Kinect Analysis of Obstacles & Feedback for the Visually-Impaired

Konnect

Samarth Shridhar, John (Jack) Prewitt, and Utkarsh Borikar

The Gwinnett School of Mathematics, Science, and Technology

Research Question or Engineering Problem/Goal

Existing Issues/Project Inspiration

Existing navigational technologies for the blind are often futile. For example, A comparative study on the efficacy of ultrasonic white canes, a major assistive device, revealed no significant impact of their usage. Thus, we seek to extend assistive technology beyond sensors and into machine learning.

Current technologies that combine deep learning exist. However, every study contains one or more of these problems: **unaffordability**, **computational inefficiency**, and **a lack of meaningful results**.

Surveys acknowledge that 42% of visually-impaired people have trouble with everyday objects. 20.6 million Americans are visually impaired, and therapy costs anywhere from **2,000 to 6,000 dollars**. Affordability is integral in rehabilitative technology.

Purpose/Engineering Goal

Purpose: The purpose of creating the Konnect Wearable is to provide visually impaired people an inexpensive, easy-to-manufacture navigation system that facilitates visual therapy and bridges the gaps between the visually impaired and the tangible world through lightweight, novel deep learning strategies.

Engineering Goal: Visually impaired persons need an auditory, interactive image processing system, which will be able to classify obstacles and provide feedback because they face difficulties in daily navigation due to obstructed vision impeding their ability to perceive obstacles and react to them. We aspire to alleviate these problems using cost-effective pixel/depth collection and processing through Microsoft's Kinect 1414 and artificial neural networks to provide auditory feedback and classification of obstacles

Method

Model Data Collection Phase

Software Pathway

Model Data Collection

Experimentation Phase

Initialize the Kinect and Program

Recieve Depth and Color Frames

Display on the GUI

Prepare Enviroment (Add Classifiable Objects)

Line Up Bands on GUI to Obstacle

Select Classifications for Each Band in GUI

Export To CSV (Model Data Collection)

First Smooth (Null Depth Evaluator) in Real-Time

Double Smooth (Post Collection)

Min-Max Algorithm

LightGBM Model Training

Needed Prior to Course Run

LightGBM Object Classification

Estimate Depths

Hierarchy Algorithm

Audio Feedback

Experimentation Phase

Have a blindfold, walking cane, and Konnect prepared for the test subject to use.

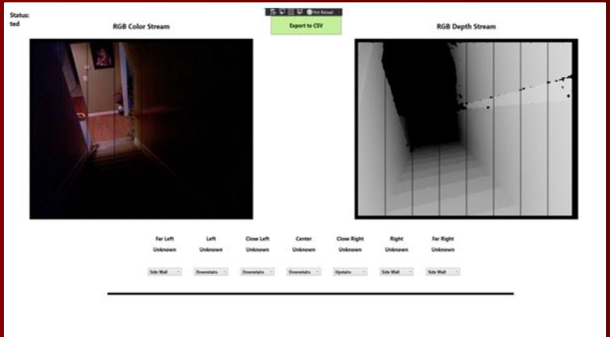
Set up 4 distinct courses with open space, walls, known obstacles, and stairs.

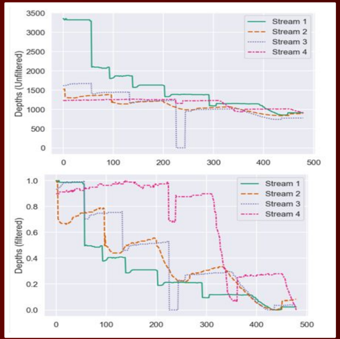
Randomly generate numbers (1 to 16) to randomly determine the course and aid that will be used (normal vision tests not included). Do not repeat test cases.

Have the test subject traverse the generated course until all cases utilizing a blindfold have been eliminated.

Randomly generate numbers (1 to 4) to randomly determine which course will be tested without blindfold. Do not repeat test cases.

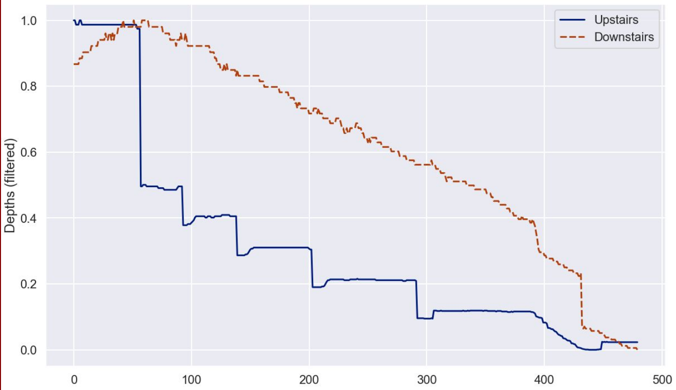
Have the test subject traverse the generated course until all four courses have normal vision trials.

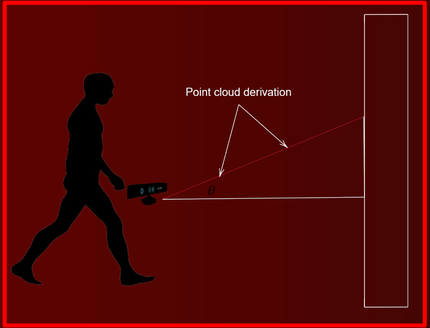




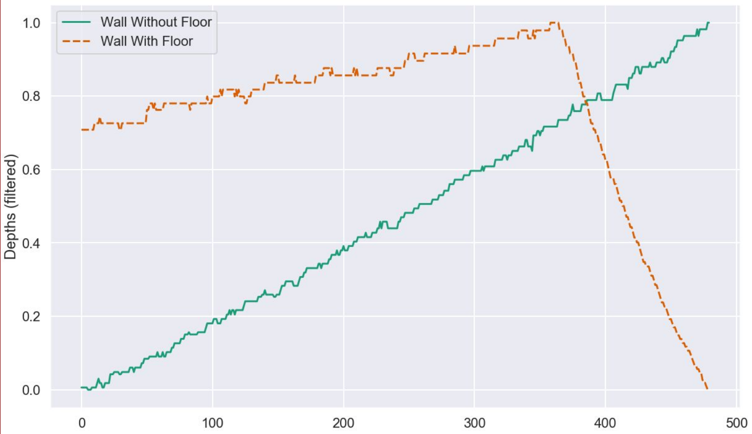
Results (Konnect Interpretation)

Model Statistics





- ➢ Model Theoretical Accuracy: 81.2%
- ➢ Model Empirical Accuracy: 96.2%
  - ○ 100 / 104 Correct Classifications



	Trainer	MicroAccuracy	MacroAccuracy	Duration	#Iteration
1	AveragedPerceptronOva	0.6632	0.3667	20.0	1
2	SdcaMaximumEntropyMulti	0.6404	0.4287	88.8	2
3	LightGbmMulti	0.8120	0.6026	41.2	3
4	SymbolicSgdLogisticRegressionOva	0.6364	0.3001	17.8	4
5	FastTreeOva	0.8067	0.5991	176.0	5
6	LinearSvmOva	0.6396	0.2833	18.5	6
7	LbfgsLogisticRegressionOva	0.6587	0.3316	24.5	7
8	SgdCalibratedOva	0.6352	0.3689	24.8	8
9	FastForestOva	0.7440	0.5762	109.0	9
10	LbfgsMaximumEntropyMulti	0.6764	0.3540	22.4	10

Experiment Results

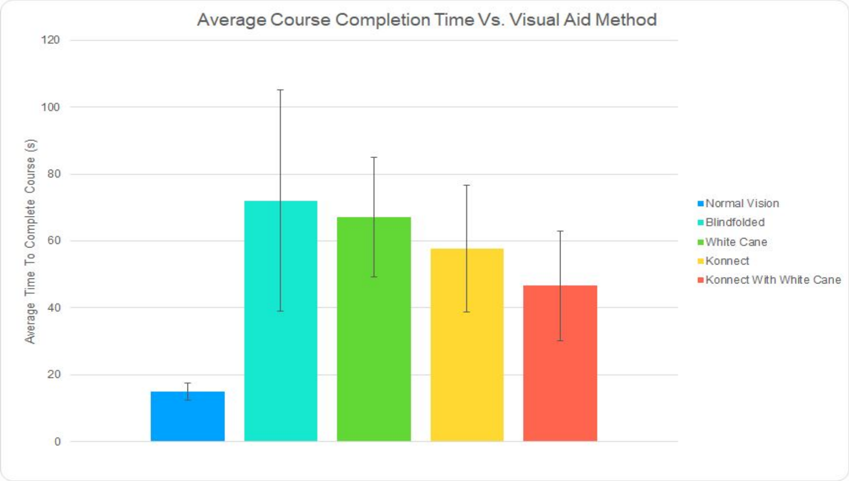
Summary

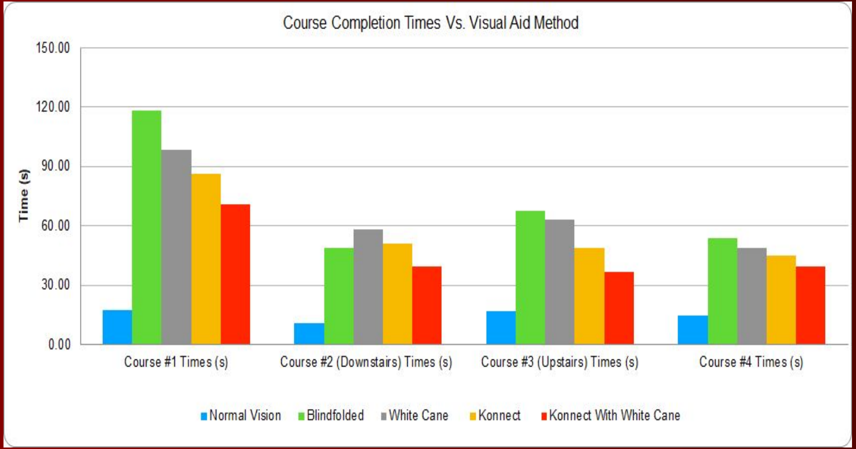
ML Task: multiclass-classification
Dataset: C:\Kinect Science Fair\Depth Data\KinectDataMinMax.csv
Label : Target
Total experiment time : 542.9832989 Secs
Total number of models explored: 10

Top 5 models explored

	Trainer	MicroAccuracy	MacroAccuracy	Duration	#Iteration
1	LightGbmMulti	0.8120	0.6026	41.2	1
2	FastTreeOva	0.8067	0.5991	176.0	2
3	FastForestOva	0.7440	0.5762	109.0	3
4	LbfgsMaximumEntropyMulti	0.6764	0.3540	22.4	4
5	AveragedPerceptronOva	0.6632	0.3667	20.0	5

Experimental Results





Experimentation Statistics

- ➢ Used nonparametric tests
- ➢ Kruskal-Wallis test value is ~0.044
- ➢ Disparity between permutations with Konnect With White Cane and that without Konnect With Cane

	Normal Vision	Blindfolded	White Cane	Konnect	Konnect With White Cane
Course Traversal Time Average (s)	14.9175	72.05	67.13	57.70	46.62

Kruskal-Wallis H Test

	Normal Vision (Control)	Blindfold (Control)	White Cane	Konnect	Konnect With Cane	
			12	11	10	
			8	7	2.5	
			9	7.5	1	
			6	4	2.5	
R			35	29.5	16	
n			4	4	4	12
R^2 / n			306.25	217.5625	64	587.8125
H						6.216346154
df						2
p						0.04468251
α						0.05
sig						yes

Pairwise Mann-Whitney tests

group 1	*group 2*	*p-value*	*U-stat*	*mean*
Normal Vision	Blindfolded	0.030382822	0	57.5
Normal Vision	White Cane	0.030382822	0	52.25
Normal Vision	Konnect	0.030382822	0	43.25
Normal Vision	Konnect With White Cane	0.029401048	0	32
Blindfolded	White Cane	0.885233914	7	5.25
Blindfolded	Konnect	0.383630327	4.5	14.25
Blindfolded	Konnect With White Cane	0.191266987	3	25.5
White Cane	Konnect	0.470486422	5	9
White Cane	Konnect With White Cane	0.191266987	3	20.25
Konnect	Konnect With White Cane	0.191266987	3	11.25

Interpretation of Results

Null Hypothesis

If a visually impaired person utilizes the Konnect Wearable, there is no statistically significant difference in the navigational time through the course than a case in which the device was not utilized.

Alternative Hypothesis

If a visually impaired person utilizes the Konnect Wearable, the visually impaired persons will experience a decrease in navigational time through their environment compared to usage without the system and with traditional navigation methods (i.e. white cane).

Kruskal-Wallis Value: ~0.044

White Cane	Konnect	~0.471
White Cane	Konnect With Cane	~0.191
Konnect	Konnect With Cane	~0.191

The Kruskal-Wallis value is less than 0.05, thus **rejecting the null hypothesis.**

There is an appreciable difference between the pairwise permutations containing Konnect with Cane than the White Cane and Konnect permutation. Hence, using the Konnect with a white cane is significantly faster than using the technologies separately.

Possible Errors:

-Small sample size and age range (~15-16)

-Potential for memorizing course traversal

-No legally blind (uncorrected and corrected) subject

Advantages Over Popular Technologies:

Electronic Canes (Ultrasonic Technology):
More Efficient, Obstacle Identification, Greater Accuracy, Significantly Cheaper

The Sound of Vision (Point Cloud Technology):
More Versatile, Obstacle Identification, Less Intrusive, Scalable

TapTapSee (GPS Technology):
Environmentally Versatile, More Efficient

Conclusions

A Promising Pioneer

Although the Konnect had several improvisations, its end result pioneers several improvements over current technologies, going beyond our expectations for its potential application.

Versatility: **Classifies** objects, no requisite APIs/Internet, efficient

Affordability: Manufacturing cost estimated around **$15**

Scalability: Codebase can be applied on **any** LiDAR/Infrared cameras

Sensible Testing: Testing/training done on both unorthodox objects and objects that will appear in **realistic, everyday scenarios**

Data Validation: A majority of deep learning assistive technologies are marketed on their theoretical accuracy. We confirmed our device works via **several course-based tests**.

Applications:

-Affordable Visual Therapy
-White Cane Facilitation
-Furthering ML x Assistive Technology Research

Future Improvements

There are numerous ways in which the Konnect can extend its potential impact.

Open Source: With a publicly accessible databases, people around the world can gather their own data with the software's user-friendly GUI and contribute to increase Konnect's accuracy.

Smaller Hardware: The codebase can be moved onto smaller alternatives than a laptop, such as the Meadow F7 BLE

Haptic Interfaces: For the blind and deaf, giving the option of haptic/vibration feedback will be more suitable

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