NIBIO
NORWEGIAN INSTITUTE OF BIOECONOMY RESEARCH

Cable logging operation supported with sensor fusion

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Outline

Aims

Introduction

Methods
- System setup
- Data preparation
- Multivariate data analysis

Results
- Video
- Transfer rates
- PCA Biplot
- PLS results

Conclusions

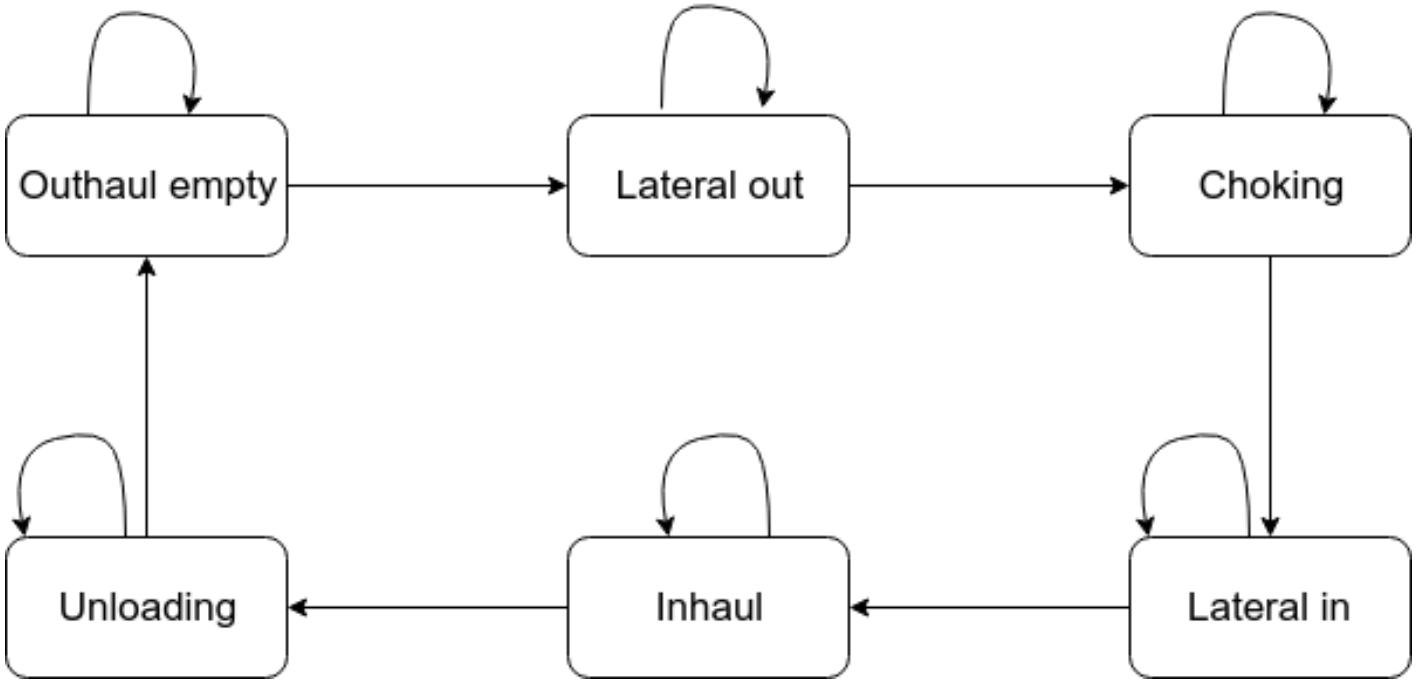
Aims

Development and test a standalone communicaton platform for capturing and processing cable-yarding operations data

1. Integration of IMU, GPS and camera data to support automatic work phase recognition.
2. Quantification of the phase prediction success of the method.

Introduction

Finite state machine can be depicted as a graph, whose nodes represent possible system states, and whose arrows represent possible transitions from state to state.



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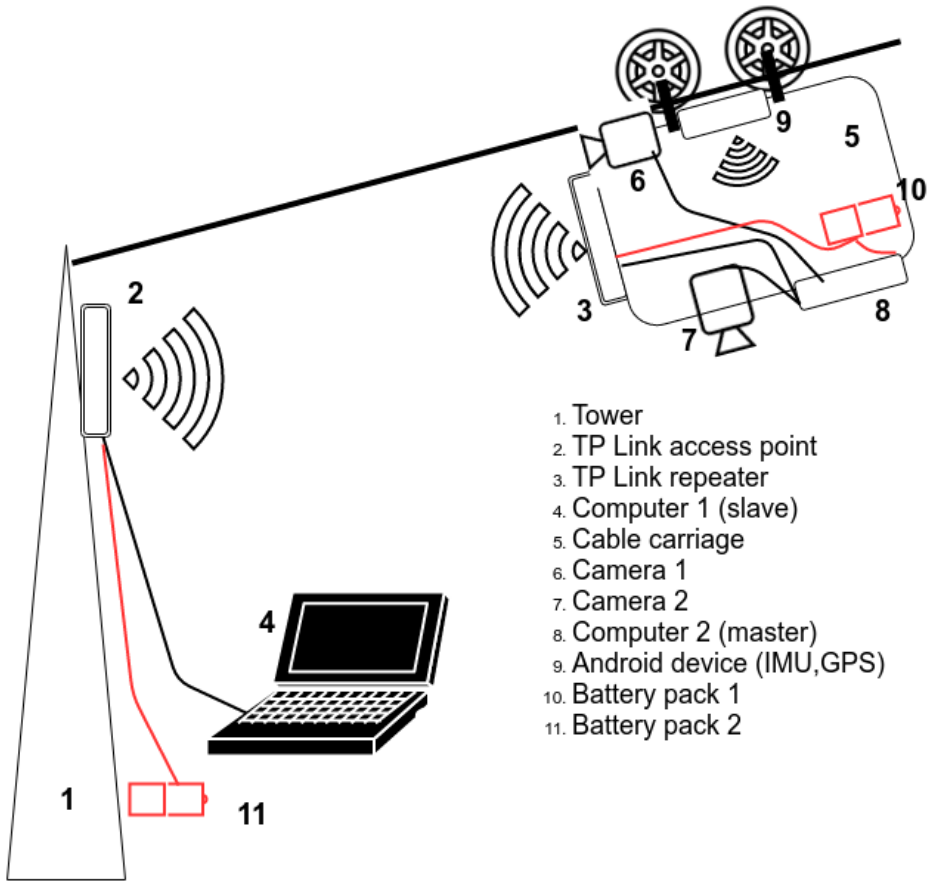
System setup

This setup was tested on self propelled Woodliner with Konrad KMS tower yarder. Whole tree harvesting was used with downhill extraction in a 160m long corridor.



1. Tower
2. TP Link access point
3. TP Link repeater
4. Computer 1 (slave)
5. Cable carriage
6. Camera 1
7. Camera 2
8. Computer 2 (master)
9. Android device (IMU,GPS)
10. Battery pack 1
11. Battery pack 2

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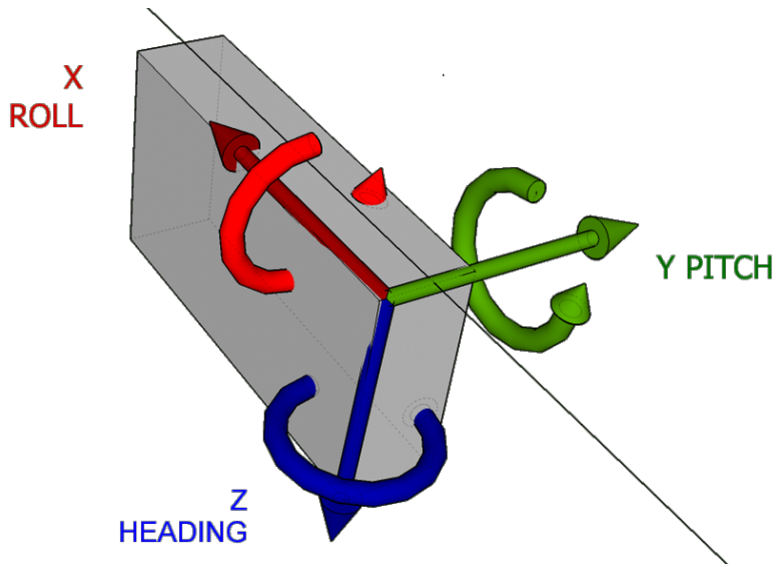
Data preparation

1. IMU (orientation, angular velocity, linear acceleration)
2. GPS (elevation, velocity)
3. Camera (optical flow - motion vectors)



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Multivariate data analysis

1. Variables recorded from different sensors were collected as rows in Matrix X
2. 6 phases were manually classified were collected in corresponding matrix Y
3. Responses in Y consisted of 6 categorical binary dummy variables

Table: Test verification responses (TP, FP, FN, TN) for PLS model classification of work phases where A is the true phase.

	Condition	
	A	Not A
Test says "A"	True positive(TP)	False positive (FP)
Test says "Not A"	False negative (FN)	True negative (TN)

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Transfer rates

Table: Data packets size (kilobytes) and data transfer rates (kilobytes/s) test results for the different sensor devices used on the communication platform.

Data source	size min (KB)	size max (KB)	frequency min (Hz)	rate min (KB/s)	rate max (KB/s)
GPS	0.12	0.12	0.96	0.12	0.12
IMU	0.32	0.32	0.01	32	32
Camera 2 (RaspiCam) compressed image	57	112	0.04	1425	2800
Camera 1 (USB cam) compressed image	59	73	0.085	694.11	858.82
Total (including compressed images only)	116.44	185.44		2151.23	3690.94
Camera 1 (USB cam) raw image	942.08	942.08	0.1	9 420.8	9 420.8
Total (all data)	1 058.52	1 127.52		11 572.03	13 111.74

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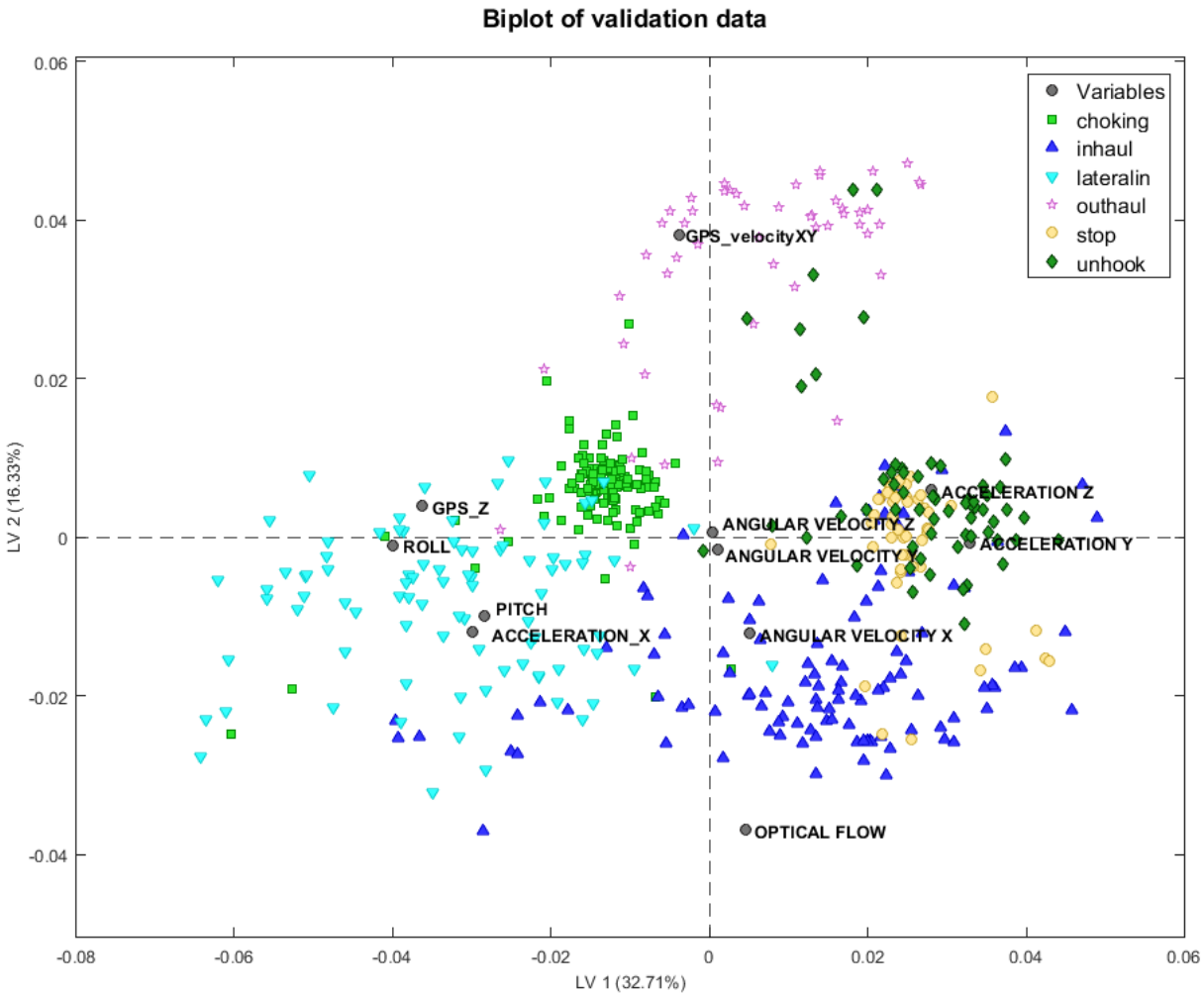
PCA Biplot


Biplot of validation data
Variables
choking
inhaul
lateralin
outhaul
stop
unhook
GPS_velocityXY
GPS_Z
ROLL
PITCH
ACCELERATION_X
ANGULAR VELOCITY Z
ANGULAR VELOCITY
ANGULAR VELOCITY X
ACCELERATION Z
ACCELERATION Y
OPTICAL FLOW
LV 2 (16.33%)
LV 1 (32.71%)
0.06
0.04
0.02
0
-0.02
-0.04
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06

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PLS results

Table: Prediction results for classification success per work phase.

[Confusion Matrix showing test verification responses, number of observations (N) and the precision of classification (P).]

Class:	TP	FP	TN	FN	N	**P**
outhaul	0.767	0.018	0.981	0.232	56	**0.843**
choking	0.947	0.076	0.923	0.052	133	**0.818**
lateral in	0.795	0.041	0.958	0.204	88	**0.804**
inhaul	0.738	0.038	0.961	0.261	111	**0.845**
unhook	0.721	0.066	0.933	0.278	61	**0.602**
stop	0.450	0.033	0.966	0.549	51	**0.605**

[Confusion Table showing the distribution of predicted classifications (rows) per actual work phase (columns).]

Predicted	*outhaul*	*choking*	*lateral in*	*inhaul*	*unhook*	*stop*
outhaul	**43**	0	0	0	8	0
choking	12	**126**	15	1	0	0
lateral in	0	6	**70**	11	0	0
inhaul	0	1	3	**82**	2	9
unhook	1	0	0	9	**44**	19
stop	0	0	0	8	7	**23**

Conclusions

1. Study showed promising method for enabling machine communication with max latency of 0.16s.
2. WLAN has a potential for cable yarding with defined spatial range
3. Data fusion from different sensors resulted in 78 % of correct classification.
4. Further implementation of this concept is considered a starting point for furhter development of autonomous routines in cable yarding.