.0	A2
...		...

Similarity score
 = DTW(Q1, S22)
 = 98
 > 10.0
Not matched

Similarity score
 = DTW(Q1, S100)
 = 4
 < 10.0
Matched

Similarity score
 = DTW(Q1, S552)
 = 54.2
 d > 10.0
Not matched

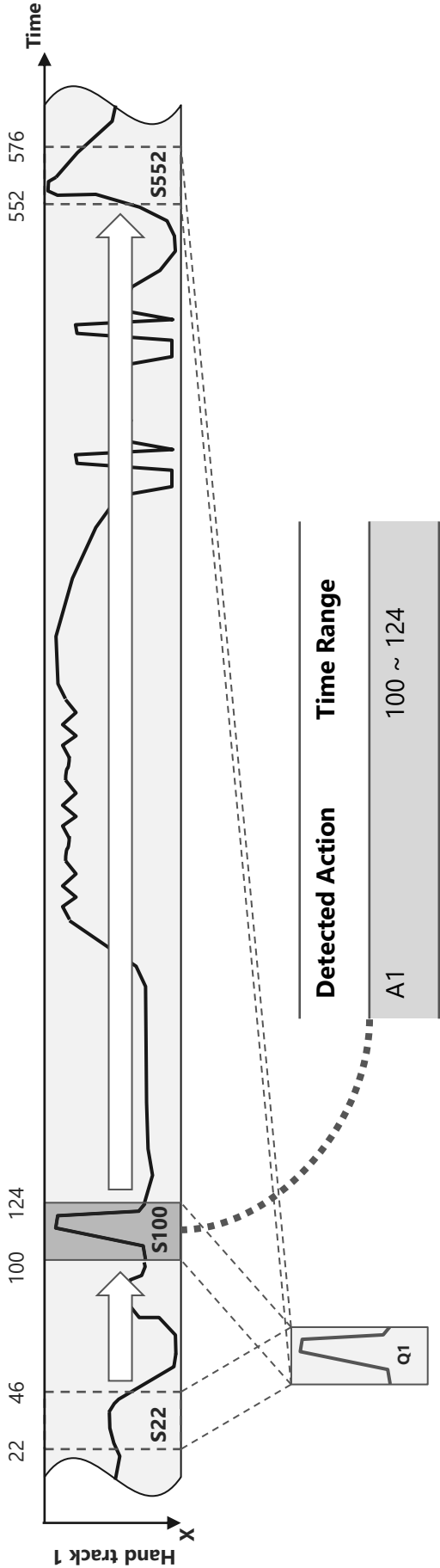


Fig. 7

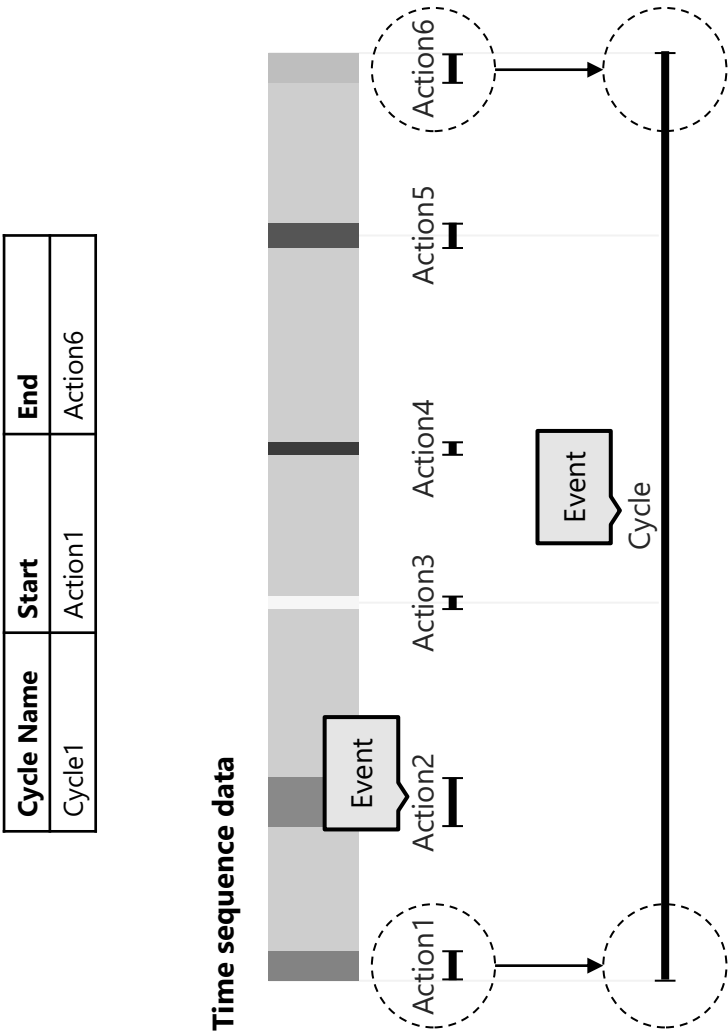


Fig. 8

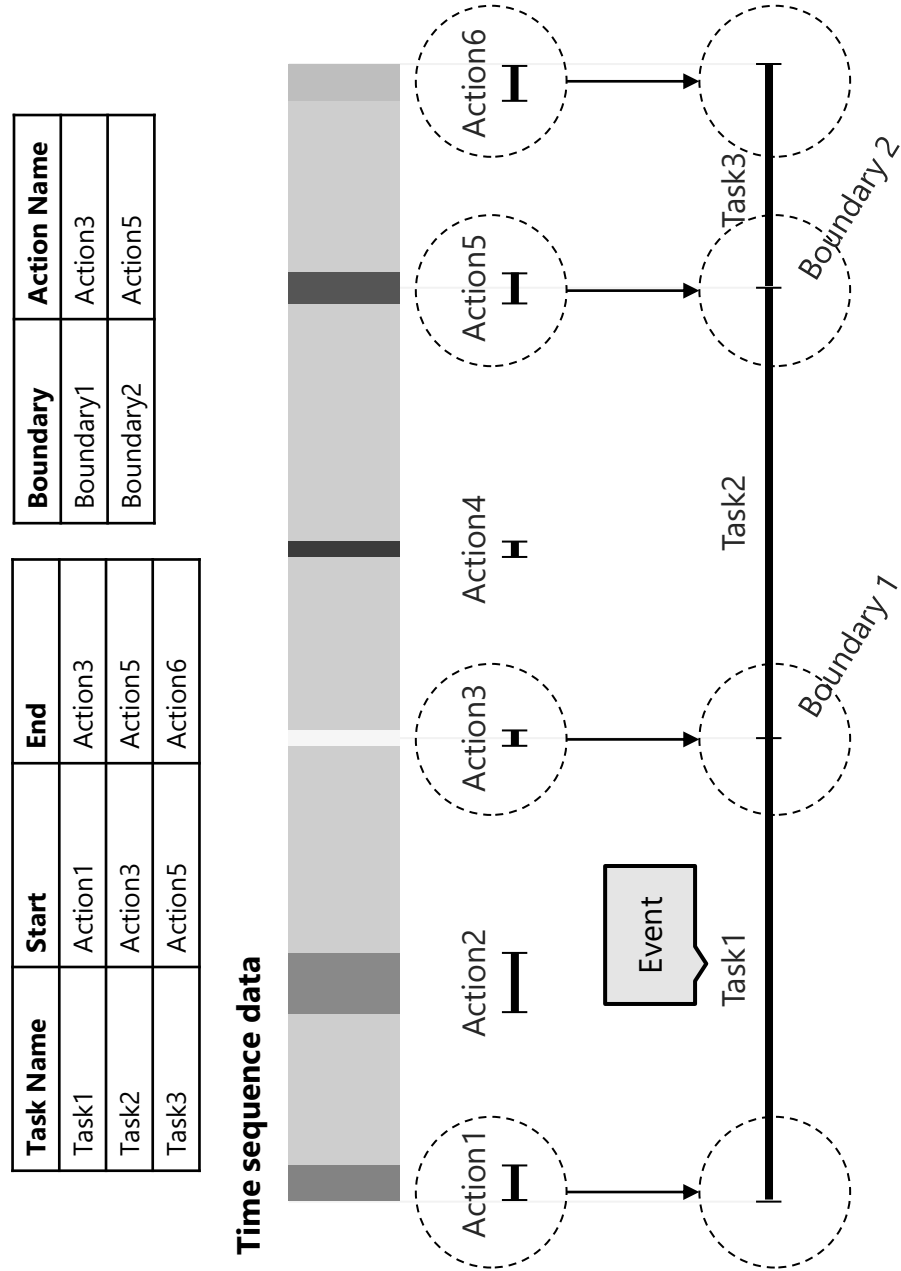


Fig. 9

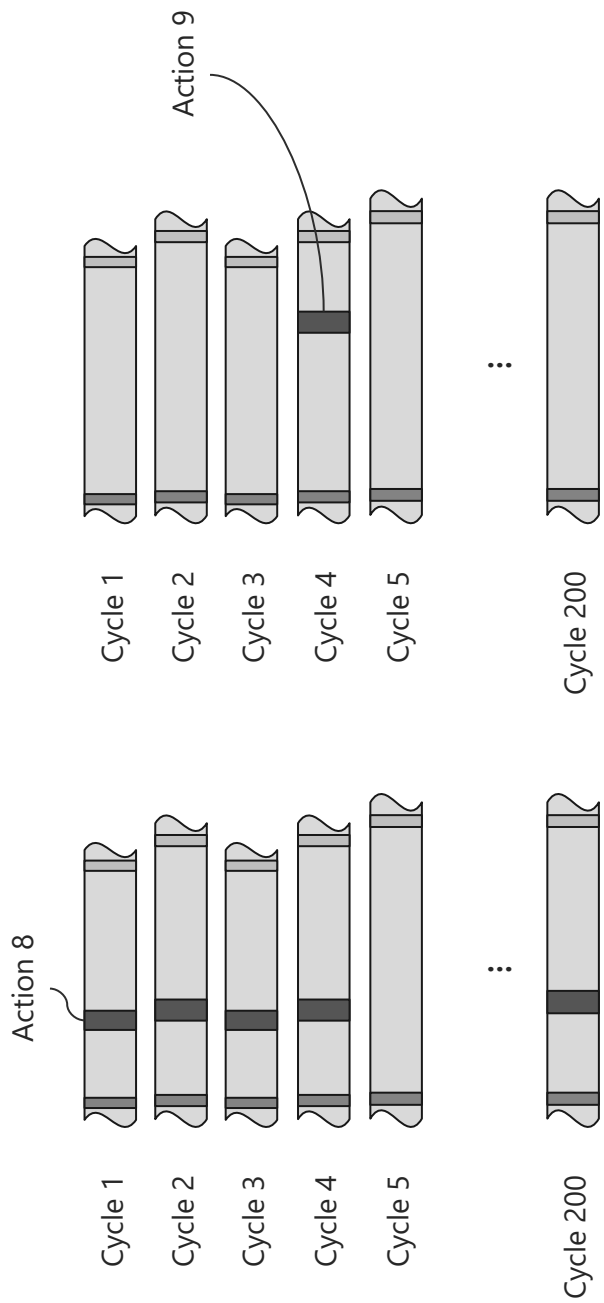


Fig. 10

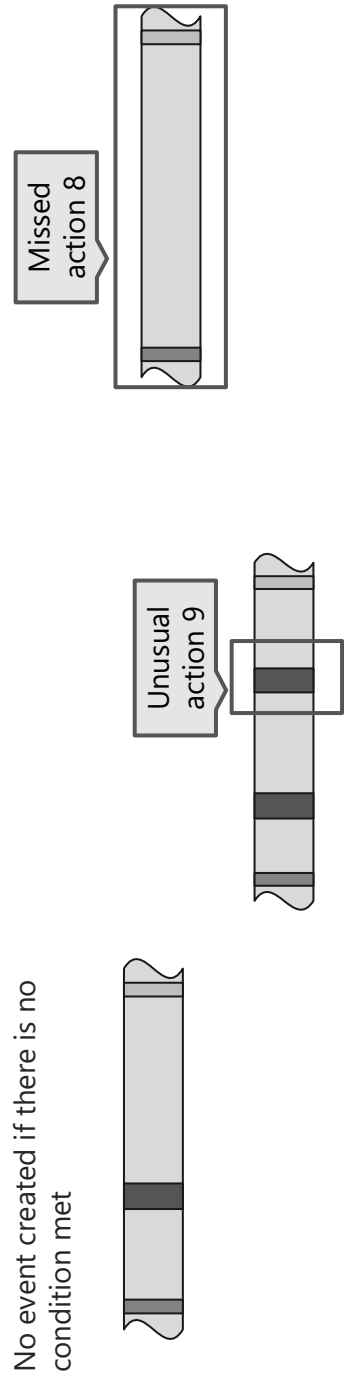


Fig. 11

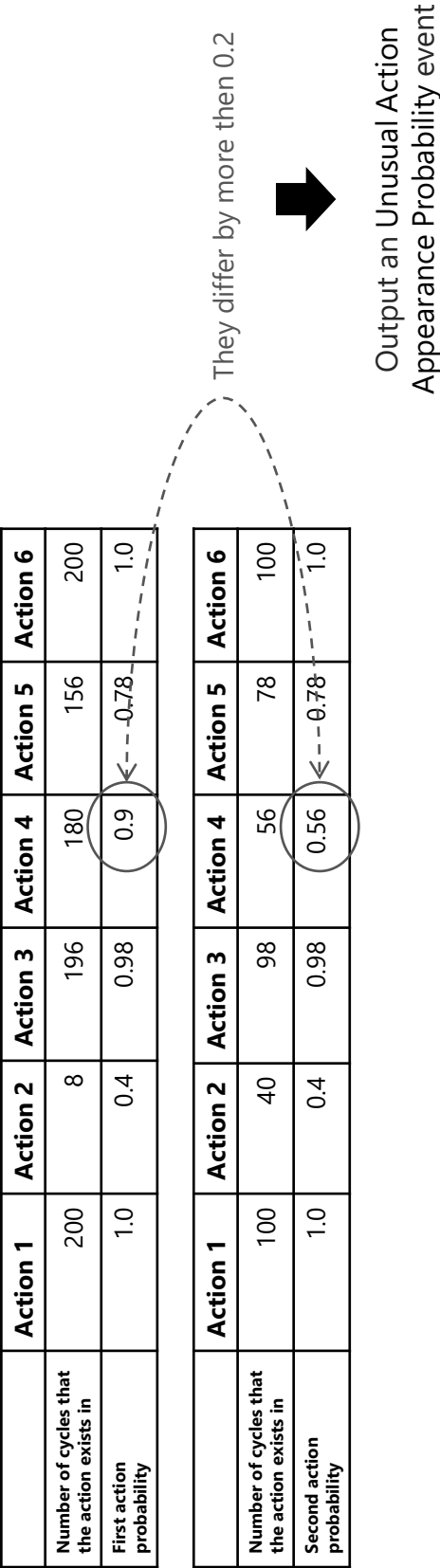


Fig. 12

	Action 1	Action 2	Action 3	Action 4	Action 5	Action 6
Number of cycles that the action exists in	200	8	196	180	156	200
Probability	1.0	0.4	0.98	0.9	0.78	1.0

(1)

First order of actions	Number of cycles where the order exists in	Percentage of this order in total number of cycle
Action 1, Action 3, Action 6	194	97%
Action 1, Action 6	4	2%
Action 1, Action 4, Action 6	2	1%

(4)

Selected as the condition

	Second order of actions
Cycle 1	Action 1, Action 3, Action 6
Cycle 2	Action 1, Action 6
Cycle 3	Action 1, Action 3, Action 6
:	:
Cycle 4	Action 1, Action 3, Action 6

(2)

Condition to detect Unusual Order of Actions event
Action 1, Action 3, Action 6

Do not match

Fig. 13

(3)

GUI

Description	Time	Corresponding Action
:	:	
9 Pick a parts P54 from the parts tray then place it on the specified position on the board.	5 seconds	Select corresponding action
10 Tighten the screw on the parts P54 by using screwdriver D3.	15 seconds	Select corresponding action
:	:	Action 1 Action 2 Action 3 Action 4 Action 5 Action 6

Work procedure manual

Confirm

(4)

	Action 1	Action 2	Action 3	Action 4	Action 5	Action 6
Probability	1.0	0.4	0.98	0.9	0.78	1.0
Usual Action P ≥ 0.95	Yes	No	Yes	Yes	No	Yes
Work process	1		5	10		12

Fig. 14

Cycles	Number of Actions		
	Action A	Action B	...
Cycle 1	3	4	
Cycle 2	3	4	
Cycle 3	2	4	
:			

Cycles	Number of Actions		
	Action A	Action B	...
N_1	2	4	
N_2	3	4	
Mode	3	4	

Fig. 15

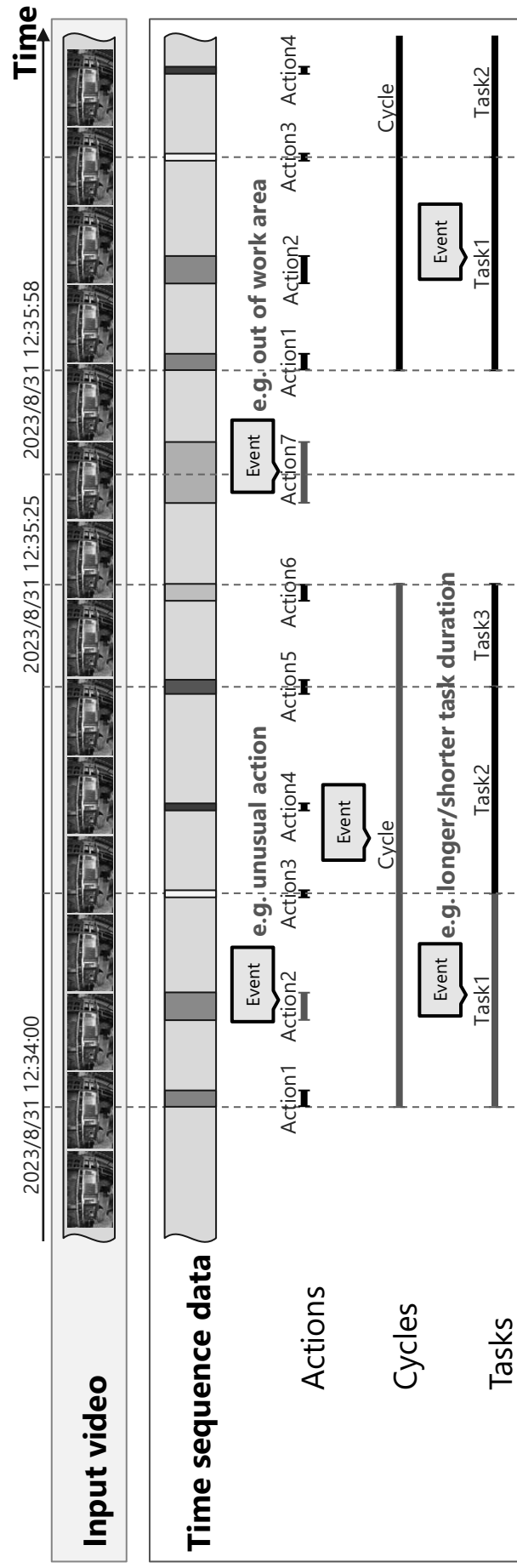


Fig. 16

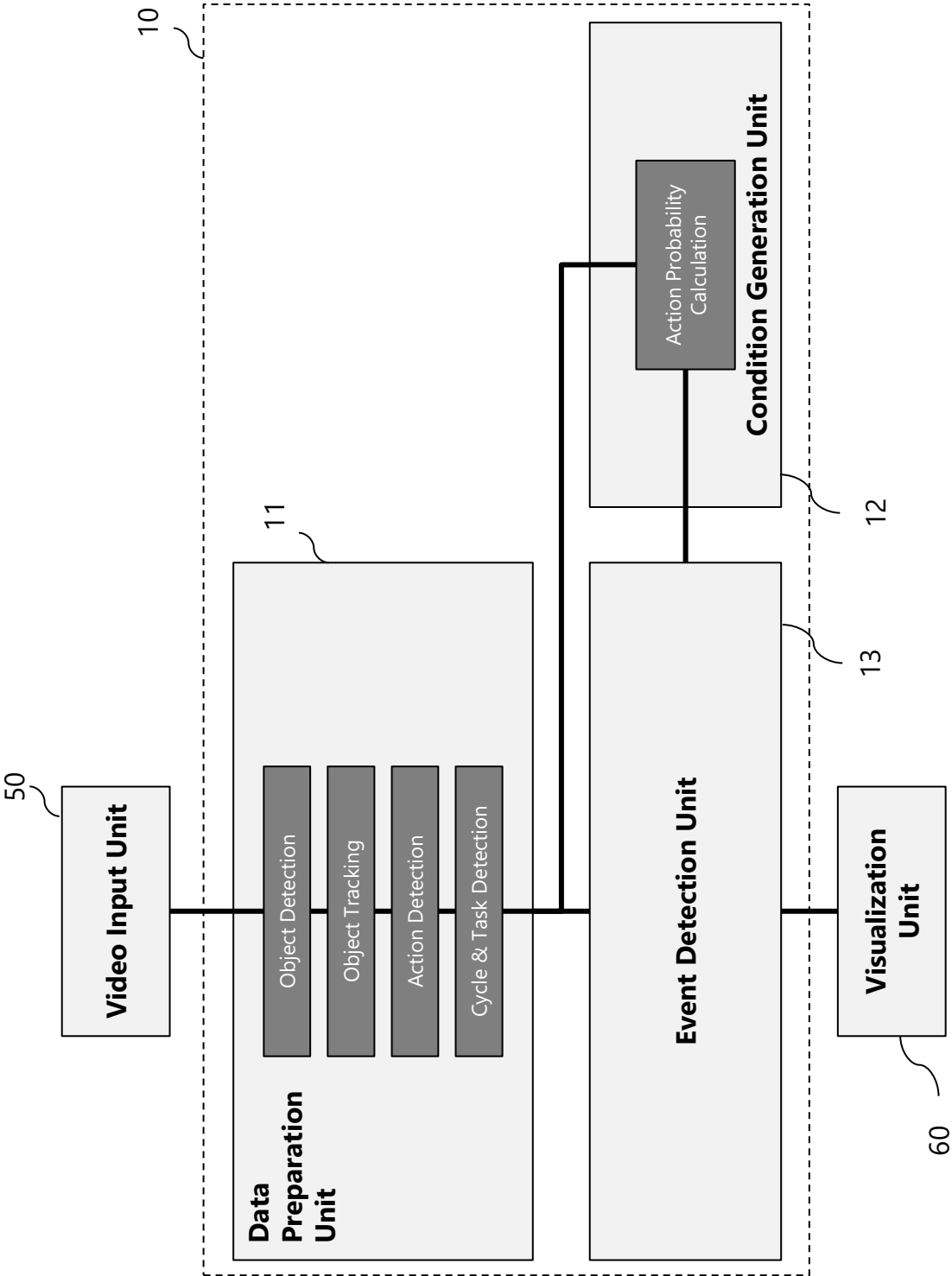


Fig. 17

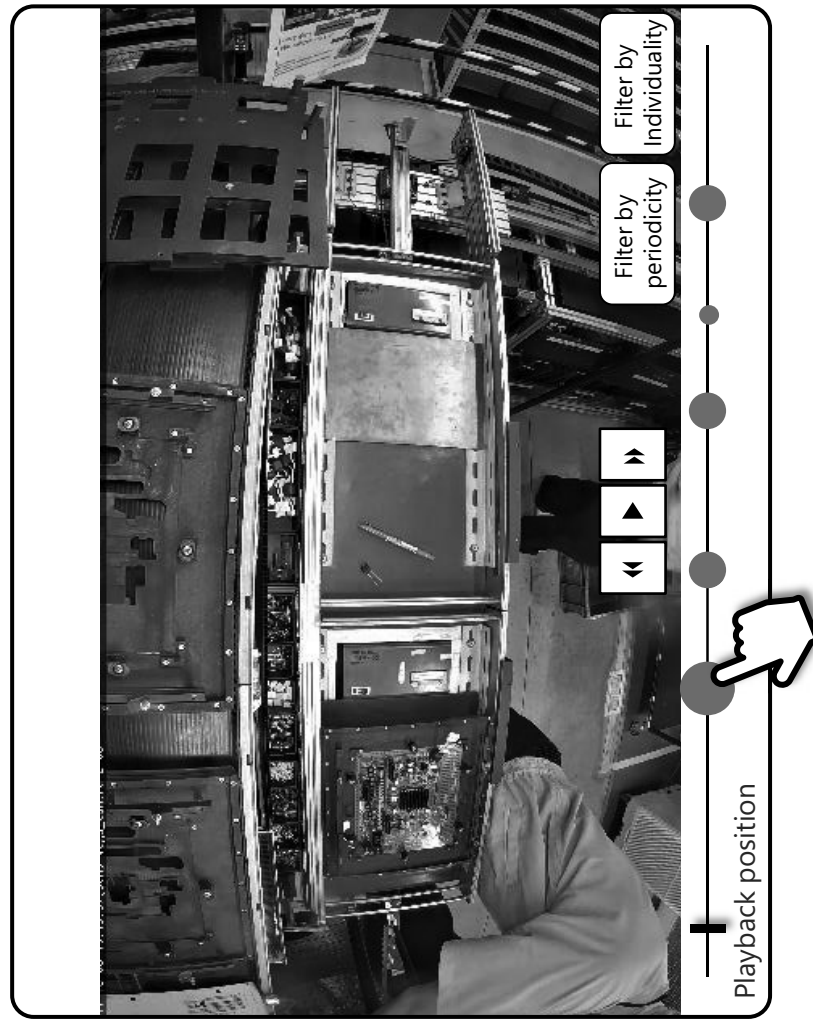


Fig. 18

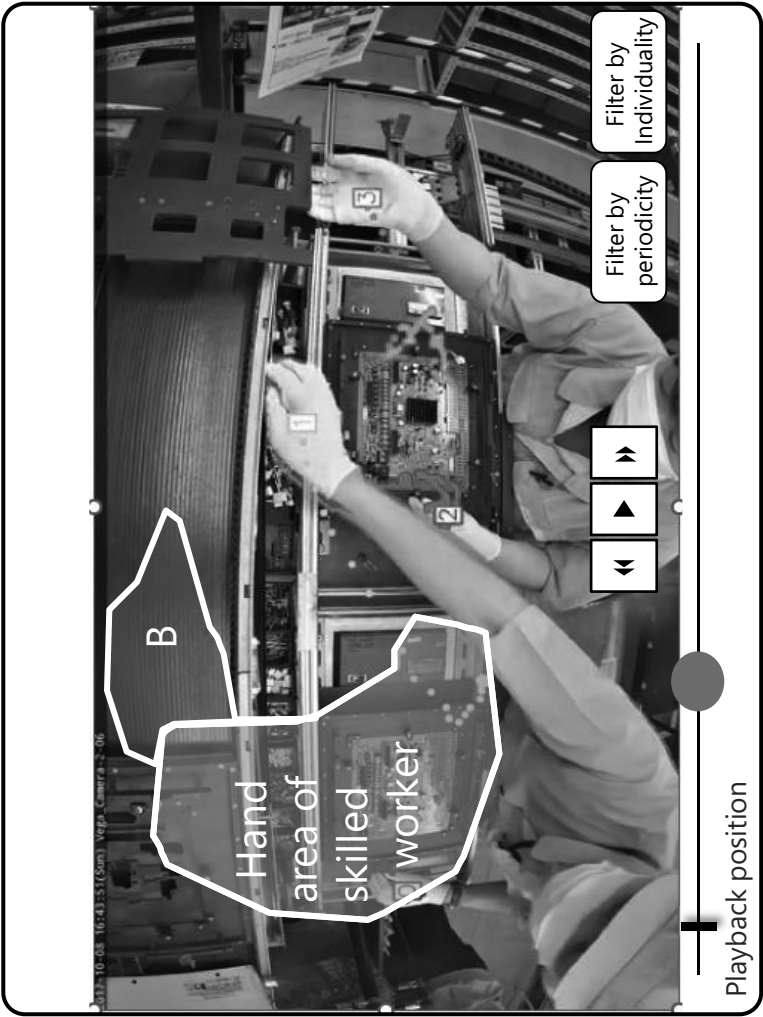


Fig. 19

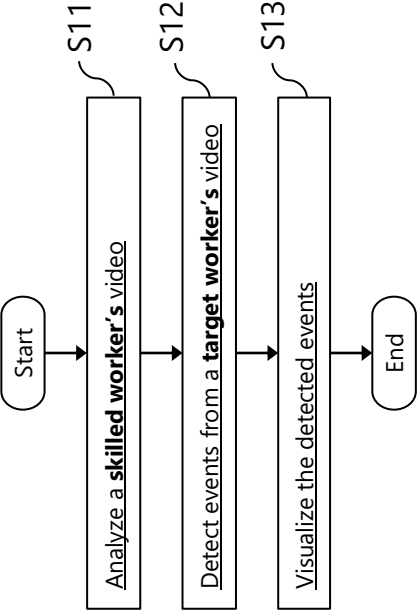


Fig. 20

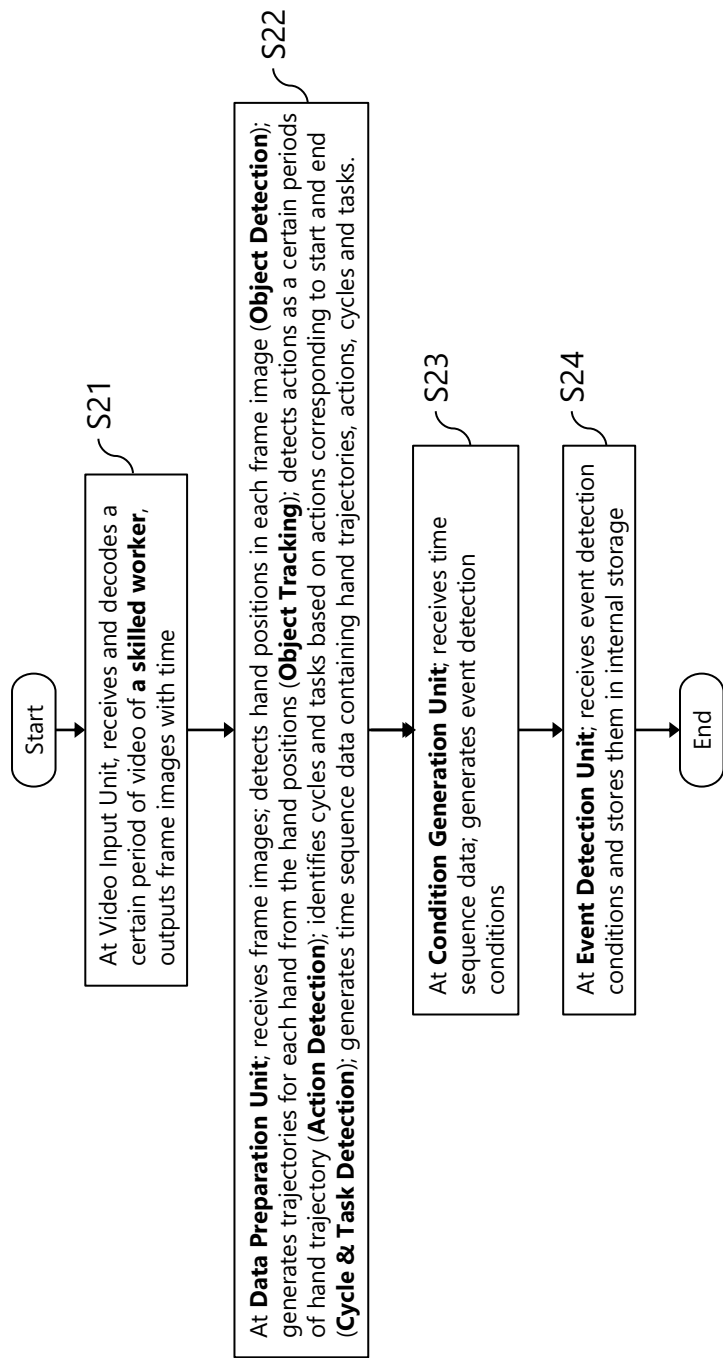


Fig. 21

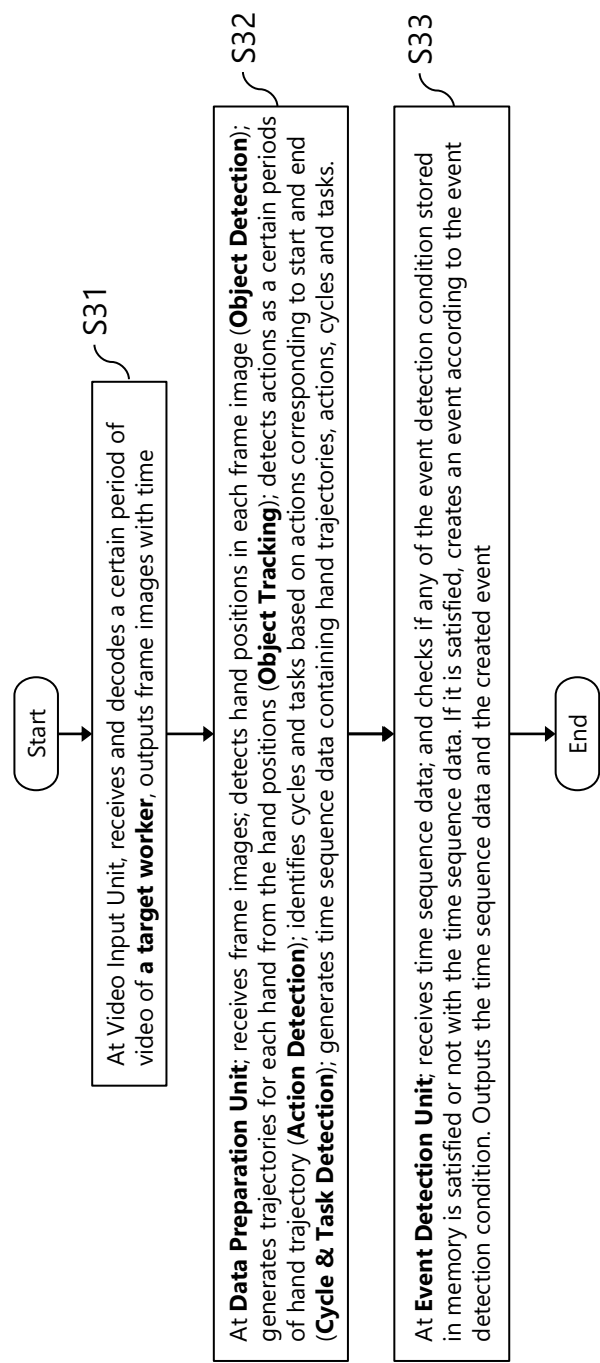


Fig. 22

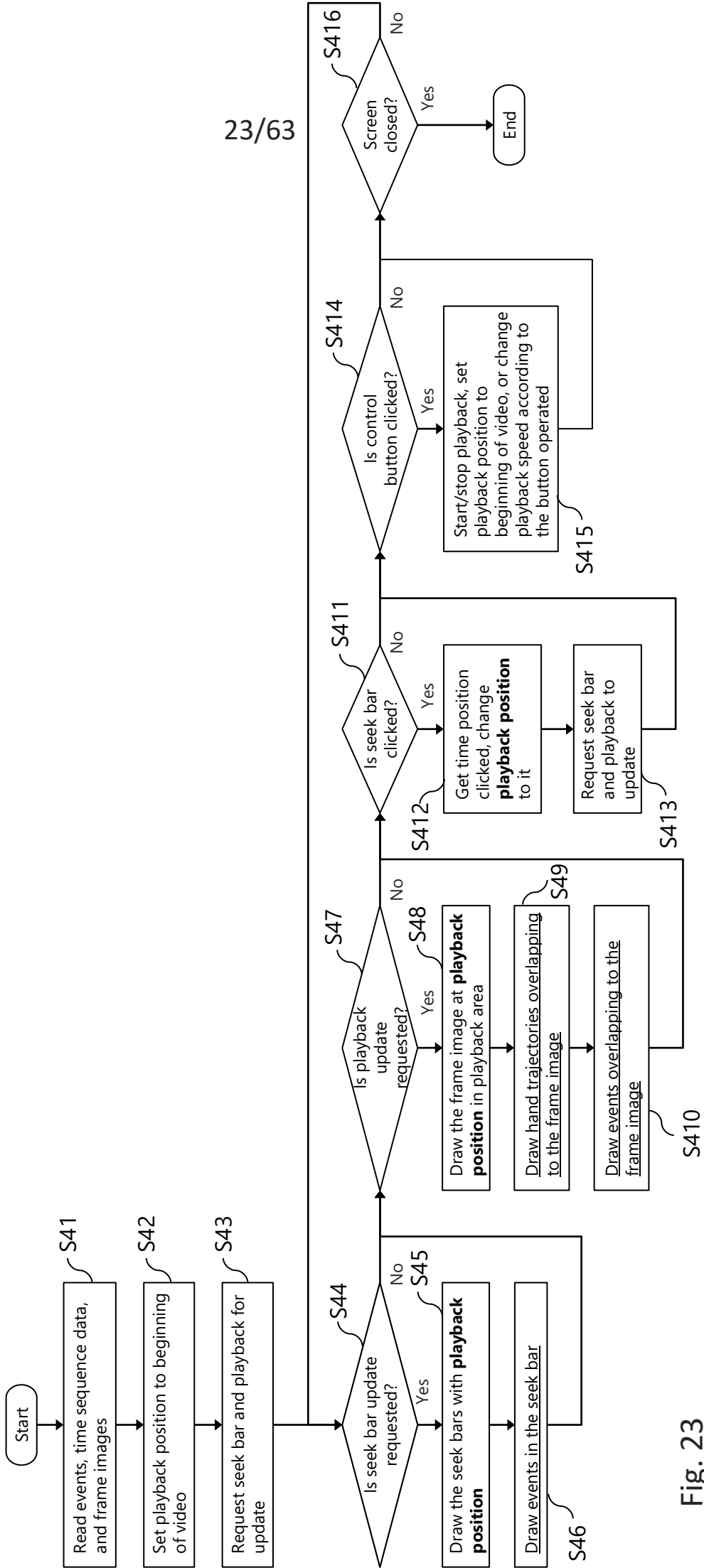


Fig. 23

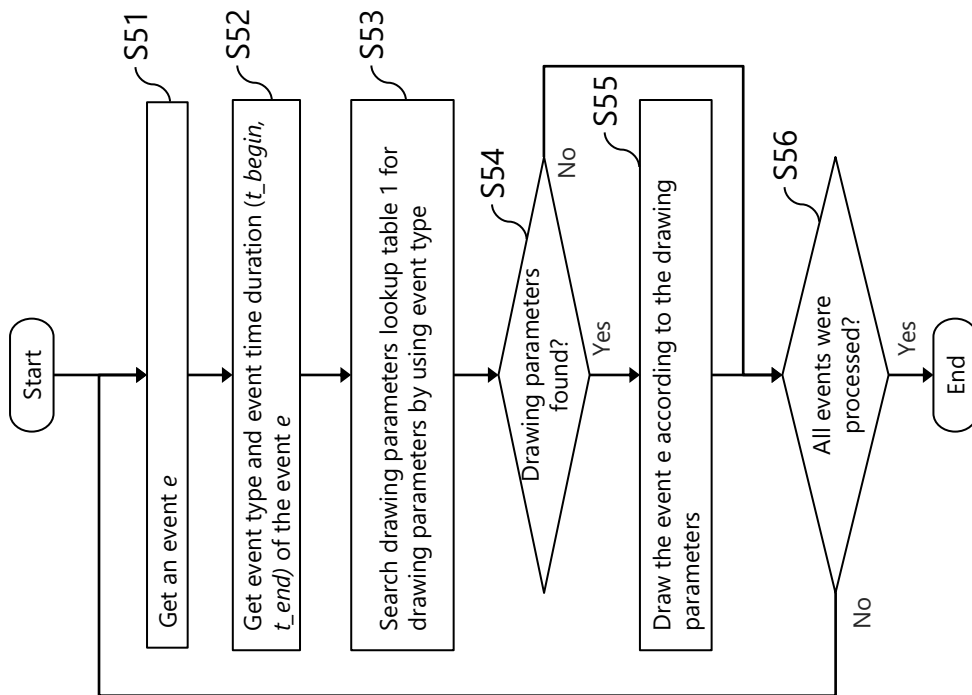


Fig. 24

Drawing parameters lookup table 1

Event type	Primitive	Color	Size
Unusual Action	Circle	Red	100
Long Task Duration	Circle	Orange	50
Short Task Duration	Circle	Orange	50
Out of Work Area	Square	Red	30

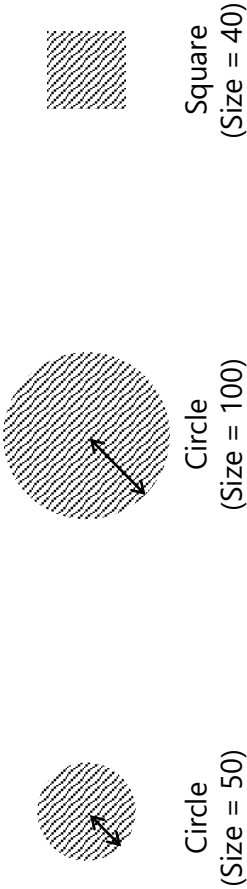


Fig. 25

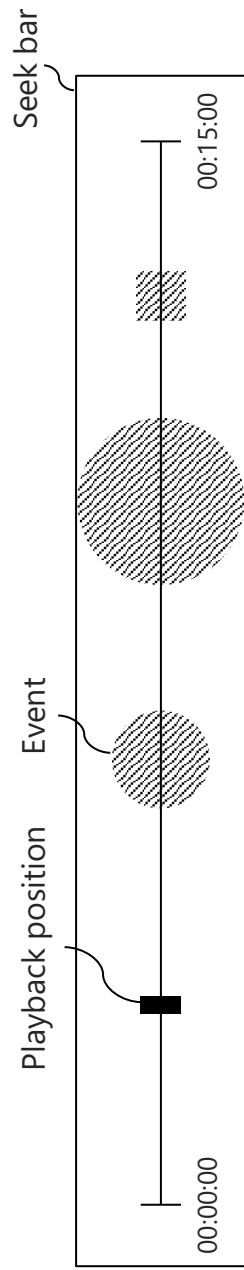


Fig. 26

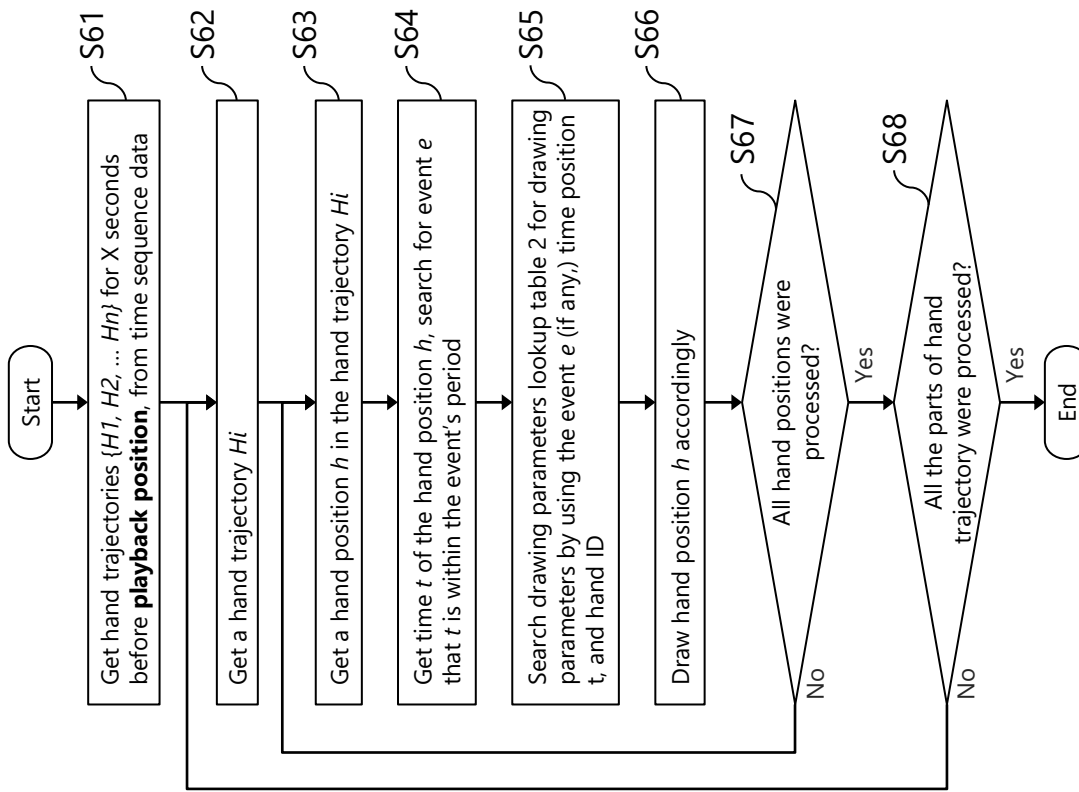


Fig. 27

1

Labelled-box
(Hand ID=1)

Dot
(Size=5)

Dot
(Size=10)

Drawing parameters lookup table 2

Event	Time position	Hand ID	Primitive	Color	Size
None	playback position	1	Labelled-box	Blue	20
None	playback position	2	Labelled-box	Yellow	20
None	< playback position	1	Dot	Blue	5
None	< playback position	2	Dot	Yellow	5
Any	playback position	1	Labelled-box	Blue	20
Any	playback position	2	Labelled-box	Yellow	20
Any	< playback position	1	Dot	Blue	10
Any	< playback position	2	Dot	Yellow	10

Fig. 28



Event	Time position	Hand ID	Primitive	Color	Size
None	< playback position	1	Triangle	Blue	10
None	< playback position	2	Triangle	Yellow	10

Fig. 29

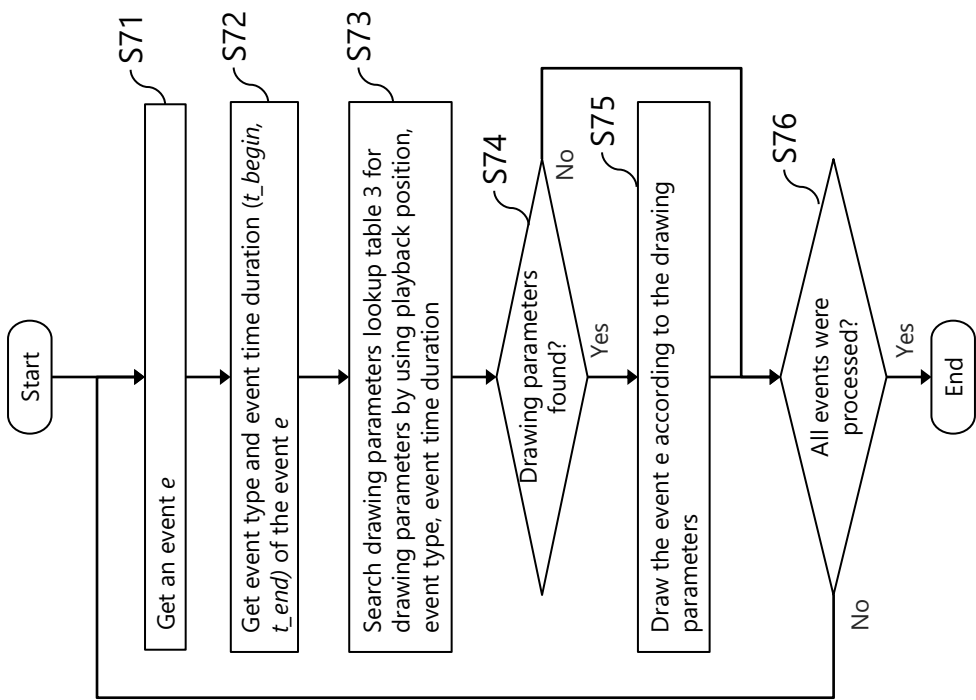


Fig. 30

Drawing parameters lookup table 3

Event type	Playback position	Primitive	Color	Size	Text
Unusual Action	$t_begin - 0.5sec \sim t_end + 0.5sec$	ThickLinePolygon	Red	50	
Long Task Duration	$t_begin - 0.5sec \sim t_end + 2sec$	AlertBox	Red		Longer task time!
Short Task Duration	$t_begin - 0.5sec \sim t_end + 2sec$	AlertBox	Red		Short task time!
Out of Work Area	anytime	WorkAreaPolygons		30	

Is playback position within
this event time duration?

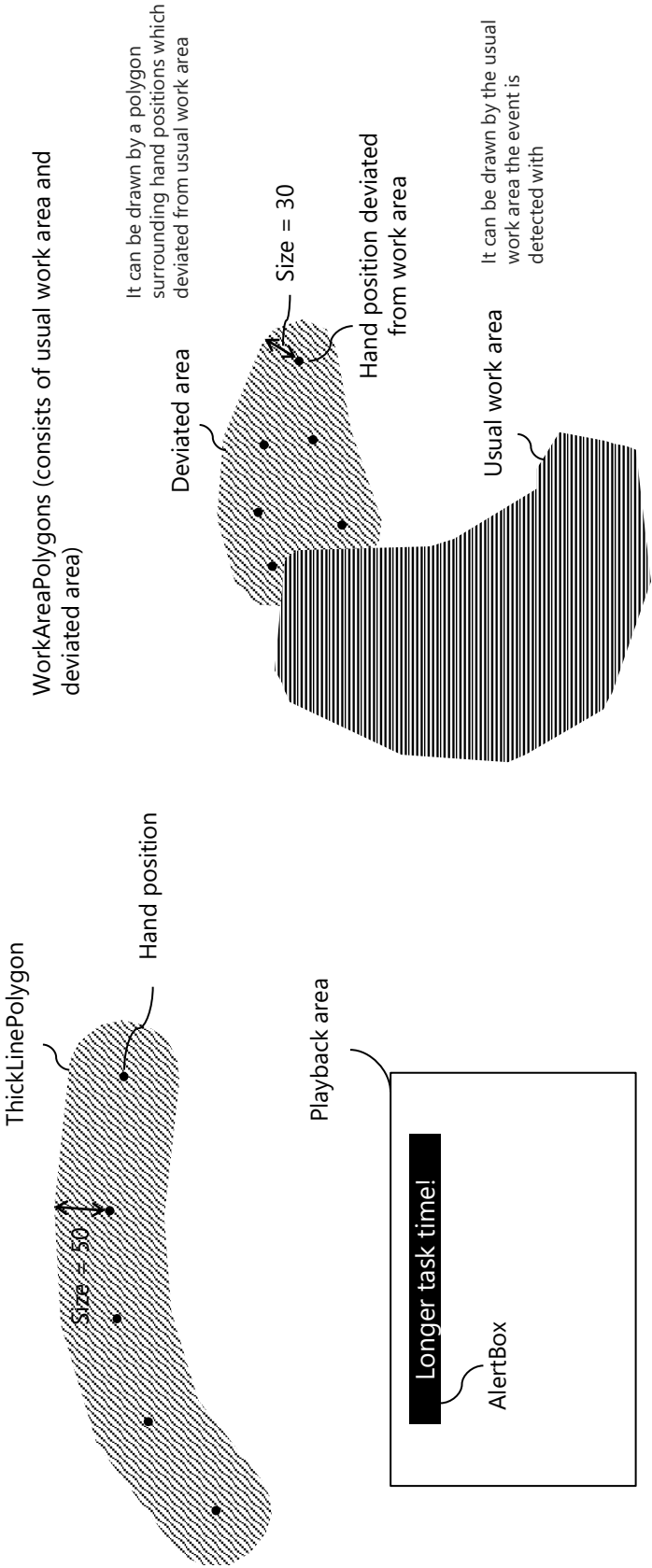


Fig. 31

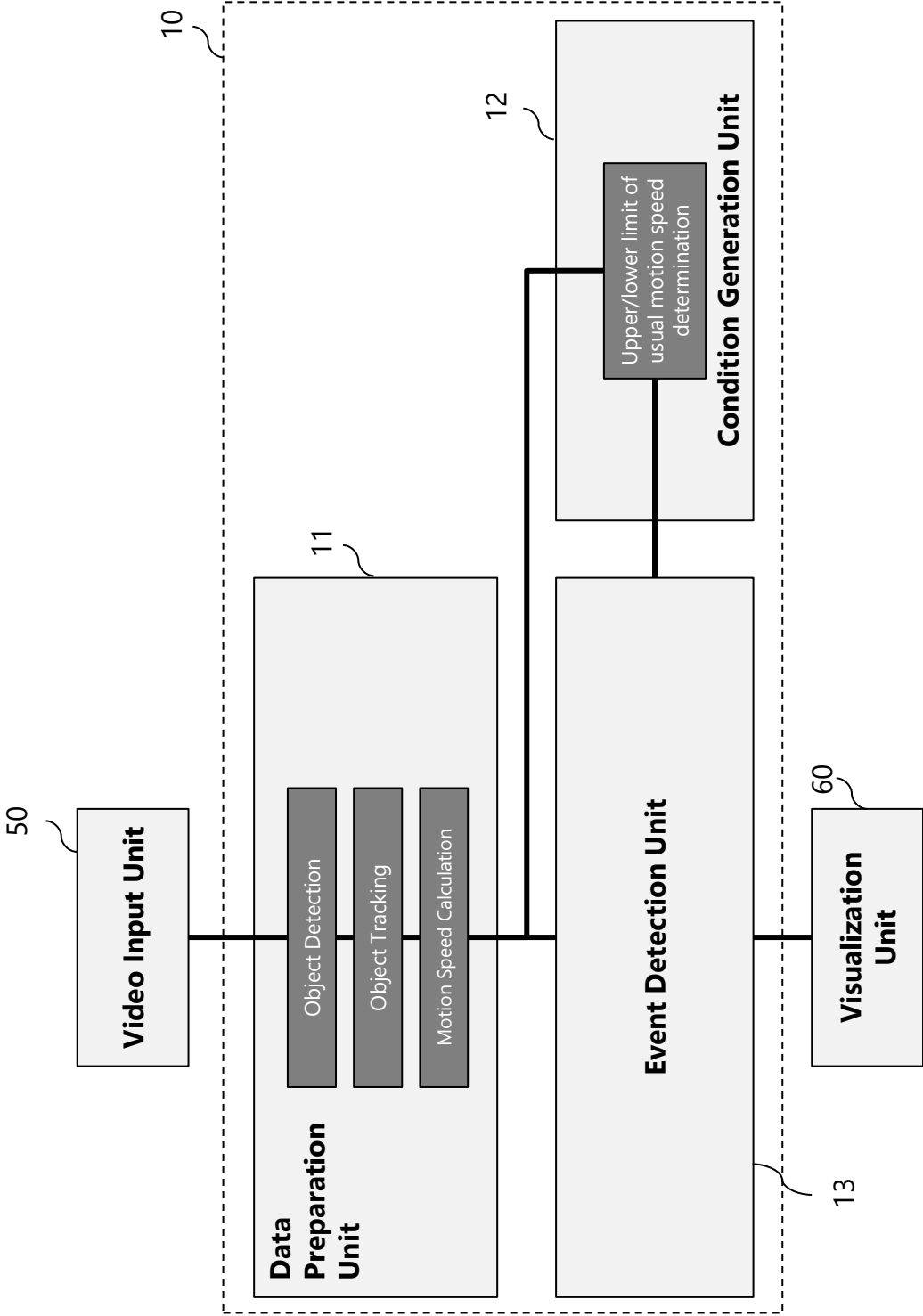


Fig. 32

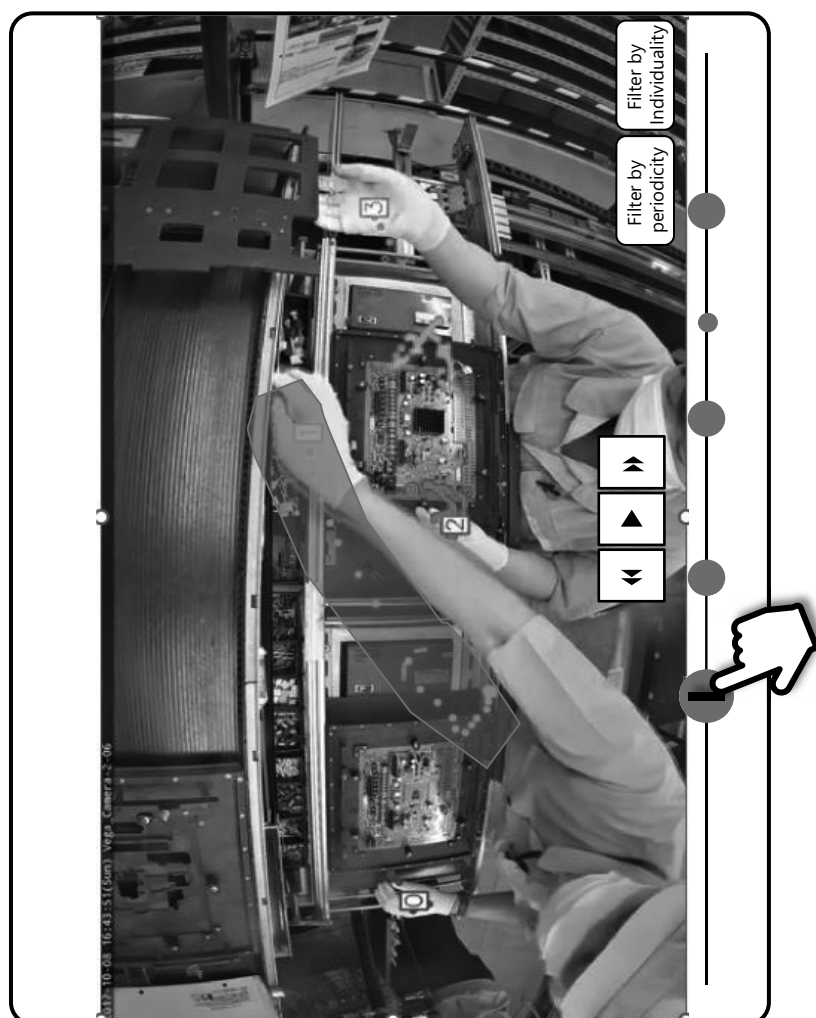


Fig. 33

Drawing parameters lookup table for drawing events in seek bar

Event type	Primitive	Color	Size
Faster hand movement speed	Circle	Red	50
Slower hand movement speed	Circle	Red	50



Circle
(Size = 50)

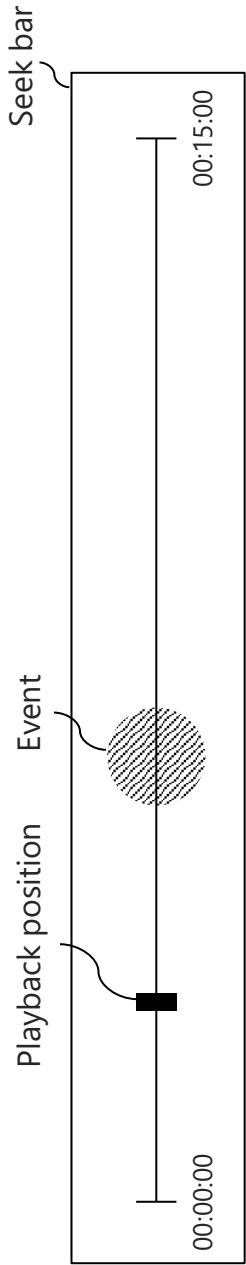


Fig. 34

Drawing parameters lookup table for drawing events
overlapping to the frame image

Event type	Playback position	Primitive	Color	Size	Text
Faster hand movement speed	$t_begin - 0.5sec \sim t_end + 0.5sec$	ThickLinePolygon	Red	50	
Slower hand movement speed	$t_begin - 0.5sec \sim t_end + 0.5sec$	ThickLinePolygon	Blue	50	

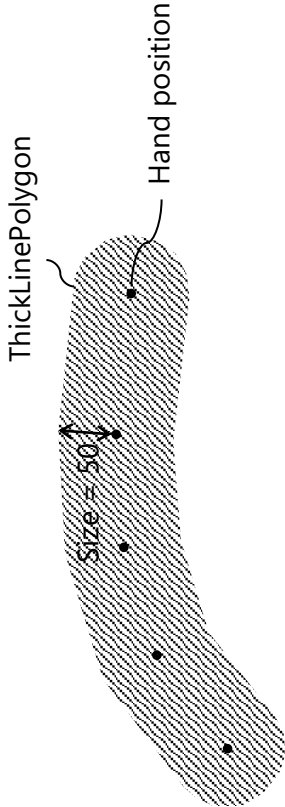


Fig. 35

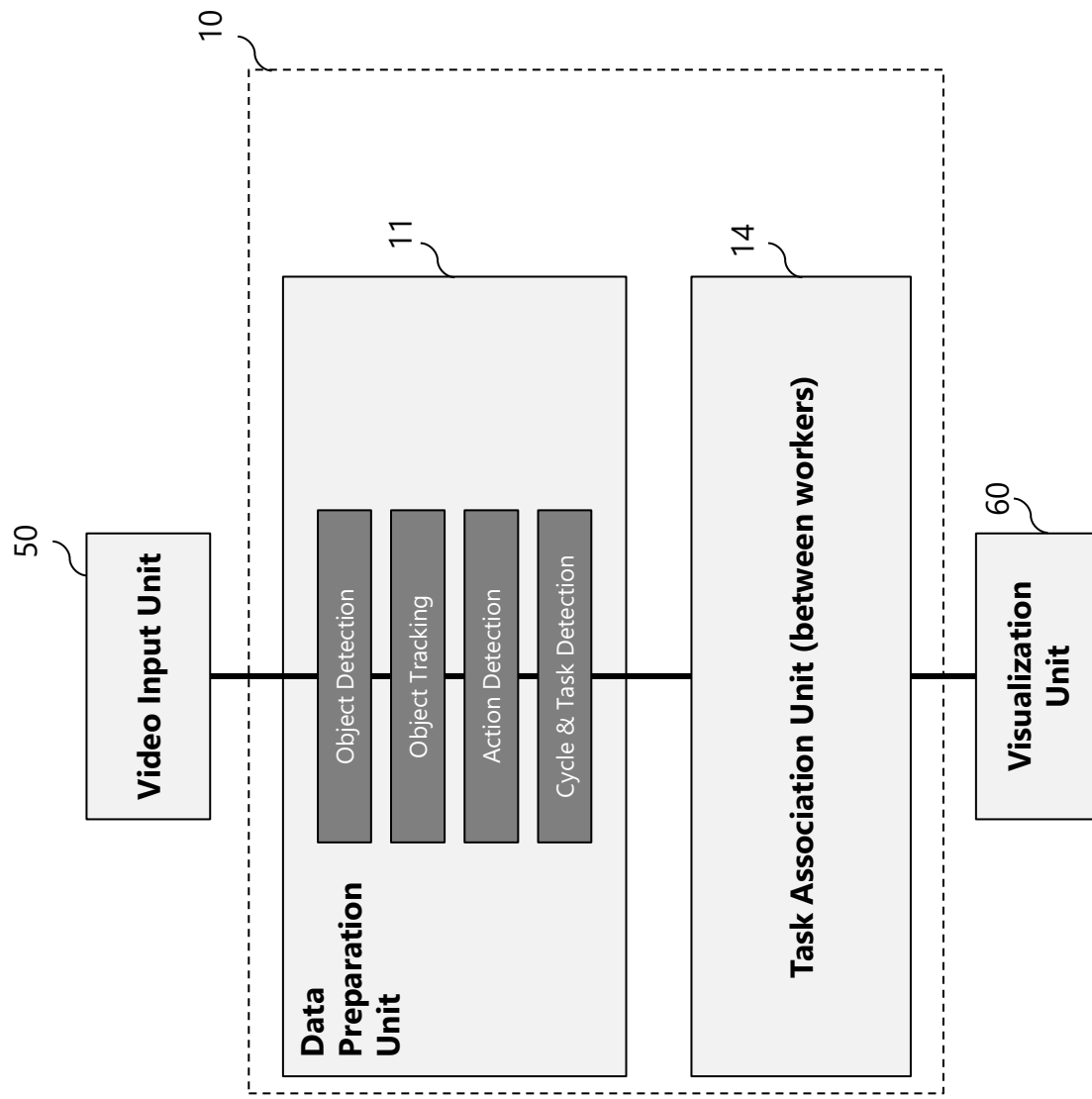


Fig. 36

Task	Task start time	
	myself	Skilled worker
Task A	00:00:00	00:00:00
Task B	00:00:15	00:00:10
Task C	00:00:40	00:00:30

Fig. 37

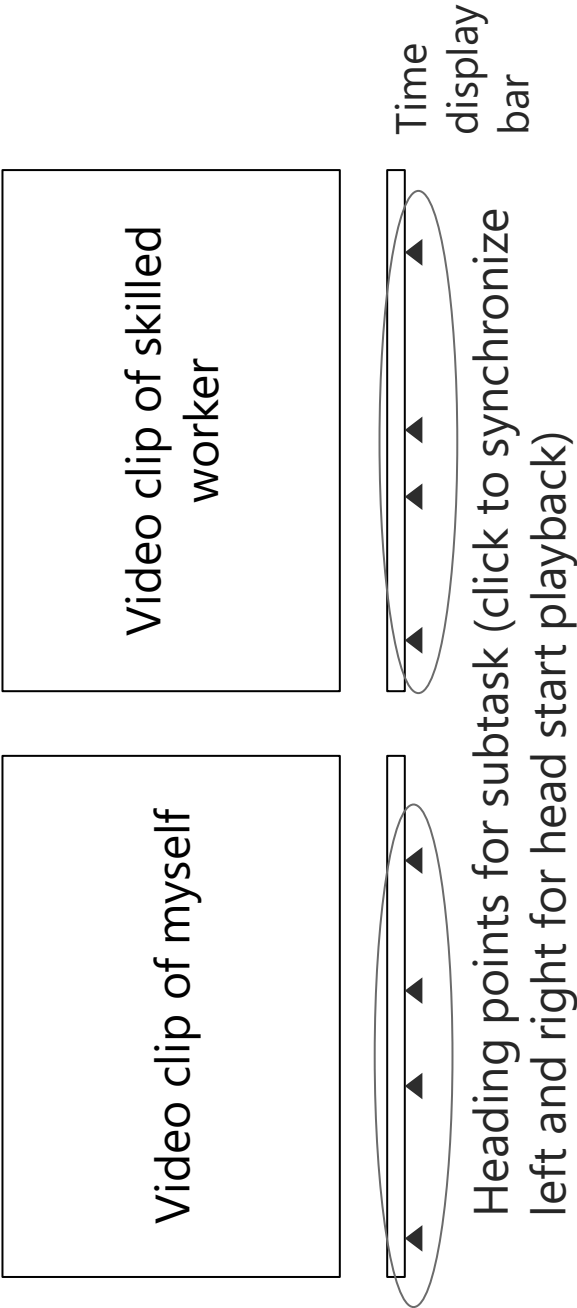


Fig. 38

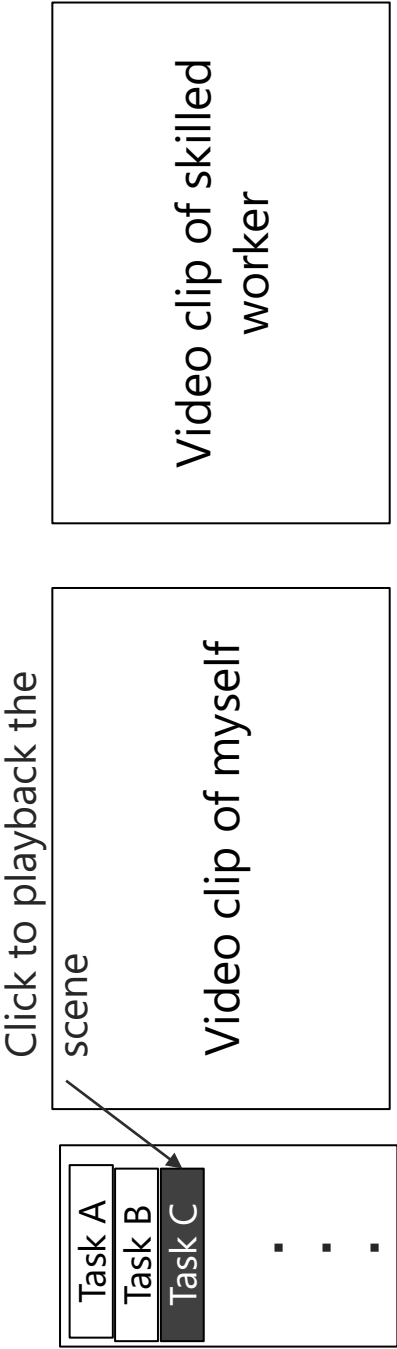


Fig. 39

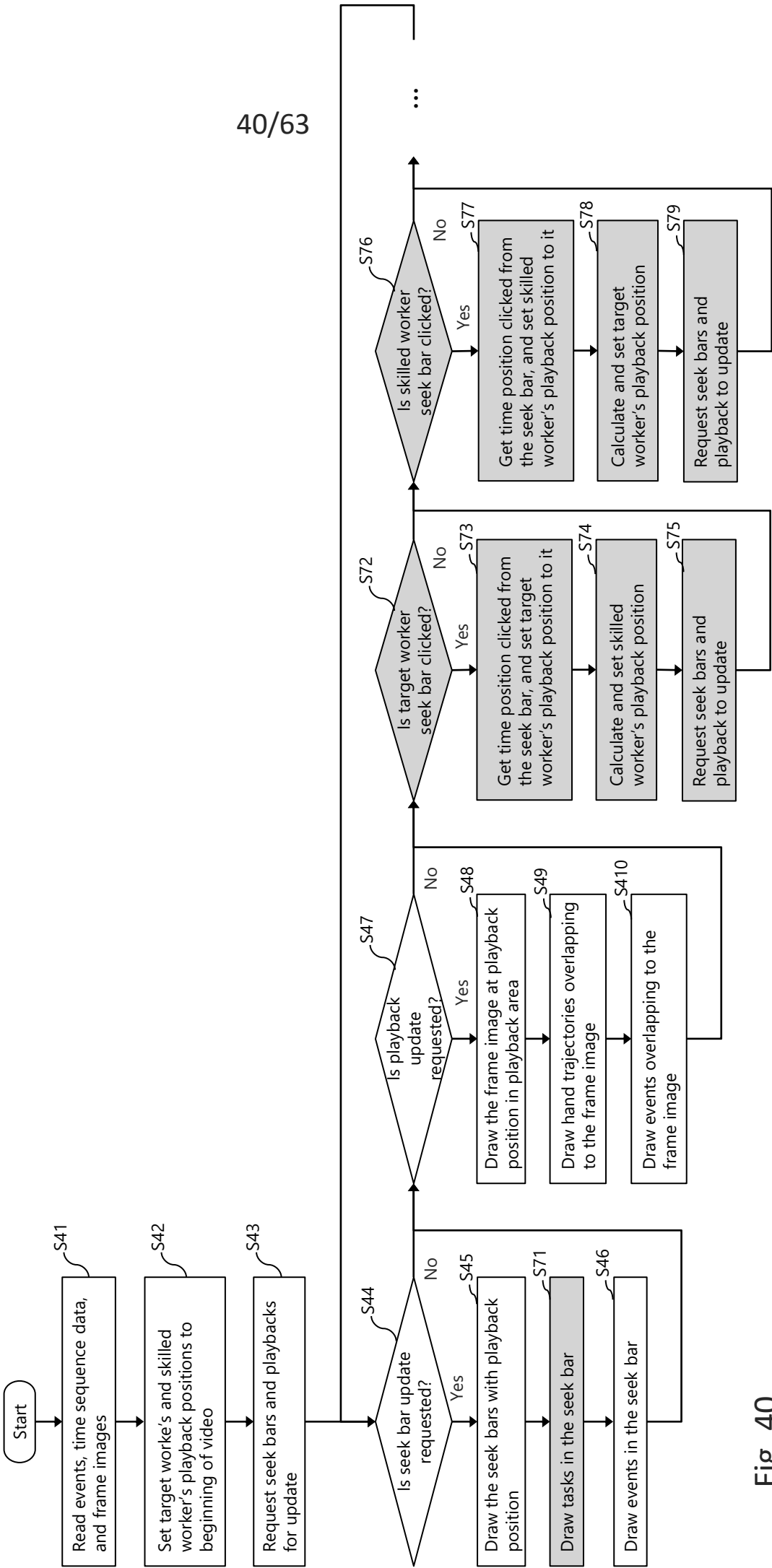


Fig. 40

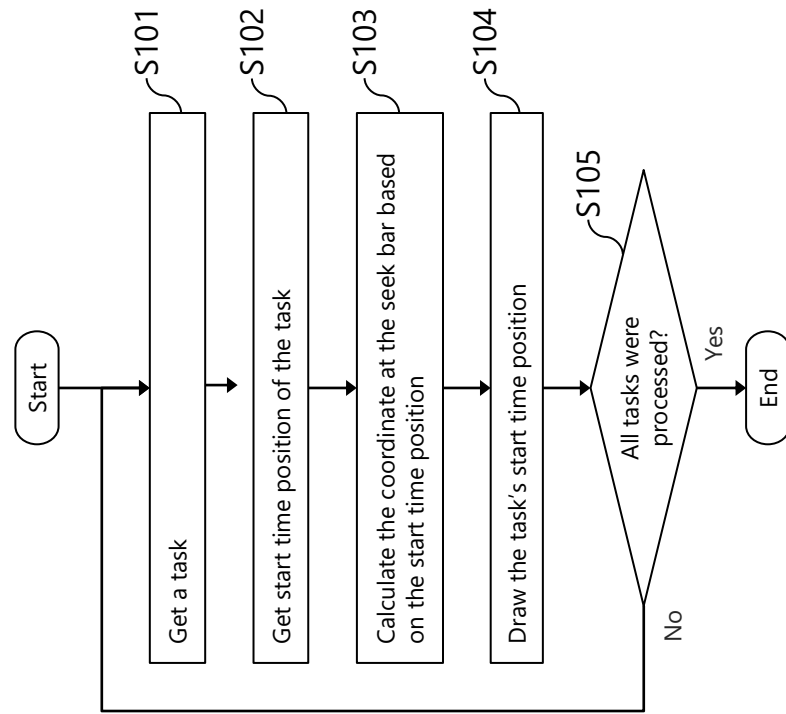


Fig. 41

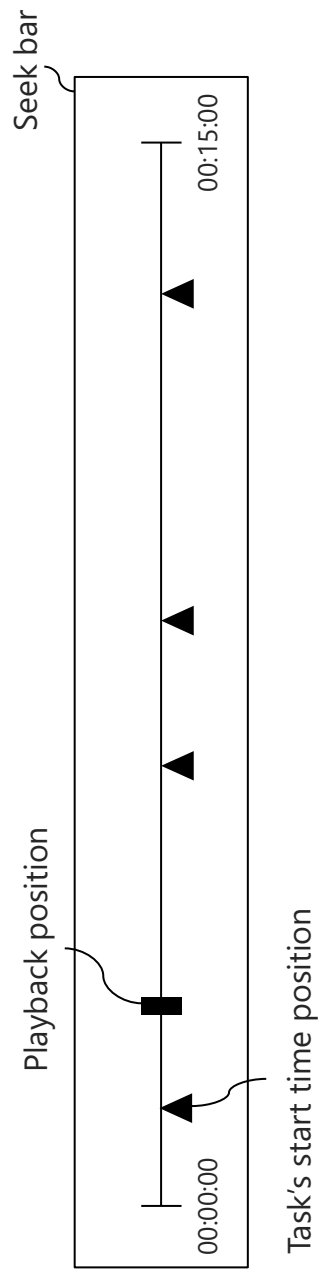


Fig. 42

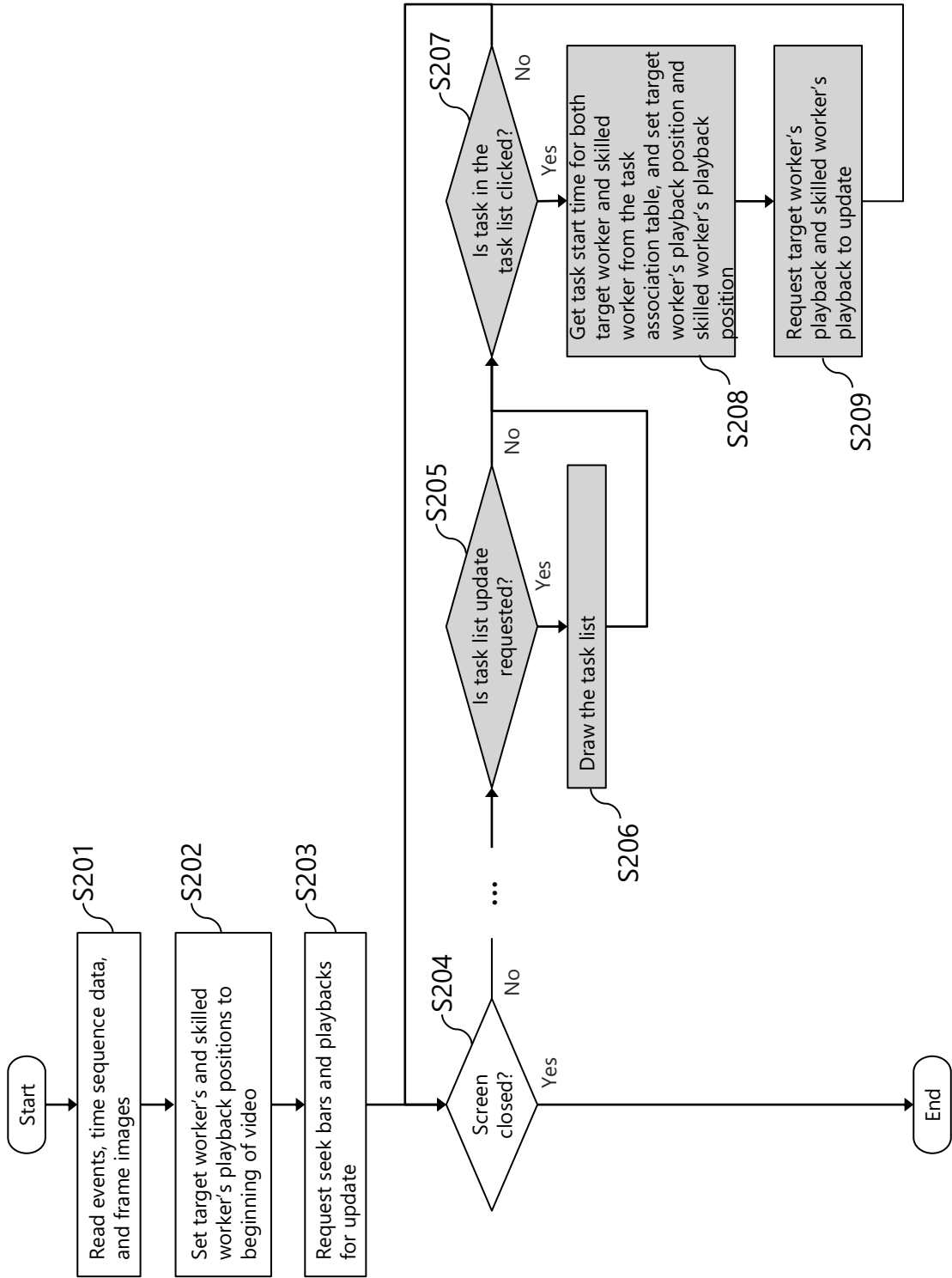


Fig. 43

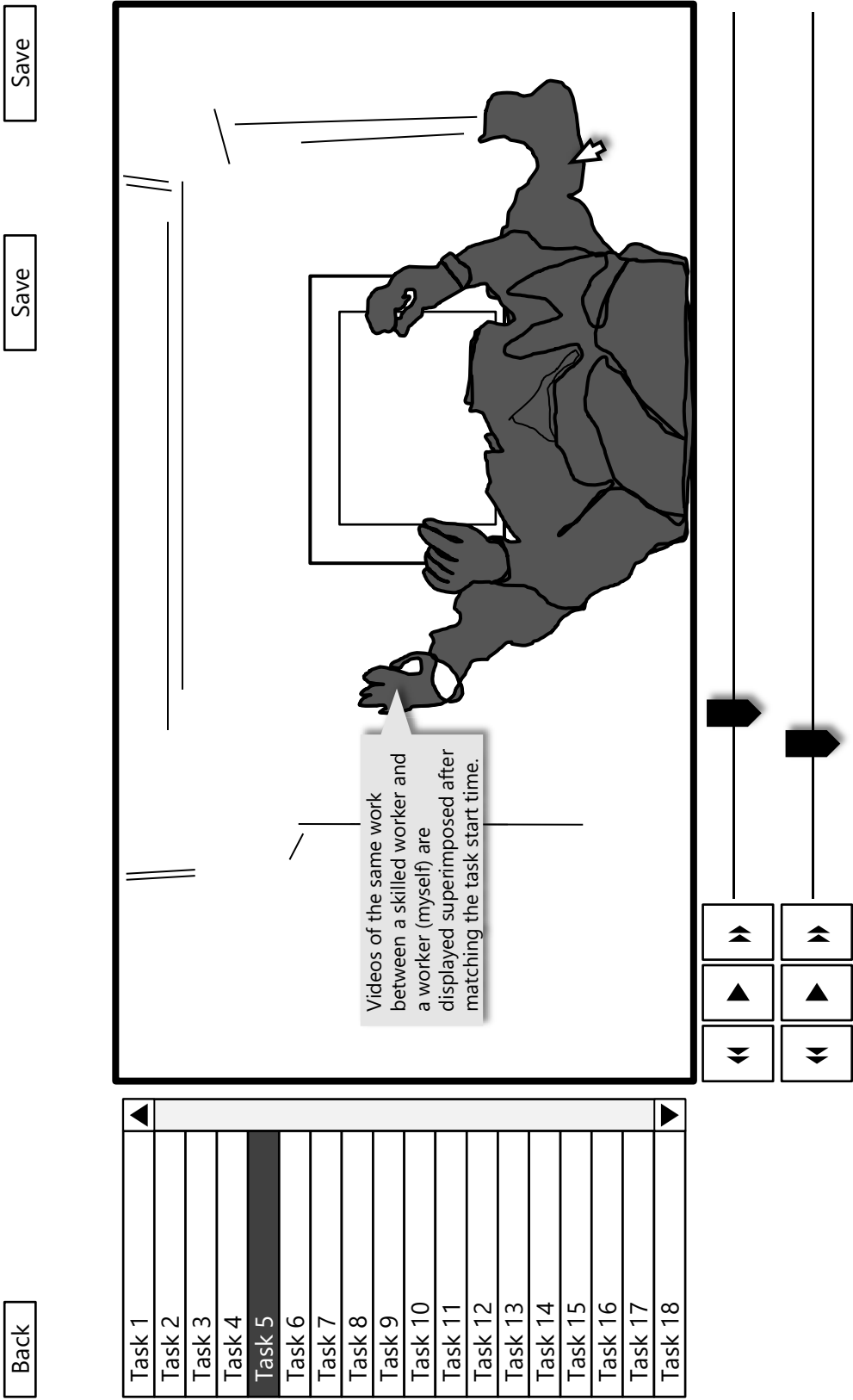


Fig. 44



Fig. 45

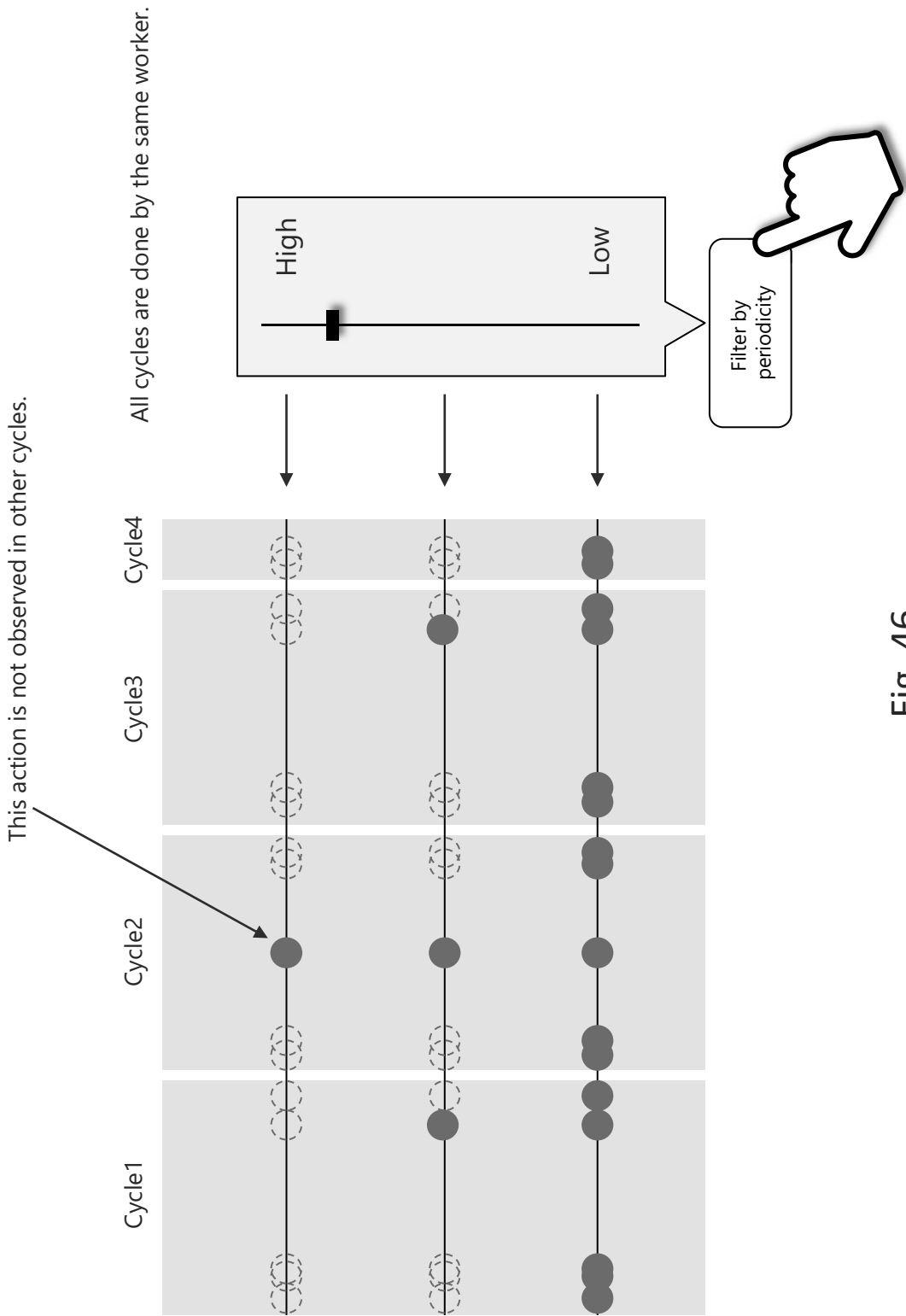


Fig. 46

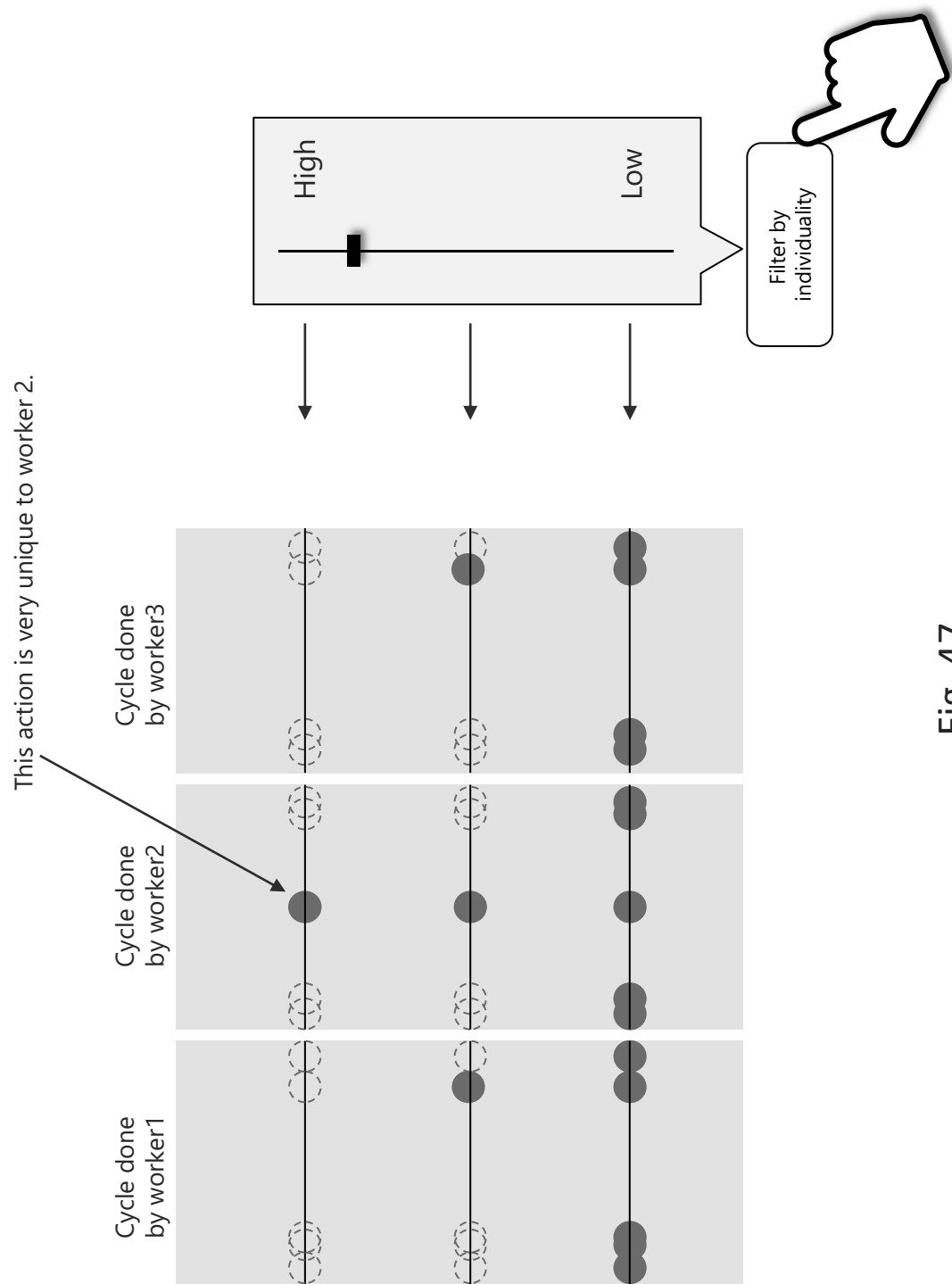


Fig. 47



Hand reached workbench 2 hand area.

Fig. 48

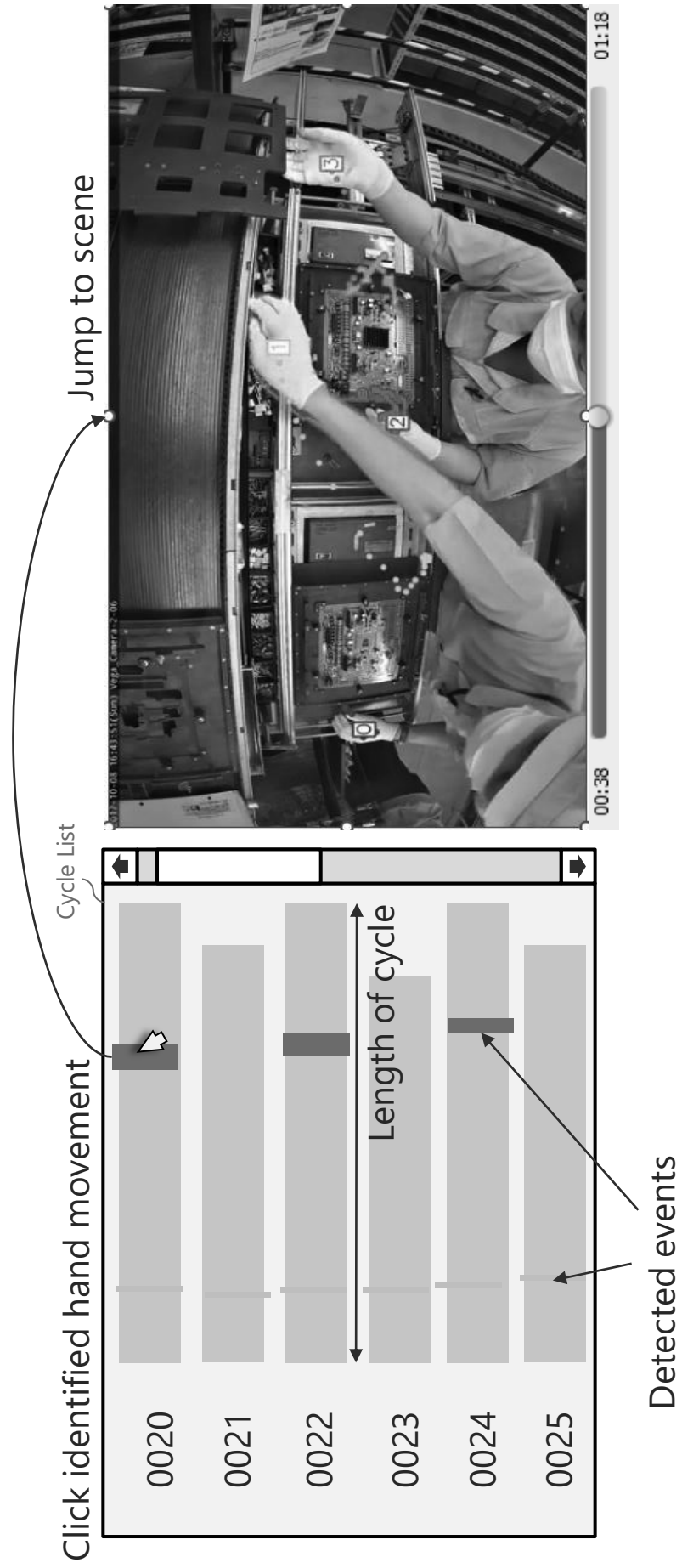


Fig. 49

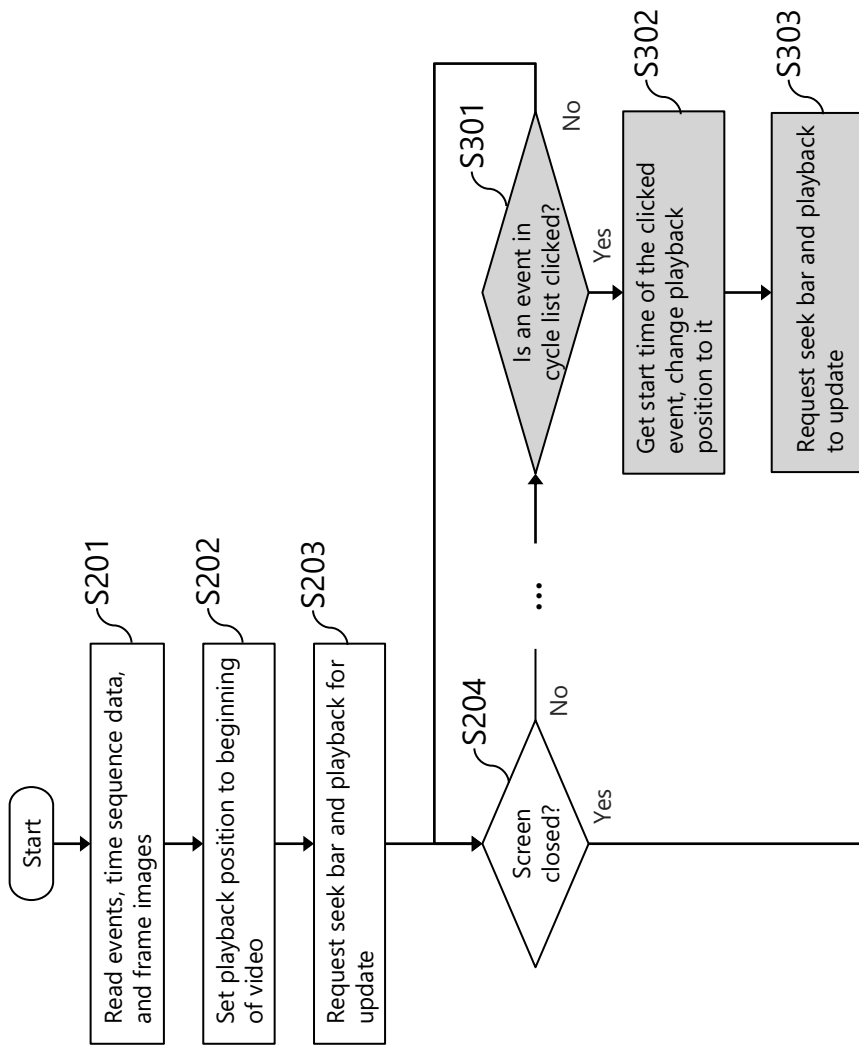


Fig. 50

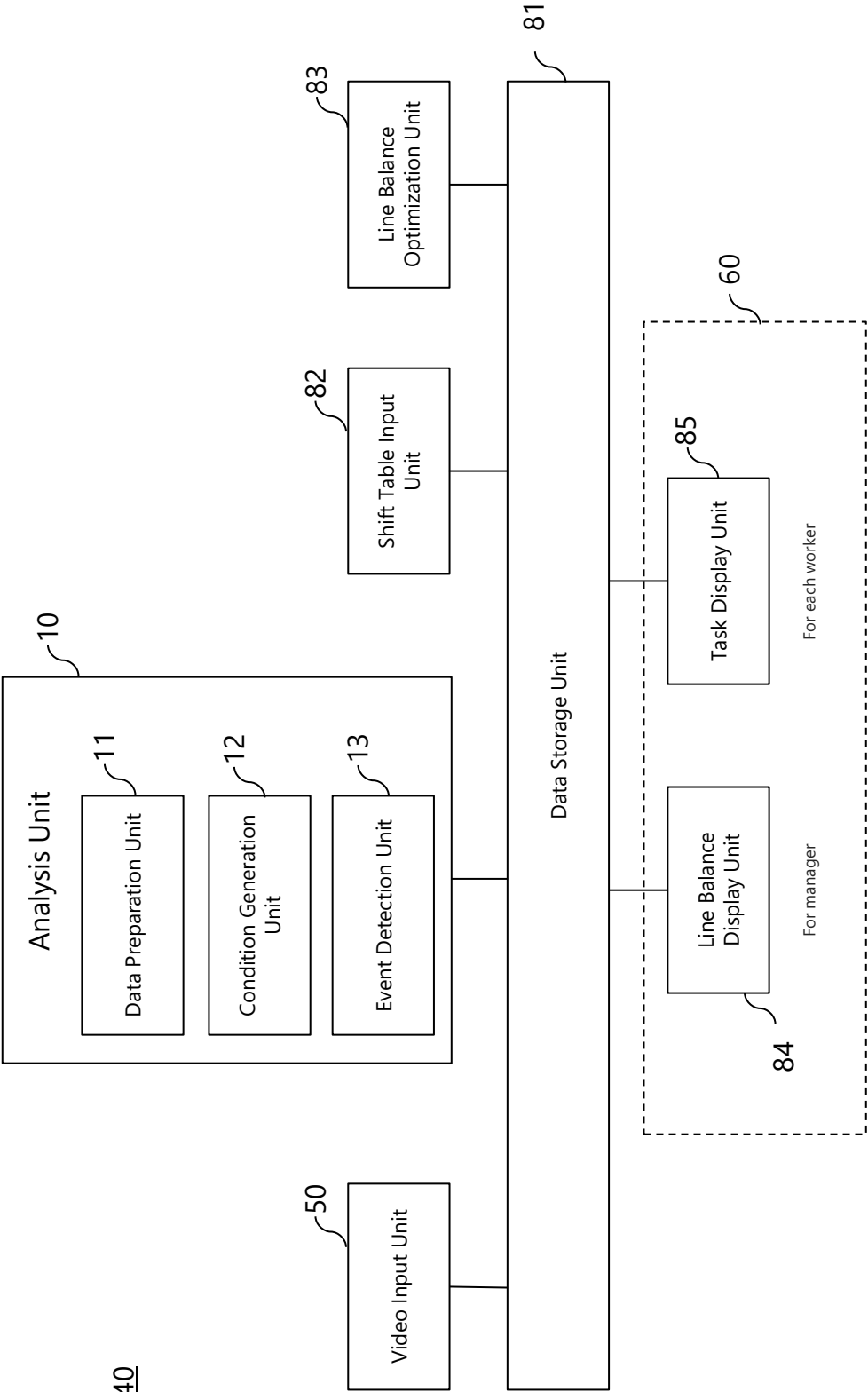


Fig. 51

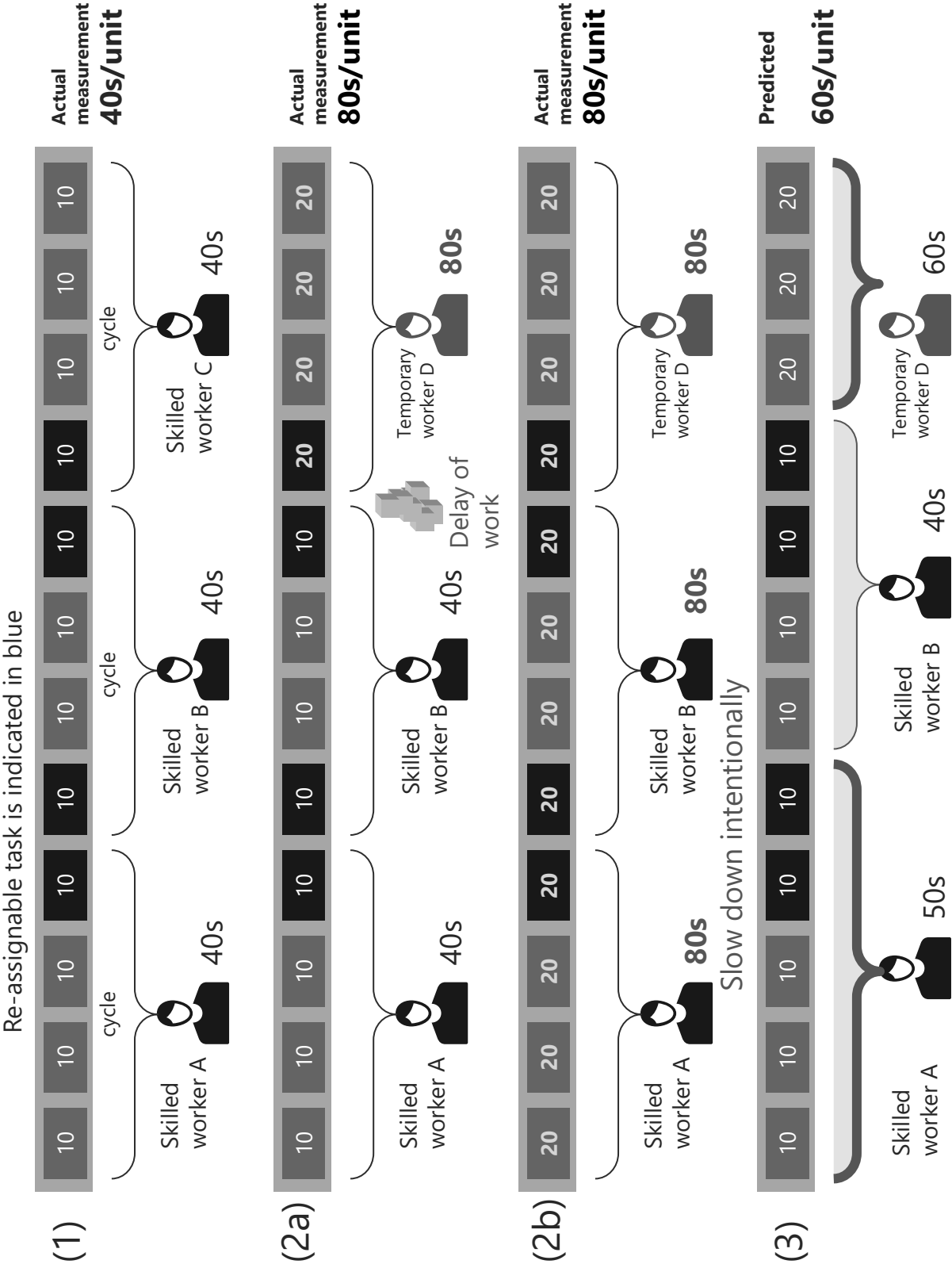


Fig. 52

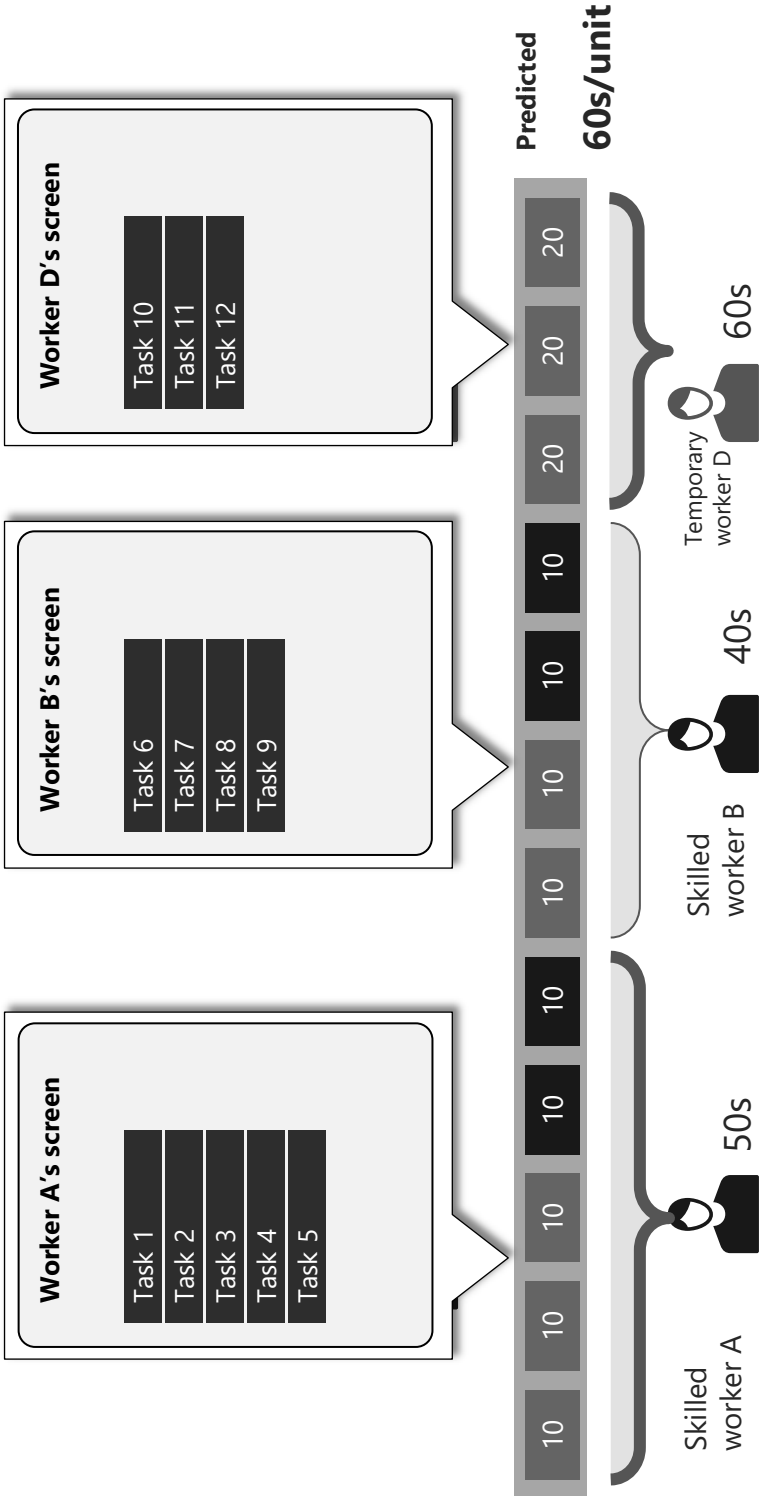


Fig. 53

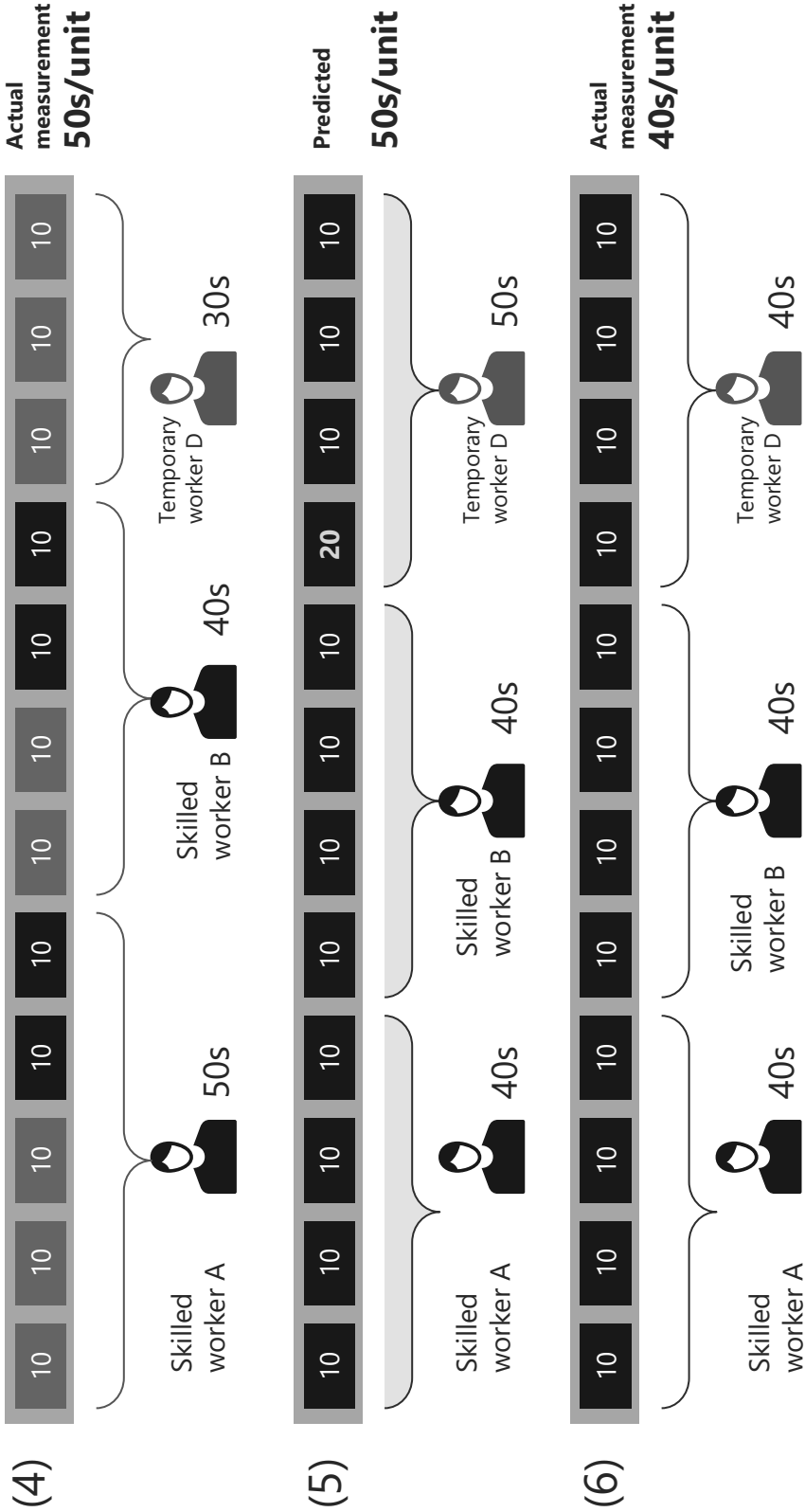


Fig. 54

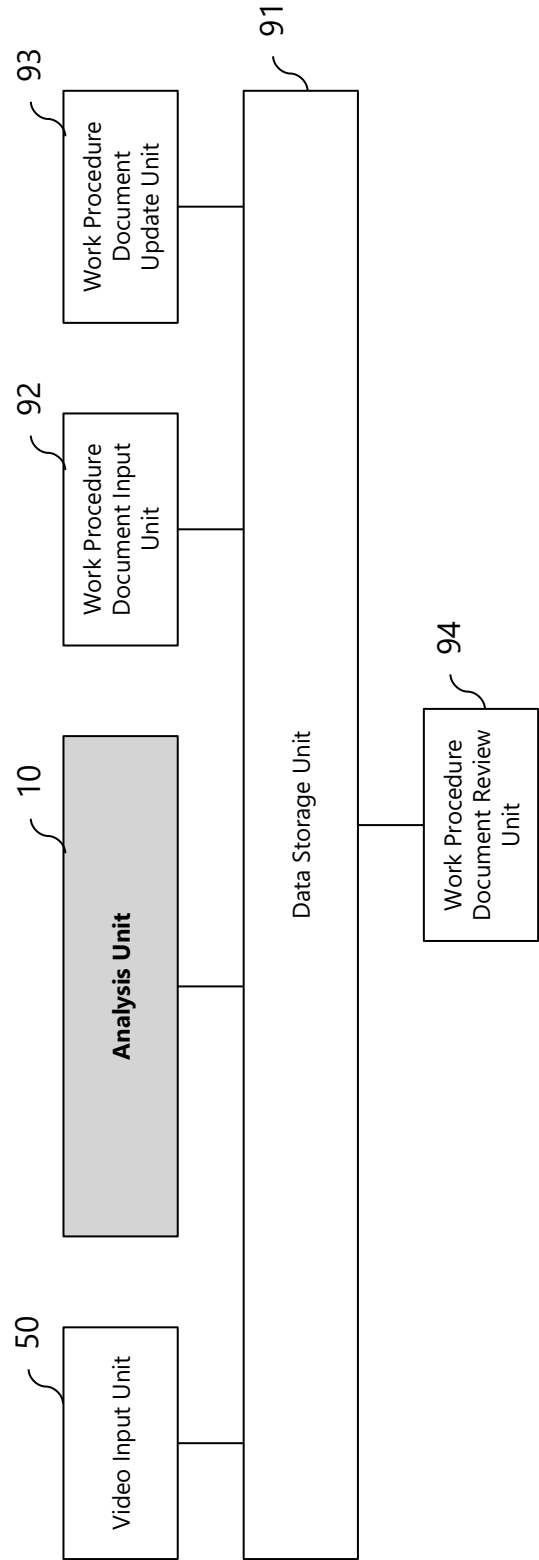


Fig. 55

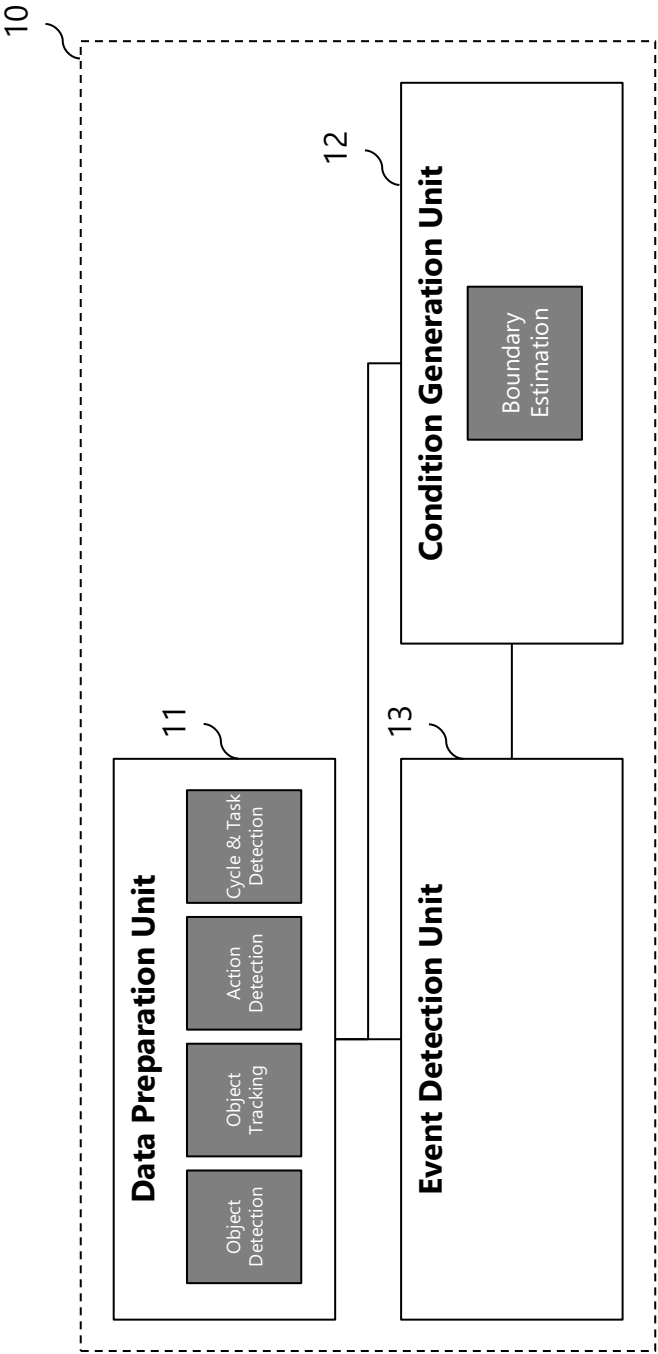


Fig. 56

Workbench

1: Motherboard assembly A

2: Motherboard assembly B

3: Handset assembly A

4: Handset assembly B

5: Handset assembly C

6: LCD assembly

7: Final assembly

8: Inspection

9: Packaging

Specify more

By workers

Taro

Hanako

Ayumi

By date

From

20 Aug 2023

to

20 Aug 2023

By cycle time

From

1 min 50 sec

to

2 min 0 sec

Back

Select data

Fig. 57

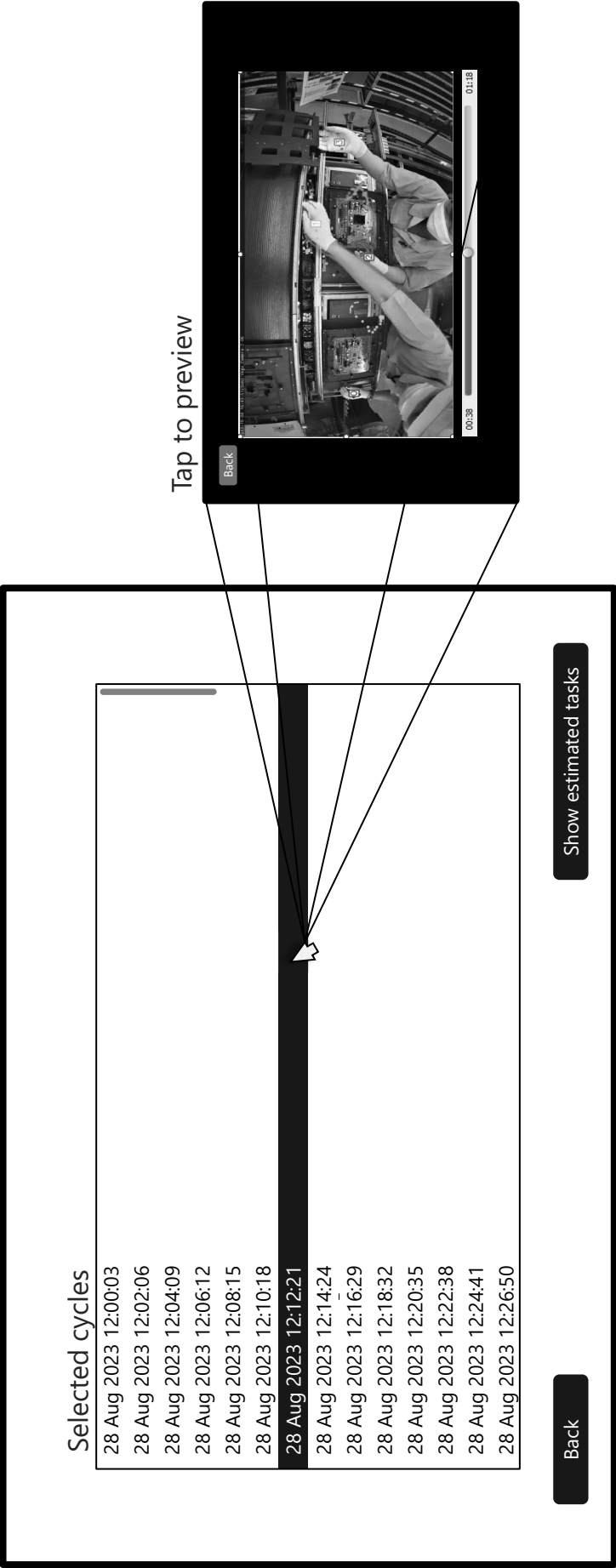
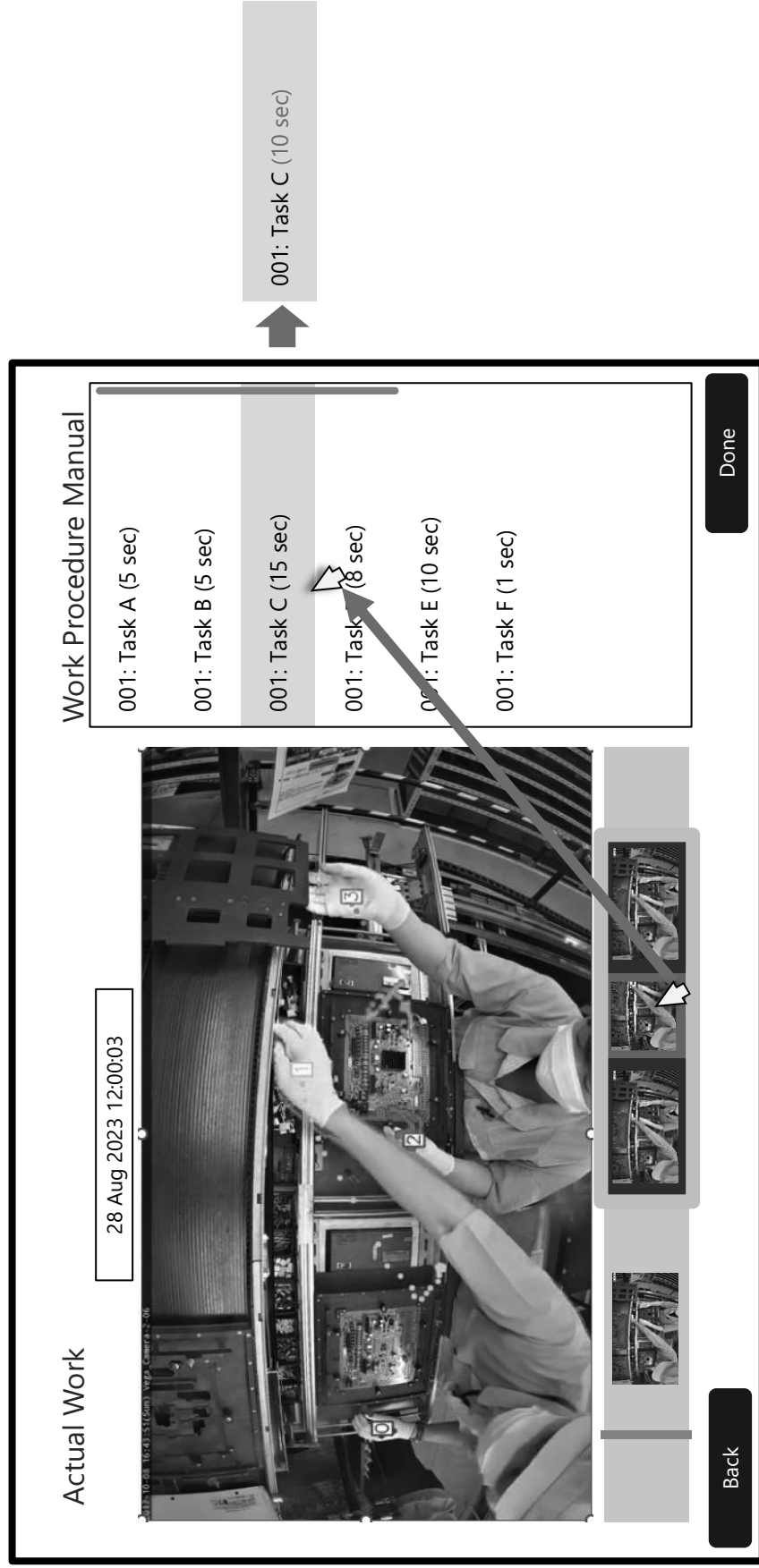


Fig. 58



59/63

Fig. 59

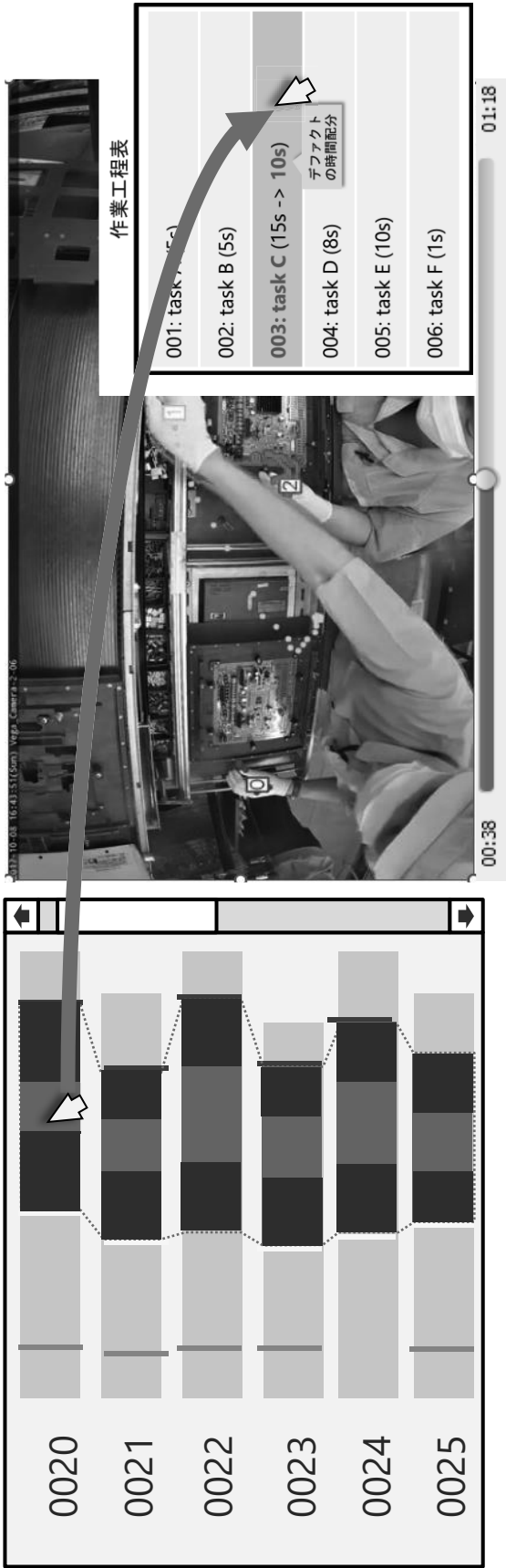


Fig. 60

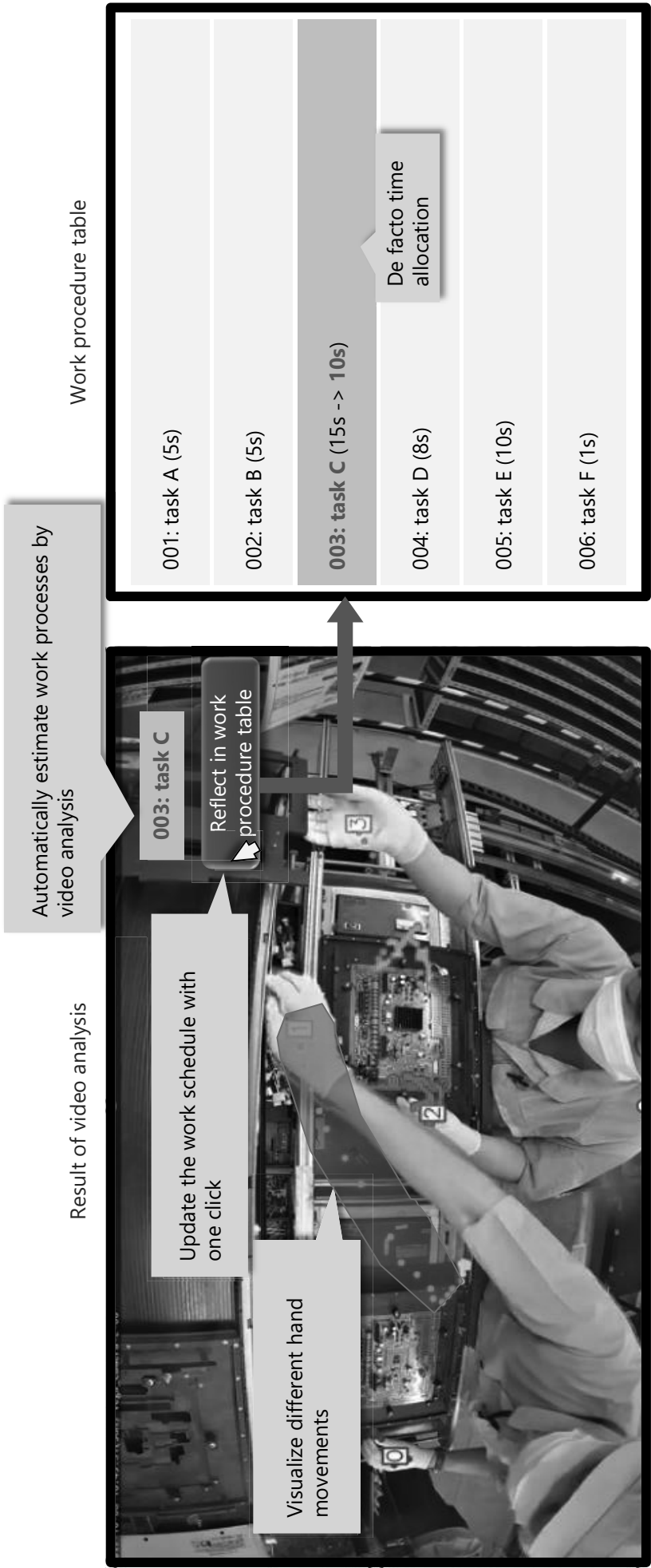


Fig. 61



When the user presses a button at the split position, the end position of this task is confirmed.

Fig. 62



Fig. 63