

# Fine-Grained Activity Detection in the Kitchen with UWB

University of Alberta



Steven Phan

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# **Chapter 1**

## **Introduction**

# **Chapter 2**

## **Literature Review**

## **Chapter 3**

### **System Testing and Tuning at the Independent Living Suite**

## **Chapter 4**

# **Classification of Time Series Data**

## Chapter 5

# Pilot Testing of Detecting Activities to make a Sandwich

# **Chapter 6**

## **Data Collection for Fine-grained Activities**

## 6.1 Selecting Cooking Tasks

To employ some of the time-series classification methods discussed in Chapter 4, a dataset of the proposed positional + IMU system is required. Chapter 2's section on the traditional assessments of ADLs will serve as a basis for the selection of tasks to perform and collect data from. Of the assessments discussed, Table 6.1 summarizes the assessments with cooking tasks mentioned in its procedure.

Table 6.1: Cooking tasks in the Assessment tools for the IADLs.

Tool	Tasks
PASS	making soup with water/milk making muffins in the oven cutting up fruit
Self-Assessment PD Disability Scale	making a cup of tea inserting electrical plug pouring milk from bottle opening tins washing
Melbourne Low-vision ADL Index	preparing meals
Lawton Instrumental ADL Scale	plans, prepares and serves adequate meals independently
Frenchay Activities Index	preparing main meals
Texas Functional Living Scale	Describe how to make peanut butter and jelly sandwich

Of the assessments in Table 6.1, the cooking task(s) in the Melbourne Low-vision ADL Index, Lawton Instrumental ADL Scale, Frenchay Activities Index, and Self-Assessment PD Disability Scale are all questionnaires and as a result do not have concrete steps on how the task should be performed.

Furthermore, the Melbourne Low-vision ADL Index, Lawton Instrumental ADL Scale and the Frenchay Activities Index only have general requirements for the cooking task such as the ability to "prepare meals," and "plans, prepares and serves adequate meals independently." These general cooking tasks may be useful in the evaluation of ADL ability in a questionnaire format by requesting the older adult to holistically consider their ability to cook, but may not be the best candidates when looking for fine-grained actions to extract.

The remaining 2 assessment tools, the Texas Functional Living Scale and Performance Assessment of Self-Care Skills (PASS), mention cooking task(s) that requires a clinician to evaluate. Upon closer inspection of the Texas Functional Living Scale, however, the individual is only required to describe the task and not actually perform it. The only candidate that has clear cooking tasks broken down into their fine-grained actions is the PASS and will be used as a reference for the experiment protocol and extraction of fine-grained tasks. 3 Cooking Scenarios are presented in the PASS: making soup with water/milk, making muffins in the oven, and cutting up fruit. The 3 cooking scenarios are shown in Figures 6.1-6.3.

Task # H24: IADL-C: Stovetop Use (Meal Preparation)		No Assistance	INDEPENDENCE DATA									SAFETY DATA	ADEQUACY DATA	
Assist level →	Subtask Criteria		0	1	2	3	4	5	6	7	8	9		
Subtasks													INDEPENDENCE subtask scores	
1	Opens soup can <b>correctly</b> (cut is even, entire top is off or <1/2" is retained in one place)												Unsafe Observations	PROCESS: Imprecise, lack of economy / missing steps
2	Removes/handles soup can lid <b>correctly</b> (lifts lid with knife; punches lid into can; does not cut finger)													QUALITY: Standards not met / improvement needed
3	Pours/spoons soup into pan <b>without spilling</b> (no soup on Ct, counter, or floor)													
4	Adds liquid <b>correctly</b> (adds 1 can of water/milk; does not spill on self, floor)													
5	Places pan on <b>correct stove burner</b> (burner closest to pan size)													
6	Turns burner on <b>correctly</b> (manipulates knob for burner that soup is on or is placed onto later; sets control on medium to high)													
7	Monitors soup <b>adequately</b> (stirs; alters heat as necessary, soup does not stick on pan; checks to make sure soup temperature is hot rather than lukewarm to touch or taste or that soup boils/bubbles)													
8	Removes pan from burner when soup is still <b>hot</b> (steam can be seen rising from pan; checks to make sure soup temperature is hot rather than lukewarm to touch or taste)													
9	Turns burner off <b>promptly</b> (+/- 1 minute of removing soup from burner)													
10	Transports & pours soup into bowls <b>correctly</b> (uses mitt under pan or slides pan across counter for stability if weakness or tremor present; does not spill on floor; only minor drips on counter)													
11	Transports bowls to table <b>correctly</b> (uses mitt under bowl or uses cart if weakness, tremors, or instability present; uses bowl rim to carry; does not spill on floor)													

Figure 6.1: PASS Soup Task [47]

Task # H25: IADL-C: Use of Sharp Utensils (Meal Preparation)		INDEPENDENCE DATA									SAFETY DATA	ADEQUACY DATA		
Assistive Technology Devices (ATDs) used during task: 1. 2. 3. Total # of ATDs used:_____		No Assistance	Verbal Supportive [Encouragement]	Verbal Non-Directive	Verbal Directive	Gestures	Task or Environment Reinforcement	Demonstration	Physical Guidance	Physical Support	Total Assist	INDEPENDENCE subtask scores	Unsafe Observations	PROCESS: Imprecision, lack of economy, missing steps QUALITY: Standards not met / improvement needed
		Assist level →	0	1	2	3	4	5	6	7	8	9		
Subtasks	Subtask Criteria													
1	Obtains correct fruit from refrigerator (Apple)													
2	Selects appropriate knife (selects paring knife or other small knife)													
3	Cuts fruit into 8 parts, removes seeds, & removes peel correctly (8 pieces; seeds removed; peel removed)													
4	Transports plate with fruit to table correctly (does not carry knife along; uses cart if weakness, tremor, or instability present; does not spill on floor)													

Figure 6.2: PASS Fruit Task [47]

Task # H23: IADL-C: Oven Use (Meal Preparation)		INDEPENDENCE DATA									SAFETY DATA	ADEQUACY DATA		
Assistive Technology Devices (ATDs) used during task: 1. 2. 3. Total # of ATDs used:_____		No Assistance	Verbal Supportive [Encouragement]	Verbal Non-Directive	Verbal Directive	Gestures	Task or Environment Reinforcement	Demonstration	Physical Guidance	Physical Support	Total Assist	INDEPENDENCE subtask scores	Unsafe Observations	PROCESS: Imprecision, lack of economy, missing steps QUALITY: Standards not met / improvement needed
		Assist level →	0	1	2	3	4	5	6	7	8	9		
Subtasks	Subtask Criteria													
1	Reports correctly that muffins must be started first													
2	Sets oven temperature control correctly (as designated on instructions)													
3	Measures liquid correctly (amount listed on the package)													
4	Prepares muffins for oven correctly (stirs until blended; greases tin or puts in paper muffin cups; fills muffin cups about 2/3 full)													
5	Places food in oven correctly (uses mitt; if tremor is evident or if placing between two oven racks; does not allow skin to touch racks or inside of oven door)													
6	Removes food from oven correctly (uses mitt/holder; does not allow skin to touch racks or inside of oven door; removes + 1 - 5 minutes of shortest or longest suggested baking time; no indication of inadequately heated cooked food or burned food)													
7	Turns off oven promptly (before or immediately after removal of food)													
8	Removes muffins from tin onto plate correctly (uses mitt/holder and knife if tin still warm; lets tin cool and then removes muffins onto plate)													
9	Transports muffins to table correctly (uses cart if weakness, tremor or instability present; does not spill on floor)													

Figure 6.3: PASS Muffin Task [47]

## 6.2 Fine-grained Task Extraction

The detail in which tasks can be broken down varies in literature. Human actions may be decomposed all the way into action primitives which is a body part + some motion (eg. right/left hand forward/backward) [118]. Fine-grained actions can be thought as being one level "coarser" than these action primitives and may combine action primitives to perform a small task (eg. cutting fruit, stir-frying, washing a fruit) [76]. A "coarser" level above fine-grained actions are coarse-grained actions and describe the activity that encompasses all of the fine-grained actions (eg. cooking, working). Although action primitives may be useful to consider when breaking down a task, the focus of the thesis is the evaluation of function and ability to perform tasks toward some goal. The detection of coarse-grained actions or activities have been successful in literature previously [68], but these coarse-grained actions are too general and do not provide insight into the functional quality of the cooking task. Thus, the focus of the task extraction will be at the "fine-grained" level.

For each cooking activity in the PASS, an experimental protocol will be developed based on the subtasks outlined in the task document. Although the PASS presents general steps to complete the task, there may sometimes be other actions, or "side-actions" involved in the task. For example, for the Cutting Fruit task in Figure 6.2, obtaining the fruit from the refrigerator would require the individual to perform OPEN-FRIDGE, GRAB-FRIDGE, and CLOSE-FRIDGE. The experimental protocol will be more detailed with steps detailing the actions in the PASS as well as any side-actions that occur. Then, from the steps in the experimental protocol, the fine-grained actions can be extracted.

## 6.3 Experimental Protocol

This section will detail the experimental protocol for each of the 3 pass tasks. The steps presented in the original PASS document (Figures 6.2-6.3) are used as reference and adapted to the environment where the experiments will take place: the Independent Living Suite. Location of items that were interacted with in the ILS that are not standard in every kitchen are labelled in Figure 6.4.



Figure 6.4: Independent Living Suite locations.

### 6.3.1 Initial Setup

The initial setup prior to conducting the experiments involved the following steps:

#### Data Recording

1. Referencing the 9H configuration the resulted in the best accuracy and repeatability determined in Chapter 3, the anchors are set up in the locations indicated by Figure 3.7.
2. Based on the documentation for the Pozyx [81], the settings for the fastest possible sample rate (16 Hz) without a large effect on the communication range was a bitrate of 850 kbit/s and a preamble length of 128. Both the anchors and the tags were set to communicate at these settings.

3. Setup a camera with a countdown timer so that segments of the data can be manually labelled at a later time.
4. Wear the Pozyx tag on the dominant hand.

### **Home Conditions**

The home conditions per the PASS Meal Preparation Tasks are listed as the following [47]:

1. Kitchen area and Electric or gas stove with oven
2. Sink, “as is”
3. Usual meal preparation utensils and supplies (e.g., spoons, spatula, bowls, oven mitt/pot holder, etc.)
4. Apple placed in refrigerator, within easy view when door is opened
5. Muffin tin for 6 muffins and muffin mix requiring only the addition of water/milk
6. Can of soup requiring the addition of water/milk
7. Cookie sheet on kitchen counter nearest stove, with items 5-6 stacked on it

Note that for the following experiments, whenever possible, the dominant hand should be used to perform the actions.

#### **6.3.2 Protocol: Cutting Fruit**

Based on Figure 6.2, this task involves getting a piece of fruit from the refrigerator, choosing a knife, peeling the fruit, cutting it into 8 pieces, plating and serving it. The detailed steps for the protocol are shown in Table 6.2 with the fruit being an apple. Figure 6.5 shows a part of the setup for the PASS fruit cutting task. Prior to performing the task, the items that the participant interacts with are placed in their original location:

- apples - refrigerator
- knife - cutlery drawer

- plate - tableware cabinet
- chopping board - chopping board holder
- towel - on oven handle

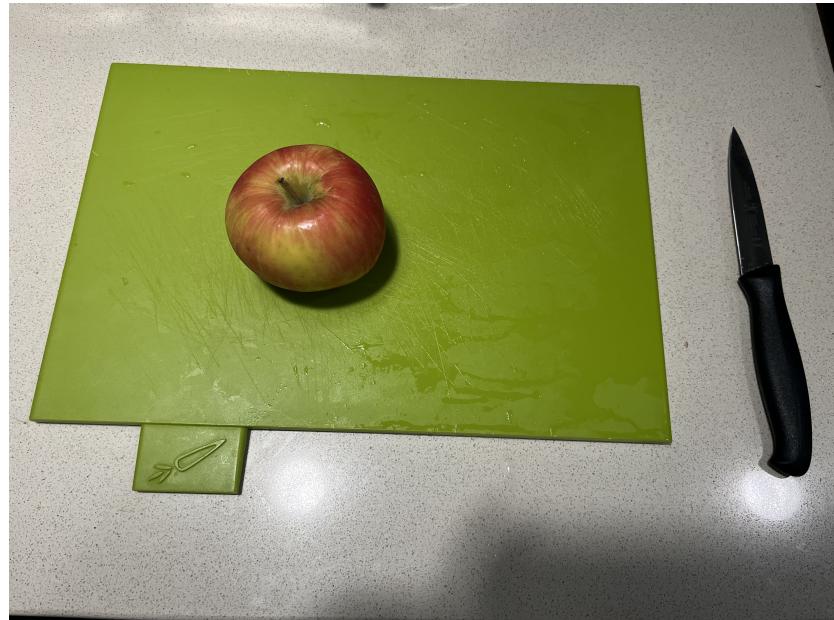


Figure 6.5: PASS: Fruit Cutting task setup.

Table 6.2: Protocol for the PASS cutting fruit task. Note that Quiet Standing (QS) refers to the position where the participant has their hands on the side of their thighs, being as still as possible.

<b>Step</b>	<b>Details</b>	<b>Fine-Grained Action</b>
1	Start the video with the countdown and just as the countdown finishes start data collection script	
<i>Continued on next page</i>		

Table 6.2 – continued from previous page

<b>Step</b>	<b>Details</b>	<b>Fine-Grained Action</b>
2	Move to the position in front of the refrigerator and stand in a Quiet Standing (QS) position for 2-3 seconds. Quickly raise and lower the hand with the sensor (for sensor and video time synchronization) and return to QS	
3	Stay in QS for 5 seconds	QS
4	Walk to the sink	
5	Open the faucet and wash hands for 10 seconds, close the faucet	WASH
6	Walk to the position in front of the oven (where the drying towel is)	
7	Dry hands	DRY
8	Walk to the position in front of the refrigerator	
9	Open the refrigerator with the dominant hand	OPEN-FRIDGE
10	Reach into the fridge and grab an apple with the dominant hand	GRAB-FRIDGE
11	Close the fridge with the dominant hand	CLOSE-FRIDGE
12	Place the apple on the kitchen counter	
13	Walk to where the cutting board is	
14	Grab the cutting board with the dominant hand	GRAB-BOARD
15	Walk to the kitchen counter	
16	Place the cutting board on the kitchen counter (beside the apple)	
17	Move to the position in front of the drawer containing the knife	

*Continued on next page*

Table 6.2 – continued from previous page

<b>Step</b>	<b>Details</b>	<b>Fine-Grained Action</b>
18	Open the drawer with the knife with the dominant hand	OPEN-CUTLERY
19	Grab the parring knife with the dominant hand	GRAB-CUTLERY
20	Close the drawer with the dominant hand	CLOSE-CUTLERY
21	Place the knife on the counter	
22	Grab the apple and move to the position in front of the sink	
23	Wash the apple	WASH
24	Move back to the position in front of the counter	
25	Peel the apple using the parring knife	PEEL
26	Cut the apple into 8ths using the chopping board	CUT
27	Move to the position in front of the tableware cabinet	
28	Open the tableware cabinet door with the dominant hand	OPEN-TABLEWARE
29	Grab a plate and place it on the kitchen counter	GRAB-TABLEWARE
30	Close the tableware cabinet with the dominant hand	CLOSE-TABLEWARE
31	Move to the position in front of the kitchen counter	
32	Transfer the apple slices from the cutting board to the plate with the dominant hand	PLATING

*Continued on next page*

Table 6.2 – continued from previous page

<b>Step</b>	<b>Details</b>	<b>Fine-Grained Action</b>
33	Grab the plate with the apples and bring it to the dining table	SERVE
34	Return to the position in front of the refrigerator and stand in QS for 5 seconds	QS
35	End data collection and end the recording	

### **6.3.3 Protocol: Making Soup**

Based on Figure 6.1, this task involves preparing soup from a soup can. The individual must locate the soup can in the pantry, open it and prepare it according to the instructions. The preparation of a soup can typically involves measuring and adding a liquid such as milk or water to the contents in the soup can and warming it up on the stove top. The detailed steps are documented in Table 6.3. Similar to the cutting fruit task, the items (shown in Figure 6.6) that the participant interacts with must be placed back in their original position:

- soup can - pantry
- towel - on oven handle
- can opener - cutlery cabinet
- spoon - cutlery drawer
- pot - cookware drawer
- bowl - tableware cabinet



Figure 6.6: Items used in the PASS make soup task. From the left: the can of soup, can opener, spoon and pot.

Table 6.3: Protocol for the PASS making soup task. Note that Quiet Standing (QS) refers to the position where the participant has their hands on the side of their thighs, being as still as possible.

<b>Step</b>	<b>Details</b>	<b>Fine-Grained Action</b>
1	Start the video with the countdown and just as the countdown finishes start data collection script	
2	Move to the position in front of the refrigerator and stand in a Quiet Standing (QS) position for 2-3 seconds. Quickly raise and lower the hand with the sensor (for sensor and video time synchronization) and return to QS	
3	Stay in QS for 5 seconds	QS
4	Walk to the sink	
5	Open the faucet and wash hands for 10 seconds, close the faucet	WASH
6	Walk to the position in front of the oven (where the drying towel is)	
7	Dry hands	DRY
8	Move to the position in front of the pantry cabinet	
9	Open the pantry cabinet with the dominant hand	OPEN-PANTRY
10	Grab the soup can inside the pantry cabinet with the dominant hand	GRAB-PANTRY
11	Close the pantry cabinet with the dominant hand	CLOSE-PANTRY
12	Bring the soup can to the kitchen counter and set it on the counter	

*Continued on next page*

Table 6.3 – continued from previous page

<b>Step</b>	<b>Details</b>	<b>Fine-Grained Action</b>
13	Move to the position in front of the cutlery drawer	
14	Open the cutlery drawer with the dominant hand	OPEN-CUTLERY
15	Grab the spoon and the can opener in the cutlery drawer and place them on the counter	GRAB-CUTLERY
16	Close the cutlery drawer with the dominant hand	CLOSE-CUTLERY
17	Move to the position in front of the cookware drawer	
18	Open the cookware drawer with the dominant hand	OPEN-COOKWARE
19	Grab the pot from the cookware drawer and place it on the counter	GRAB-COOKWARE
20	Close the cookware drawer with the dominant hand	CLOSE-COOKWARE
21	Move to the position in front of the kitchen counter	
22	Using the can opener, open the can of soup with the dominant hand	OPEN-CAN
23	Pour the contents into the pot with the dominant hand	POUR
24	While holding the empty can, move to the position in front of the sink	
25	Fill the soup can to the top with tap water with the dominant hand	FILL-WATER
26	Move back to the position in front of the kitchen counter	

*Continued on next page*

Table 6.3 – continued from previous page

<b>Step</b>	<b>Details</b>	<b>Fine-Grained Action</b>
27	Pour the water into the pot containing the concentrated soup with the dominant hand	POUR
28	Grab the pot and move to the position in front of the stove with the dominant hand	
29	Place the pot on one of the burners	
30	Turn the burner on with the dominant hand	BURNER-ON
31	Move back about a meter and stand in QS for about 10 seconds to mimic waiting for the soup to boil	QS
32	Grab the spoon on the counter and use it to stir the soup for about 10 seconds with the dominant hand	STIR
33	Turn the burner off	BURNER-OFF
34	Move to the position in front of the tableware cabinet	
35	Open the tableware cabinet door with the dominant hand	OPEN-TABLEWARE
36	Grab a bowl and place it on the kitchen counter	GRAB-TABLEWARE
37	Close the tableware cabinet with the dominant hand	CLOSE-TABLEWARE
38	Move to the position in front of the stove and grab the pot	
39	Move to the position in front of the cabinet with the pot	
40	Pour the soup in the pot into the bowl (being careful not to spill any) with the dominant hand	POUR

*Continued on next page*

Table 6.3 – continued from previous page

<b>Step</b>	<b>Details</b>	<b>Fine-Grained Action</b>
41	Grab the bowl of soup and bring it to the dining table	SERVE
42	Return to the position in front of the refrigerator and stand in QS for 5 seconds	QS
43	End data collection and end the recording	

### **6.3.4 Protocol: Making Muffins**

From Figure 6.3, this PASS task evaluates the older adult's ability to use the oven through baking muffins. The muffin batter is made using pre-made muffin mix to minimize the number of steps required in gathering the ingredients per the PASS task instructions. The participant is required to make the muffin batter, pour the batter into the muffin tin for 6 muffins and place the muffin tin into the oven. To simulate a speed up in the baking process, a pre-baked 6 pack of muffin has been placed in the oven before hand and used as the finished product for plating and serving. Items used in this experiment are shown in Figure 6.7 Detailed steps are found in Table 6.4. Similar to the making soup task, the items (shown in Figure 6.7) that the participant interacts with must be placed back in their original position:

- muffin mix - pantry
- towel - on oven handle
- measuring cup - cutlery drawer
- tongs - cutlery drawer
- spoon - cutlery drawer
- mixing bowl - cookware drawer
- muffin tin - baking trays drawer
- water measuring cup - cups cabinet
- oven mitts - cookware drawer
- 6-pack pre-baked muffins - inside the oven, to one side



Figure 6.7: Items used in the Baking Muffin task. From the left: the muffin mix, the mixing bowl, the spoon, the muffin tin, the water measuring cup, the (green) measuring cup, and assorted oven mitts. The 6 pack of muffins and tongs are not shown in the image, but can be found at any local supermarket and kitchen supply store respectively.

Table 6.4: Protocol for the PASS making muffins task. Note that Quiet Standing (QS) refers to the position where the participant has their hands on the side of their thighs, being as still as possible.

<b>Step</b>	<b>Details</b>	<b>Fine-Grained Action</b>
1	Start the video with the countdown and just as the countdown finishes start data collection script	
2	Move to the position in front of the refrigerator and stand in a Quiet Standing (QS) position for 2-3 seconds. Quickly raise and lower the hand with the sensor (for sensor and video time synchronization) and return to QS	
3	Stay in QS for 5 seconds	QS
4	Walk to the sink	
5	Open the faucet and wash hands for 10 seconds, close the faucet	WASH
6	Walk to the position in front of the oven (where the drying towel is)	
7	Dry hands	DRY
8	Move to the position in front of the pantry cabinet	
9	Open the pantry cabinet with the dominant hand	OPEN-PANTRY
10	Grab the muffin mix in the pantry with the dominant hand	GRAB-PANTRY
11	Close the pantry cabinet with the dominant hand	CLOSE-PANTRY
12	Bring the muffin mix kitchen counter and set it on the counter	

*Continued on next page*

Table 6.4 – continued from previous page

<b>Step</b>	<b>Details</b>	<b>Fine-Grained Action</b>
13	Move to the position in front of the cutlery drawer	
14	Open the cutlery drawer with the dominant hand	OPEN-CUTLERY
15	Grab the spoon and the measuring cup in the cutlery drawer and place them on the counter	GRAB-CUTLERY
16	Close the cutlery drawer with the dominant hand	CLOSE-CUTLERY
17	Move to the position in front of the cups cabinet	
18	Open the cup cabinet with the dominant hand	OPEN-CUPS
19	Grab the water measuring cup with the dominant hand	GRAB-CUPS
20	Close the cup cabinet with the dominant hand	GRAB-CUPS
21	Move to the position in front of the cookware drawer	
22	Open the cookware drawer with the dominant hand	OPEN-COOKWARE
23	Grab the mixing bowl from the cookware drawer and place it on the counter	GRAB-COOKWARE
24	Close the cookware drawer with the dominant hand	CLOSE-COOKWARE
25	Move to the position in front of the kitchen counter	
26	Open the muffin mix and grab the measuring cup with the dominant hand	

*Continued on next page*

Table 6.4 – continued from previous page

<b>Step</b>	<b>Details</b>	<b>Fine-Grained Action</b>
27	Scoop the required amount of muffin mix into the mixing bowl	SCOOP
28	Put down the measuring cup and grab the water measuring cup with the dominant hand	
29	While holding the empty water measuring cup, move to the position in front of the sink	
30	Fill the water measuring cup can to the required level (per muffin mix directions) with tap water	FILL-WATER
31	Move back to the position in front of the kitchen counter	
32	Pour the water in the water measuring cup into the mixing bowl containing the muffin mix	POUR
33	Put down the water measuring cup and grab the spoon	
34	Mix the water and muffin mix together in the mixing bowl using a stirring motion	STIR
35	Put the spoon down and move to the position in front of the drawer for the baking trays	
36	Open the baking tray drawer with the dominant hand	OPEN-BAKING-TRAYS
37	Grab the muffin tin from the drawer with the dominant hand	GRAB-BAKING-TRAYS
38	Close the baking tray drawer with the dominant hand	CLOSE-BAKING-TRAYS
39	Bring the tray to the kitchen counter and set it close to the mixing bowl	

*Continued on next page*

Table 6.4 – continued from previous page

<b>Step</b>	<b>Details</b>	<b>Fine-Grained Action</b>
40	Grab the measuring cup with the dominant hand	
41	Scoop the muffin batter in the mixing bowl into the muffin tin	SCOOP
42	Move in front of the oven	
43	Simulate turning on the oven (do not actually turn it on) with the dominant hand	OVEN-POWER
44	Step backwards around 1 meter away from the oven and stand in QS for about 10 seconds to mimic waiting for the oven to preheat	QS
45	Once the oven has "pre-heated" move back to the position in front of the oven	
46	Open the oven using the dominant hand	OPEN-OVEN
47	Grab the muffin tin with the muffin batter and place it into one of the oven racks	GRAB-OVEN
48	Close the oven with the dominant hand	CLOSE-OVEN
49	Step backwards around 1 meter away from the oven and stand in QS for about 10 seconds to mimic waiting for the muffins to bake	QS
50	Move back in front of the oven	
51	Simulate turning off the oven with the dominant hand	OVEN-POWER
52	Move in front of the cookware drawer	
53	Open the cookware drawer with the dominant hand	OPEN-COOKWARE
54	Grab some oven mitts that are in the cookware drawer	GRAB-COOKWARE

*Continued on next page*

Table 6.4 – continued from previous page

<b>Step</b>	<b>Details</b>	<b>Fine-Grained Action</b>
55	Close the cookware drawer with the dominant hand	CLOSE-COOKWARE
56	Put on the oven mitts	
57	Move to the position in front of the oven	
58	Open the oven with the dominant hand	OPEN-OVEN
59	Reach in and grab the pre-made 6-pack of muffins with the dominant hand and place the muffins on the stovetop (because in a real baking scenario it should be hot)	GRAB-OVEN
60	Close the oven with the dominant hand	CLOSE-OVEN
61	Take the oven mitts off and move to the position in front of the cookware drawer	
62	Open the cookware drawer with the dominant hand	OPEN-COOKWARE
63	Place the oven mitts into the cookware drawer	GRAB-COOKWARE
64	Close the cookware drawer with the dominant hand	CLOSE-COOKWARE
65	Move to the position in front of the cutler drawer	
66	Open the cutlery drawer with the dominant hand	OPEN-CUTLERY
67	Grab the tongs from the cutlery drawer with the dominant hand	GRAB-CUTLERY
68	Close the cutlery drawer with the dominant hand	CLOSE-CUTLERY

*Continued on next page*

Table 6.4 – continued from previous page

<b>Step</b>	<b>Details</b>	<b>Fine-Grained Action</b>
69	Move to the position in front of the tableware cabinet	
70	Open the tableware cabinet door with the dominant hand	OPEN-TABLEWARE
71	Grab a plate and place it on the kitchen counter	GRAB-TABLEWARE
72	Close the tableware cabinet with the dominant hand	CLOSE-TABLEWARE
73	Move to the position in front of the kitchen counter	
74	Use the tongs to transfer 3 muffins from the "muffin tin" to the plate	PLATING
75	Put the tongs down	
76	Grab the plate with the muffins on it and bring it to the dining table	SERVE
77	Return to the position in front of the refrigerator and stand in QS for 5 seconds	QS
78	End data collection and end the recording	

## 6.4 Disability Simulation

To both further the amount of data collected as well as increase the variation in the data, 3 disability simulations will be used while following the experimental protocol described in Section 6.3. Figure 6.8 shows the items used to simulate the disabilities and the disability simulations are as follows:

1. Vision Impairment: Covering one eye
2. Mild Physical Impairment: Wearing Knitted Gloves
3. Severe Physical Impairment: Wearing Electrical Gloves



Figure 6.8: Items used to simulate disability.

## **Chapter 7**

# **Data Preparation and Creation of the Classification Model**

The previous chapter highlighted the experimental protocol. Building upon the previous chapter, this chapter will review the resulting dataset and use the dataset to try and create a model to classify cooking tasks within the ILS. But before classification can be done, the specific sub actions as well as the time-window that the specific sub actions occurs must be labelled.

## 7.1 The Dataset

8 trials for each task (cutting fruit, making soup, making muffins) and each type of disability + able-bodied (one-eyed: OE, knitted gloves: KG, electrical gloves: EG, able-bodied: AB) were recorded resulting in a total  $8 * 3 * 4 = 96$  trials lasting a duration of 6 hours 3 minutes and 53 seconds of data. The data collected with the descriptions and units are shown in Table 7.1.

## 7.2 Data Labelling

For each trial, the video was used to confirm the synchronization between the sensor and the video. In all of the trials, the timestamp for the quick raising of the hand always corresponded to the timestamp where a sudden spike in the acceleration occurred so issues with time synchronization between the video and sensor were mitigated in this dataset. Using a custom Python script leveraging matplotlib's ginput method, the beginning and ending of each fine-grained action derived in Tables 6.2, 6.3, and 6.4 were manually labelled by referencing the timestamps of the beginning and ending of the fine-grained action in the associated video. An example of the output is shown in Listing 7.1:

Listing 7.1: Manual labelling output for the cutting fruit task.

```
BEGIN_QS: 1716994151.777581
END_QS: 1716994158.2329004
BEGIN_WASH: 1716994160.7433023
END_WASH: 1716994170.1393783
BEGIN_DRY: 1716994173.367038
END_DRY: 1716994175.4470851
BEGIN_OPEN_FRIDGE: 1716994178.7443902
END_OPEN_FRIDGE: 1716994180.1809862
BEGIN_GRAB_FRIDGE: 1716994180.467889
```

END\_GRAB\_FRIDGE: 1716994183.7672746  
BEGIN\_CLOSE\_FRIDGE: 1716994183.982452  
END\_CLOSE\_FRIDGE: 1716994185.4169674  
BEGIN\_GRAB\_BOARD: 1716994189.2184331  
END\_GRAB\_BOARD: 1716994190.7964  
BEGIN\_OPEN\_CUTLERY: 1716994193.2350764  
END\_OPEN\_CUTLERY: 1716994195.243398  
BEGIN\_GRAB\_CUTLERY: 1716994195.3868494  
END\_GRAB\_CUTLERY: 1716994196.8930907  
BEGIN\_CLOSE\_CUTLERY: 1716994198.2558804  
END\_CLOSE\_CUTLERY: 1716994199.4034927  
BEGIN\_WASH: 1716994201.6987174  
END\_WASH: 1716994210.234084  
BEGIN\_PEEL: 1716994213.5334694  
END\_PEEL: 1716994266.2519107  
BEGIN\_CUT: 1716994273.0658588  
END\_CUT: 1716994293.005623  
BEGIN\_OPEN\_TABLEWARE: 1716994295.3008478  
END\_OPEN\_TABLEWARE: 1716994296.5201857  
BEGIN\_GRAB\_TABLEWARE: 1716994296.5201857  
END\_GRAB\_TABLEWARE: 1716994301.3975382  
BEGIN\_CLOSE\_TABLEWARE: 1716994301.469264  
END\_CLOSE\_TABLEWARE: 1716994302.9037795  
BEGIN\_PLATING: 1716994304.912101  
END\_PLATING: 1716994312.0129523  
BEGIN\_SERVE: 1716994312.084678  
END\_SERVE: 1716994318.4682715  
BEGIN\_QS: 1716994323.8477044  
END\_QS: 1716994329.8009434

Table 7.1: Details of the data collected through the Pozyx system [119].

<b>Name</b>	<b>Units</b>	<b>Description</b>
POS_X	mm	Position of sensor relative to the origin in the X axis
POS_Y	mm	Position of sensor relative to the origin in the Y axis
POS_Z	mm	Position of sensor relative to the origin in the Z axis
Heading	deg	Heading orientation of the sensor
Roll	deg	Roll orientation of the sensor
Pitch	deg	Pitch orientation of the sensor
ACC_X	g	X axis acceleration with gravity
ACC_Y	g	Y axis acceleration with gravity
ACC_Z	g	Z axis acceleration with gravity
LINACC_X	g	X axis acceleration with the gravity removed
LINACC_Y	g	Y axis acceleration with the gravity removed
LINACC_Z	g	Z axis acceleration with the gravity removed
GYRO_X	deg/s	Angular Velocity in the X axis
GYRO_Y	deg/s	Angular Velocity in the Y axis
GYRO_Z	deg/s	Angular Velocity in the Z axis
Pressure	Pa	The pressure (low-resolution)

## 7.3 Inspecting the Dataset

The fine-grained actions were broken down such that there would be overlap between the different tasks. For example, washing hands and drying hands were common fine-grained actions shared among all cooking tasks. Opening the pantry, grabbing something from the pantry and closing the pantry were shared between the muffin making task and the making soup task. Further cooking skills such as mixing and pouring were common among the making muffin and making soup tasks.

After manually labelling all of the tasks, the overall details of the dataset for the fine-grained actions are summarized in Table 7.2. A total of 40 fine-grained actions were derived from the PATH experiments with a combined number of occurrences of 2879 across all fine-grained actions. As expected, the continuous fine-grained actions that involve preparing the ingredients such as PEEL, CUT, STIR, and SCOOP had the longest average duration of 43.82s, 25.05s, 21.77s, and 13.53s respectively. Opening and closing the cabinets, drawers, and appliances consisted of short motion in one direction and took from 0.86s (OPEN-CUPS) to 2.11s (OPEN-OVEN) on average. The duration labelled as grabbing something from these cabinets, drawers and appliances were an action catch-all between the opening and closing actions. Thus, the "grab" action typically contained multiple finer actions such as "putting the item on the kitchen counter" or "grabbing multiple items" such as grabbing the spoon and measuring cup from the cutlery drawer. The duration of the grabbing action ranged from 3.13s (GRAB-PANTRY) to 8.87 (GRAB-OVEN).

Table 7.2: Overall Descriptive Summary of the fine-grained actions.

Action	Count	Avg. Time (s)	Std. Time (s)
PEEL	33	43.82	10.95
CUT	32	25.05	11.33
STIR	62	21.77	10.78
SCOOP	61	13.53	9.36
GRAB-OVEN	62	8.87	4.37

*Continued on next page*

Table 7.2 – continued from previous page

Action	Count	Avg. Time (s)	Std. Time (s)
OPEN-CAN	32	7.92	1.81
PLATING	63	7.66	3.77
WASH	127	7.6	1.79
SERVE	95	5.67	0.62
QS	281	5.51	1.95
GRAB-TABLEWARE	95	5.37	2.77
GRAB-FRIDGE	32	5.33	5.04
DRY	95	5.17	1.34
GRAB-CUTLERY	126	5.02	2.81
GRAB-COOKWARE	103	4.24	2.13
GRAB-BAKING-TRAYS	31	4.12	7.81
GRAB-CUPS	31	3.82	0.54
GRAB-PANTRY	63	3.13	1.02
FILL-WATER	63	2.96	1.13
OVEN-POWER	58	2.4	1.81
POUR	129	2.29	0.98
OPEN-OVEN	62	2.11	0.55
CLOSE-OVEN	62	1.83	1.29
OPEN-FRIDGE	32	1.73	0.54
CLOSE-FRIDGE	32	1.68	0.37
GRAB-BOARD	32	1.28	0.45

*Continued on next page*

Table 7.2 – continued from previous page

Action	Count	Avg. Time (s)	Std. Time (s)
BURNER-ON	33	1.27	0.53
OPEN-CUTLERY	126	1.26	0.57
BURNER-OFF	31	1.26	0.35
CLOSE-COOKWARE	120	1.24	0.85
CLOSE-CUTLERY	114	1.17	0.48
OPEN-COOKWARE	121	1.14	0.27
OPEN-TABLEWARE	95	1.13	0.34
OPEN-PANTRY	63	1.05	0.28
CLOSE-PANTRY	63	1.05	0.67
CLOSE-TABLEWARE	95	1.03	0.37
CLOSE-BAKING-TRAYS	31	1.01	0.26
OPEN-BAKING-TRAYS	31	0.99	1.57
CLOSE-CUPS	31	0.94	0.29
OPEN-CUPS	31	0.86	0.27

# Bibliography

- [1] Pozyx, “Creator One Kit for research and prototyping - Pozyx.” [Online]. Available: <https://www.pozyx.io/creator-one-kit>
- [2] S. C. Government of Canada, “The Daily — Population projections: Canada, the provinces and territories, 2013 to 2063,” Sep. 2014, last Modified: 2014-09-17. [Online]. Available: <https://www150.statcan.gc.ca/n1/daily-quotidien/140917/dq140917a-eng.htm>
- [3] L. M. Tijsen, E. W. Derkx, W. P. Achterberg, and B. I. Buijck, “Challenging rehabilitation environment for older patients,” *Clinical Interventions in Aging*, vol. Volume 14, pp. 1451–1460, Aug. 2019. [Online]. Available: <https://www.dovepress.com/challenging-rehabilitation-environment-for-older-patients-peer-reviewed-article-CIA>
- [4] I. Wilkinson and A. Harper, “Comprehensive geriatric assessment, rehabilitation and discharge planning,” *Medicine*, vol. 49, no. 1, pp. 10–16, Jan. 2021. [Online]. Available: <https://linkinghub.elsevier.com/retrieve/pii/S1357303920302711>
- [5] P. F. Edemekong, D. L. Bomgaars, S. Sukumaran, and S. B. Levy, “Activities of Daily Living,” in *StatPearls*. Treasure Island (FL): StatPearls Publishing, 2022. [Online]. Available: <http://www.ncbi.nlm.nih.gov/books/NBK470404/>
- [6] E. Jaul and J. Barron, “Age-Related Diseases and Clinical and Public Health Implications for the 85 Years Old and Over Population,” *Frontiers in Public Health*, vol. 5, p. 335, Dec. 2017. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5732407/>

- [7] J. Hewitt, S. Long, B. Carter, S. Bach, K. McCarthy, and A. Clegg, “The prevalence of frailty and its association with clinical outcomes in general surgery: a systematic review and meta-analysis,” *Age and Ageing*, vol. 47, no. 6, pp. 793–800, Nov. 2018. [Online]. Available: <https://doi.org/10.1093/ageing/afy110>
- [8] S. Conroy, “Defining frailty — the holy grail of geriatric medicine,” *The Journal of Nutrition, Health and Aging*, vol. 13, no. 4, pp. 389–389, Apr. 2009. [Online]. Available: <http://link.springer.com/10.1007/s12603-009-0050-9>
- [9] X. Chen, G. Mao, and S. X. Leng, “Frailty syndrome: an overview,” *Clinical Interventions in Aging*, vol. 9, pp. 433–441, Mar. 2014. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3964027/>
- [10] “Diagnosis and Management of Dementia: Review | Dementia and Cognitive Impairment | JAMA | JAMA Network.” [Online]. Available: <https://jamanetwork.com/journals/jama/fullarticle/2753376>
- [11] I. Arevalo-Rodriguez, N. Smailagic, M. Roqué I Figuls, A. Ciapponi, E. Sanchez-Perez, A. Giannakou, O. L. Pedraza, X. Bonfill Cosp, and S. Cullum, “Mini-Mental State Examination (MMSE) for the detection of Alzheimer’s disease and other dementias in people with mild cognitive impairment (MCI),” *The Cochrane Database of Systematic Reviews*, vol. 2015, no. 3, p. CD010783, Mar. 2015.
- [12] M. Desai, L. A. Pratt, H. Lentzner, and K. N. Robinson, “Trends in vision and hearing among older Americans,” *Aging Trends (Hyattsville, Md.)*, no. 2, pp. 1–8, Mar. 2001.
- [13] J. R. Evans, A. E. Fletcher, R. P. L. Wormald, E. S.-W. Ng, S. Stirling, L. Smeeth, E. Breeze, C. J. Bulpitt, M. Nunes, D. Jones, and A. Tulloch, “Prevalence of visual impairment in people aged 75 years and older in Britain: results from the MRC trial of assessment and management of older people in the community,” *The British Journal of Ophthalmology*, vol. 86, no. 7, pp. 795–800, Jul. 2002.
- [14] B. K. Swenor, M. J. Lee, V. Varadaraj, H. E. Whitson, and P. Y. Ramulu, “Aging With Vision Loss: A Framework for Assessing the

- Impact of Visual Impairment on Older Adults,” *The Gerontologist*, vol. 60, no. 6, pp. 989–995, Aug. 2020. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7427480/>
- [15] M. E. Tinetti, C. S. Williams, and T. M. Gill, “Dizziness among older adults: a possible geriatric syndrome,” *Annals of Internal Medicine*, vol. 132, no. 5, pp. 337–344, Mar. 2000.
  - [16] S. Iwasaki and T. Yamasoba, “Dizziness and Imbalance in the Elderly: Age-related Decline in the Vestibular System,” *Aging and Disease*, vol. 6, no. 1, pp. 38–47, Feb. 2014. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4306472/>
  - [17] G. Savarese and L. H. Lund, “Global Public Health Burden of Heart Failure,” *Cardiac Failure Review*, vol. 3, no. 1, pp. 7–11, Apr. 2017. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5494150/>
  - [18] B. Ziaeian and G. C. Fonarow, “Epidemiology and aetiology of heart failure,” *Nature Reviews. Cardiology*, vol. 13, no. 6, pp. 368–378, Jun. 2016.
  - [19] R. D. S. Watson, C. R. Gibbs, and G. Y. H. Lip, “Clinical features and complications,” *BMJ : British Medical Journal*, vol. 320, no. 7229, pp. 236–239, Jan. 2000. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1117436/>
  - [20] I. o. M. U. C. o. S. S. C. D. Criteria, “Ischemic Heart Disease,” in *Cardiovascular Disability: Updating the Social Security Listings*. National Academies Press (US), 2010. [Online]. Available: <https://www.ncbi.nlm.nih.gov/books/NBK209964/>
  - [21] M. V. Madhavan, B. J. Gersh, K. P. Alexander, C. B. Granger, and G. W. Stone, “Coronary Artery Disease in Patients Å ª 80 Years of Age,” *Journal of the American College of Cardiology*, vol. 71, no. 18, pp. 2015–2040, May 2018. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0735109718336167>
  - [22] A. Sapra and P. Bhandari, “Diabetes Mellitus,” in *StatPearls*. Treasure Island (FL): StatPearls Publishing, 2021. [Online]. Available: <http://www.ncbi.nlm.nih.gov/books/NBK551501/>

- [23] “Glucose tolerance tests: What exactly do they involve?” in *InformedHealth.org [Internet]*. Institute for Quality and Efficiency in Health Care (IQWiG), Oct. 2020. [Online]. Available: <https://www.ncbi.nlm.nih.gov/books/NBK279331/>
- [24] M. J. Lespasio, A. A. Sultan, N. S. Piuzzi, A. Khlopas, M. E. Husni, G. F. Muschler, and M. A. Mont, “Hip Osteoarthritis: A Primer,” *The Permanente Journal*, vol. 22, pp. 17–084, Jan. 2018. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5760056/>
- [25] J. M. Hootman and C. G. Helmick, “Projections of US prevalence of arthritis and associated activity limitations,” *Arthritis and Rheumatism*, vol. 54, no. 1, pp. 226–229, Jan. 2006.
- [26] D. Prieto-Lambra, D. Hunter, and N. Arden, *Osteoarthritis: The Facts*, second edition ed., ser. The Facts Series. Oxford, New York: Oxford University Press, Sep. 2014.
- [27] D. J. Hunter and S. Bierma-Zeinstra, “Osteoarthritis,” *The Lancet*, vol. 393, no. 10182, pp. 1745–1759, Apr. 2019. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0140673619304179>
- [28] R. Altman, E. Asch, D. Bloch, G. Bole, D. Borenstein, K. Brandt, W. Christy, T. D. Cooke, R. Greenwald, and M. Hochberg, “Development of criteria for the classification and reporting of osteoarthritis. Classification of osteoarthritis of the knee. Diagnostic and Therapeutic Criteria Committee of the American Rheumatism Association,” *Arthritis and Rheumatism*, vol. 29, no. 8, pp. 1039–1049, Aug. 1986.
- [29] J. E. Compston, M. R. McClung, and W. D. Leslie, “Osteoporosis,” *The Lancet*, vol. 393, no. 10169, pp. 364–376, Jan. 2019, publisher: Elsevier. [Online]. Available: [https://www-thelancet-com.login.ezproxy.library.ualberta.ca/journals/lancet/article/PIIS0140-6736\(18\)32112-3/fulltext](https://www-thelancet-com.login.ezproxy.library.ualberta.ca/journals/lancet/article/PIIS0140-6736(18)32112-3/fulltext)
- [30] J. L. Porter and M. Varacallo, “Osteoporosis,” in *StatPearls*. Treasure Island (FL): StatPearls Publishing, 2023. [Online]. Available: <http://www.ncbi.nlm.nih.gov/books/NBK441901/>
- [31] D. L. Glaser and F. S. Kaplan, “Osteoporosis: Definition and Clinical Presentation,” *Spine*, vol. 22, no. 24, p. 12S, Dec. 1997.

- [32] M. Pashmdarfard and A. Azad, “Assessment tools to evaluate Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL) in older adults: A systematic review,” *Medical Journal of the Islamic Republic of Iran*, vol. 34, p. 33, Apr. 2020. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7320974/>
- [33] E. McMahon, “Katz Index of Independence in Activities of Daily Living,” p. 2.
- [34] P. P. Katz for the Association of Rheumatology Health Professionals Outcomes Measures Task Force, “Measures of adult general functional status: The Barthel Index, Katz Index of Activities of Daily Living, Health Assessment Questionnaire (HAQ), MACTAR Patient Preference Disability Questionnaire, and Modified Health Assessment Questionnaire (MHAQ),” *Arthritis Care & Research*, vol. 49, no. S5, pp. S15–S27, 2003, eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1002/art.11415>. [Online]. Available: <https://onlinelibrary.wiley.com/doi/abs/10.1002/art.11415>
- [35] AHS, “Barthel Index of Activities of Daily Living.”
- [36] S. Katz, A. B. Ford, R. W. Moskowitz, B. A. Jackson, and M. W. Jaffe, “Studies of Illness in the Aged: The Index of ADL: A Standardized Measure of Biological and Psychosocial Function,” *JAMA*, vol. 185, no. 12, pp. 914–919, Sep. 1963. [Online]. Available: <https://doi.org/10.1001/jama.1963.03060120024016>
- [37] M. Davidson, “Functional Independence Measure,” in *Encyclopedia of Quality of Life and Well-Being Research*, A. C. Michalos, Ed. Dordrecht: Springer Netherlands, 2014, pp. 2373–2376.
- [38] “FIM(TM).” [Online]. Available: <https://www.tbims.org/combi/FIM/>
- [39] E. Dutil, A. Forget, M. Vanier, and C. Gaudreault, “Development of the ADL Profile: An Evaluation for Adults with Severe Head Injury,” *Occupational Therapy In Health Care*, vol. 7, no. 1, pp. 7–22, Jan. 1990.
- [40] C. L. Bottari, C. Dassa, C. M. Rainville, and E. Dutil, “The IADL profile: development, content validity, intra- and interrater agreement,” *Canadian Journal of Occupational Therapy. Revue Canadienne D'ergotherapie*, vol. 77, no. 2, pp. 90–100, Apr. 2010.

- [41] N. Kennedy, A. Barion, A. Rademaker, G. Rehkemper, and S. Weintraub, “The Activities of Daily Living Questionnaire A Validation Study in Patients with Dementia,” *Alzheimer disease and associated disorders*, vol. 18, pp. 223–30, Oct. 2004.
- [42] A. Perry, M. Morris, C. Unsworth, S. Duckett, J. Skeat, K. Dodd, N. Taylor, and K. Reilly, “Therapy outcome measures for allied health practitioners in Australia: the AusTOMs,” *International Journal for Quality in Health Care*, vol. 16, no. 4, pp. 285–291, Aug. 2004. [Online]. Available: <https://doi.org/10.1093/intqhc/mzh059>
- [43] S. A. Haymes, A. W. Johnston, and A. D. Heyes, “The Development of the Melbourne Low-Vision ADL Index: A Measure of Vision Disability,” *Investigative Ophthalmology & Visual Science*, vol. 42, no. 6, pp. 1215–1225, May 2001.
- [44] R. G. Brown, B. MacCarthy, M. Jahanshahi, and C. D. Marsden, “Accuracy of Self-Reported Disability in Patients With Parkinsonism,” *Archives of Neurology*, vol. 46, no. 9, pp. 955–959, Sep. 1989. [Online]. Available: <https://doi.org/10.1001/archneur.1989.00520450025014>
- [45] M. Holbrook and C. E. Skilbeck, “AN ACTIVITIES INDEX FOR USE WITH STROKE PATIENTS,” *Age and Ageing*, vol. 12, no. 2, pp. 166–170, 1983. [Online]. Available: <https://academic.oup.com/ageing/article-lookup/doi/10.1093/ageing/12.2.166>
- [46] M. P. Lawton and E. M. Brody, “Assessment of older people: self-maintaining and instrumental activities of daily living,” *The Gerontologist*, vol. 9, no. 3, pp. 179–186, 1969.
- [47] J. C. Rogers, “Performance Assessment of Self-Care Skills,” Apr. 2014. [Online]. Available: <http://doi.apa.org/getdoi.cfm?doi=10.1037/t16068-000>
- [48] D. Chisholm, P. Toto, K. Raina, M. Holm, and J. Rogers, “Evaluating capacity to live independently and safely in the community: Performance Assessment of Self-care Skills,” *The British journal of occupational therapy*, vol. 77, no. 2, pp. 59–63, Feb. 2014. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4186770/>

- [49] C. M. Cullum, K. Saine, L. D. Chan, K. Martin-Cook, K. F. Gray, and M. F. Weiner, “Performance-Based instrument to assess functional capacity in dementia: The Texas Functional Living Scale,” *Neuropsychiatry, Neuropsychology, and Behavioral Neurology*, vol. 14, no. 2, pp. 103–108, 2001.
- [50] A. Staff, “The (Original) Barthel Index of ADLs,” Sep. 2008. [Online]. Available: <https://www.elitelearning.com/resource-center/rehabilitation-therapy/the-original-barthel-index-of-adls/>
- [51] “Measures of adult general functional status: The Barthel Index, Katz Index of Activities of Daily Living, Health Assessment Questionnaire (HAQ), MACTAR Patient Preference Disability Questionnaire, and Modified Health Assessment Questionnaire (MHAQ).” [Online]. Available: <https://onlinelibrary.wiley.com/doi/10.1002/art.11415>
- [52] K. M. Hall, B. B. Hamilton, W. A. Gordon, and N. D. Zasler, “Functional Independence Measure and Functional Assessment Measure,” Jun. 2014, institution: American Psychological Association. [Online]. Available: <http://doi.apa.org/getdoi.cfm?doi=10.1037/t28782-000>
- [53] “ADL Profile – Strokengine.” [Online]. Available: <https://strokengine.ca/en/assessments/adl/>
- [54] cunsworth2014, “AusTOMs,” Nov. 2019. [Online]. Available: <https://austoms.com/>
- [55] “Self-assessment Parkinsonâ€™s Disease Disability Scale | RehabMeasures Database,” May 2013. [Online]. Available: <https://www.sralab.org/rehabilitation-measures/self-assessment-parkinsons-disease-disability-scale>
- [56] J. Schuling, R. De Haan, M. Limburg, and K. H. Groenier, “The Frenchay Activities Index. Assessment of functional status in stroke patients.” *Stroke*, vol. 24, no. 8, pp. 1173–1177, Aug. 1993. [Online]. Available: <https://www.ahajournals.org/doi/10.1161/01.STR.24.8.1173>
- [57] E. McMahon, “Lawton â€“ Brody Instrumental Activities of Daily Living Scale (IADL).”

- [58] “Performance Assessment of Self-Care Skills | RehabMeasures Database,” Jun. 2015. [Online]. Available: <https://www.sralab.org/rehabilitation-measures/performance-assessment-self-care-skills>
- [59] U. F. O. Themes, “Texas Functional Living Scale (TFLS),” Jul. 2017. [Online]. Available: <https://nursekey.com/texas-functional-living-scale-tfls/>
- [60] N. Camp, M. Lewis, K. Hunter, J. Johnston, M. Zecca, A. Di Nuovo, and D. Magistro, “Technology Used to Recognize Activities of Daily Living in Community-Dwelling Older Adults,” *International Journal of Environmental Research and Public Health*, vol. 18, no. 1, p. 163, Jan. 2021, number: 1 Publisher: Multidisciplinary Digital Publishing Institute. [Online]. Available: <https://www.mdpi.com/1660-4601/18/1/163>
- [61] N. Gadey, P. Pataunia, A. Chan, and A. RÃos RincÃ³n, “Technologies for monitoring activities of daily living in older adults: a systematic review,” *Disability and Rehabilitation. Assistive Technology*, pp. 1–10, Mar. 2023.
- [62] S. A. Sikkes and J. d. Rotrou, “A qualitative review of instrumental activities of daily living in dementia: what’s cooking?” *Neurodegenerative Disease Management*, vol. 4, no. 5, pp. 393–400, Oct. 2014. [Online]. Available: <https://www.futuremedicine.com/doi/10.2217/nmt.14.24>
- [63] B. Bouchard, K. Bouchard, and A. Bouzouane, “A smart cooking device for assisting cognitively impaired users,” *Journal of Reliable Intelligent Environments*, vol. 6, no. 2, pp. 107–125, Jun. 2020. [Online]. Available: <https://link.springer.com/10.1007/s40860-020-00104-3>
- [64] E. Dubuc, M. Gagnon-Roy, M. Couture, N. Bier, S. Giroux, and C. Bottari, “Perceived needs and difficulties in meal preparation of people living with traumatic brain injury in a chronic phase: Supporting long-term services and interventions,” *Australian Occupational Therapy Journal*, vol. 66, no. 6, pp. 720–730, 2019, eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1111/1440-1630.12611> [Online]. Available: <https://onlinelibrary.wiley.com/doi/abs/10.1111/1440-1630.12611>

- [65] T. A. Doherty, L. A. Barker, R. Denniss, A. Jalil, and M. D. Beer, “The cooking task: Making a meal of executive functions,” vol. 9, p. 22. [Online]. Available: <https://PMC4324235/>
- [66] P. Malani, J. Kullgren, E. Solway, J. Wolfson, C. Leung, D. Singer, and M. Kirch, “The Joy of Cooking and its Benefits for Older Adults,” University of Michigan, Tech. Rep., Jun. 2020.
- [67] R. Yared, B. Abdulrazak, T. Tessier, and P. Mabilleau, “Cooking risk analysis to enhance safety of elderly people in smart kitchen,” in *Proceedings of the 8th ACM International Conference on PErvasive Technologies Related to Assistive Environments*. Corfu Greece: ACM, Jul. 2015, pp. 1–4. [Online]. Available: <https://dl.acm.org/doi/10.1145/2769493.2769516>
- [68] D. J. Cook, “Learning Setting-Generalized Activity Models for Smart Spaces,” *IEEE intelligent systems*, vol. 2010, no. 99, p. 1, Sep. 2010. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3068197/>
- [69] B. Logan and J. Healey, “Sensors to Detect the Activities of Daily Living,” in *2006 International Conference of the IEEE Engineering in Medicine and Biology Society*, Aug. 2006, pp. 5362–5365, iSSN: 1557-170X.
- [70] N. Sarma, S. Chakraborty, and D. S. Banerjee, “Activity Recognition through Feature Learning and Annotations using LSTM,” in *2019 11th International Conference on Communication Systems & Networks (COMSNETS)*. Bengaluru, India: IEEE, Jan. 2019, pp. 444–447. [Online]. Available: <https://ieeexplore.ieee.org/document/8711147/>
- [71] M. Mokhtari, B. Abdulrazak, and H. Aloulou, Eds., *Smart Homes and Health Telematics, Designing a Better Future: Urban Assisted Living: 16th International Conference, ICOST 2018, Singapore, Singapore, July 10-12, 2018, Proceedings*, ser. Lecture Notes in Computer Science. Cham: Springer International Publishing, 2018, vol. 10898. [Online]. Available: <http://link.springer.com/10.1007/978-3-319-94523-1>
- [72] K. Yordanova, S. Lüdtke, S. Whitehouse, F. Krüger, A. Paiement, M. Mirmehdi, I. Craddock, and T. Kirste, “Analysing Cooking

- Behaviour in Home Settings: Towards Health Monitoring,” *Sensors*, vol. 19, no. 3, p. 646, Jan. 2019, number: 3 Publisher: Multidisciplinary Digital Publishing Institute. [Online]. Available: <https://www.mdpi.com/1424-8220/19/3/646>
- [73] D. J. Cook and M. Schmitter-Edgecombe, “Assessing the Quality of Activities in a Smart Environment,” *Methods of Information in Medicine*, vol. 48, no. 05, pp. 480–485, 2009. [Online]. Available: <http://www.thieme-connect.de/DOI/DOI?10.3414/ME0592>
- [74] P. N. Dawadi, D. J. Cook, M. Schmitter-Edgecombe, and C. Parsey, “Automated Assessment of Cognitive Health Using Smart Home Technologies,” *Technology and health care : official journal of the European Society for Engineering and Medicine*, vol. 21, no. 4, pp. 323–343, 2013. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4143248/>
- [75] P.-W. Chen, N. A. Baune, I. Zwir, J. Wang, V. Swamidass, and A. W. Wong, “Measuring Activities of Daily Living in Stroke Patients with Motion Machine Learning Algorithms: A Pilot Study,” *International Journal of Environmental Research and Public Health*, vol. 18, no. 4, p. 1634, Feb. 2021. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7915561/>
- [76] S. Pan, M. Berges, J. Rodakowski, P. Zhang, and H. Y. Noh, “Fine-Grained Activity of Daily Living (ADL) Recognition Through Heterogeneous Sensing Systems With Complementary Spatiotemporal Characteristics,” *Frontiers in Built Environment*, vol. 6, 2020. [Online]. Available: <https://www.frontiersin.org/articles/10.3389/fbuil.2020.560497>
- [77] J. Chung, G. Demiris, and H. J. Thompson, “Ethical Considerations Regarding the Use of Smart Home Technologies for Older Adults: An Integrative Review,” *Annual Review of Nursing Research*, vol. 34, no. 1, pp. 155–181, Jan. 2016. [Online]. Available: <http://connect.springerpub.com/lookup/doi/10.1891/0739-6686.34.155>
- [78] G. Demiris, “Privacy and social implications of distinct sensing approaches to implementing smart homes for older adults,” *Annual Inter-*

*national Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual International Conference*, vol. 2009, pp. 4311–4314, 2009.

- [79] J. Leo and D. Goodwin, “Negotiated Meanings of Disability Simulations in an Adapted Physical Activity Course: Learning From Student Reflections,” *Adapted Physical Activity Quarterly*, vol. 31, no. 2, pp. 144–161, Apr. 2014. [Online]. Available: <https://journals.humankinetics.com/view/journals/apaq/31/2/article-p144.xml>
- [80] Pozyx, “Hardware setup.” [Online]. Available: <https://docs.pozyx.io/creator/hardware-setup>
- [81] ——, “Configuration of the UWB parameters (Arduino).” [Online]. Available: <https://docs.pozyx.io/creator/configuration-of-the-uwb-parameters-arduino>
- [82] Z. Zhang, “Introduction to machine learning: K-nearest neighbors,” vol. 4, no. 11, p. 218. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4916348/>
- [83] Scipy.stats.mode — SciPy v0.7 Reference Guide (DRAFT). [Online]. Available: <https://docs.scipy.org/doc/scipy-0.7.x/reference/generated/scipy.stats.mode.html>
- [84] J. Faouzi, “Time Series Classification: A Review of Algorithms and Implementations,” in *Time Series Analysis - Recent Advances, New Perspectives and Applications*, J. Rocha, C. M. Viana, and S. Oliveira, Eds. IntechOpen. [Online]. Available: <https://www.intechopen.com/chapters/1185930>
- [85] J. Cervantes, F. Garcia-Lamont, L. Rodríguez-Mazahua, and A. Lopez, “A comprehensive survey on support vector machine classification: Applications, challenges and trends,” vol. 408, pp. 189–215. [Online]. Available: <https://linkinghub.elsevier.com/retrieve/pii/S0925231220307153>
- [86] 1.12. Multiclass and multioutput algorithms. scikit-learn. [Online]. Available: <https://scikit-learn/stable/modules/multiclass.html>

- [87] Y. Liu, Y. Wang, and J. Zhang, “New Machine Learning Algorithm: Random Forest,” in *Information Computing and Applications*, B. Liu, M. Ma, and J. Chang, Eds. Springer, pp. 246–252.
- [88] V. E. Lee and L. Liu, “Decision Trees: Theory and Algorithms.”
- [89] L. Breiman, “Random Forests,” vol. 45, no. 1, pp. 5–32. [Online]. Available: <https://doi.org/10.1023/A:1010933404324>
- [90] 1.10. Decision Trees. scikit-learn. [Online]. Available: <https://scikit-learn/stable/modules/tree.html>
- [91] Scikit-learn/sklearn/tree/splitter.pyx at main · scikit-learn/scikit-learn · GitHub. [Online]. Available: [https://github.com/scikit-learn/scikit-learn/blob/0b0b90b75102226d27e3947b9766729325d7042c/sklearn/tree/\\_splitter.pyx](https://github.com/scikit-learn/scikit-learn/blob/0b0b90b75102226d27e3947b9766729325d7042c/sklearn/tree/_splitter.pyx)
- [92] RandomForestClassifier. scikit-learn. [Online]. Available: <https://scikit-learn/stable/modules/generated/sklearn.ensemble.RandomForestClassifier.html>
- [93] P. Probst, M. Wright, and A.-L. Boulesteix, “Hyperparameters and Tuning Strategies for Random Forest,” vol. 9, no. 3, p. e1301. [Online]. Available: <http://arxiv.org/abs/1804.03515>
- [94] L. Ye and E. Keogh, “Time series shapelets: A new primitive for data mining,” in *Proceedings of the 15th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*. ACM, pp. 947–956. [Online]. Available: <https://dl.acm.org/doi/10.1145/1557019.1557122>
- [95] D. A. Roberts, S. Yaida, and B. Hanin, *The Principles of Deep Learning Theory*. [Online]. Available: <http://arxiv.org/abs/2106.10165>
- [96] What is a Neural Network? — IBM. [Online]. Available: <https://www.ibm.com/topics/neural-networks>
- [97] M. M. Taye, “Theoretical Understanding of Convolutional Neural Network: Concepts, Architectures, Applications, Future Directions,” vol. 11, no. 3, p. 52. [Online]. Available: <https://www.mdpi.com/2079-3197/11/3/52>

- [98] K. B. Prakash, R. Kannan, S. Alexander, and G. R. Kanagachidambaresan, Eds., *Advanced Deep Learning for Engineers and Scientists: A Practical Approach*, ser. EAI/Springer Innovations in Communication and Computing. Springer International Publishing. [Online]. Available: <https://link.springer.com/10.1007/978-3-030-66519-7>
- [99] P. Purwono, A. Ma’arif, W. Rahmani, H. Imam, H. I. K. Fathurrahman, A. Frisky, and Q. M. U. Haq, “Understanding of Convolutional Neural Network (CNN): A Review,” vol. 2, pp. 739–748.
- [100] L. Alzubaidi, J. Zhang, A. J. Humaidi, A. Al-Dujaili, Y. Duan, O. Al-Shamma, J. Santamaría, M. A. Fadhel, M. Al-Amidie, and L. Farhan, “Review of deep learning: Concepts, CNN architectures, challenges, applications, future directions,” vol. 8, no. 1, p. 53. [Online]. Available: <https://doi.org/10.1186/s40537-021-00444-8>
- [101] M. Swapna, D. Y. Sharma, and B. Prasad, “CNN Architectures: Alex Net, Le Net, VGG, Google Net, Res Net,” vol. 8, pp. 953–959.
- [102] Training a Classifier — PyTorch Tutorials 2.4.0+cu121 documentation. [Online]. Available: [https://pytorch.org/tutorials/beginner/blitz/cifar10\\_tutorial.html](https://pytorch.org/tutorials/beginner/blitz/cifar10_tutorial.html)
- [103] R. Vasudev. Understanding and Calculating the number of Parameters in Convolution Neural Networks (CNNs). Medium. [Online]. Available: <https://towardsdatascience.com/understanding-and-calculating-the-number-of-parameters-in-convolution-neural-networks-cnns-fc88790d530d>
- [104] N. Zakaria. Backpropagation in CNN; A Mathematically Explicit Exposition. Medium. [Online]. Available: <https://nordinzakaria.medium.com/backpropagation-in-cnn-a-mathematically-explicit-exposition-3f723f0ad9a0>
- [105] A. Sherstinsky, “Fundamentals of Recurrent Neural Network (RNN) and Long Short-Term Memory (LSTM) network,” vol. 404, p. 132306. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0167278919305974>

- [106] F. M. Salem, *Recurrent Neural Networks: From Simple to Gated Architectures*. Springer International Publishing. [Online]. Available: <https://link.springer.com/10.1007/978-3-030-89929-5>
- [107] CS231n Convolutional Neural Networks for Visual Recognition. [Online]. Available: <https://cs231n.github.io/rnn/>
- [108] A. Vaswani, N. Shazeer, N. Parmar, J. Uszkoreit, L. Jones, A. N. Gomez, L. Kaiser, and I. Polosukhin. Attention Is All You Need. [Online]. Available: <http://arxiv.org/abs/1706.03762>
- [109] Torchtext.data.utils — Torchtext 0.18.0 documentation. [Online]. Available: [https://pytorch.org/text/stable/data\\_utils.html](https://pytorch.org/text/stable/data_utils.html)
- [110] T. H. Teng, K. D. Varathan, and F. Crestani, “A comprehensive review of cyberbullying-related content classification in online social media,” vol. 244, p. 122644. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0957417423031469>
- [111] Amanatullah. The Attention Mechanism. Medium. [Online]. Available: <https://medium.com/@amanatulla1606/the-attention-mechanism-797e51c45d46>
- [112] Longx. Transformer Attention Layer gradient. Longxiang He. [Online]. Available: <https://say-hello2y.github.io/2022-09-07/attention-gradient>
- [113] Y. Yin, “Prediction and analysis of time series data based on granular computing,” vol. 17. [Online]. Available: <https://www.frontiersin.org/journals/computational-neuroscience/articles/10.3389/fncom.2023.1192876/full>
- [114] Z. Wang, W. Yan, and T. Oates. Time Series Classification from Scratch with Deep Neural Networks: A Strong Baseline. [Online]. Available: <http://arxiv.org/abs/1611.06455>
- [115] LSTM — PyTorch 2.5 documentation. [Online]. Available: <https://pytorch.org/docs/stable/generated/torch.nn.LSTM.html>

- [116] M. Barandas, D. Folgado, L. Fernandes, S. Santos, M. Abreu, P. Bota, H. Liu, T. Schultz, and H. Gamboa, “TSFEL: Time Series Feature Extraction Library,” vol. 11, p. 100456. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S2352711020300017>
- [117] List of available features — TSFEL 0.1.9 documentation. [Online]. Available: [https://tsfel.readthedocs.io/en/latest/descriptions/feature\\_list.html](https://tsfel.readthedocs.io/en/latest/descriptions/feature_list.html)
- [118] Z. L. Husz, A. M. Wallace, and P. R. Green, “Human activity recognition with action primitives,” in *2007 IEEE Conference on Advanced Video and Signal Based Surveillance*, pp. 330–335. [Online]. Available: <https://ieeexplore.ieee.org/document/4425332/?arnumber=4425332>
- [119] Tutorial 3: Orientation 3d (arduino). [Online]. Available: <https://docs.pozyx.io/creator/tutorial-3-orientation-3d-arduino>