Early detection of sleep disorders

develop an autonomous system to detect and **predict** sleep disorders reliably based on real-time covert sensing.

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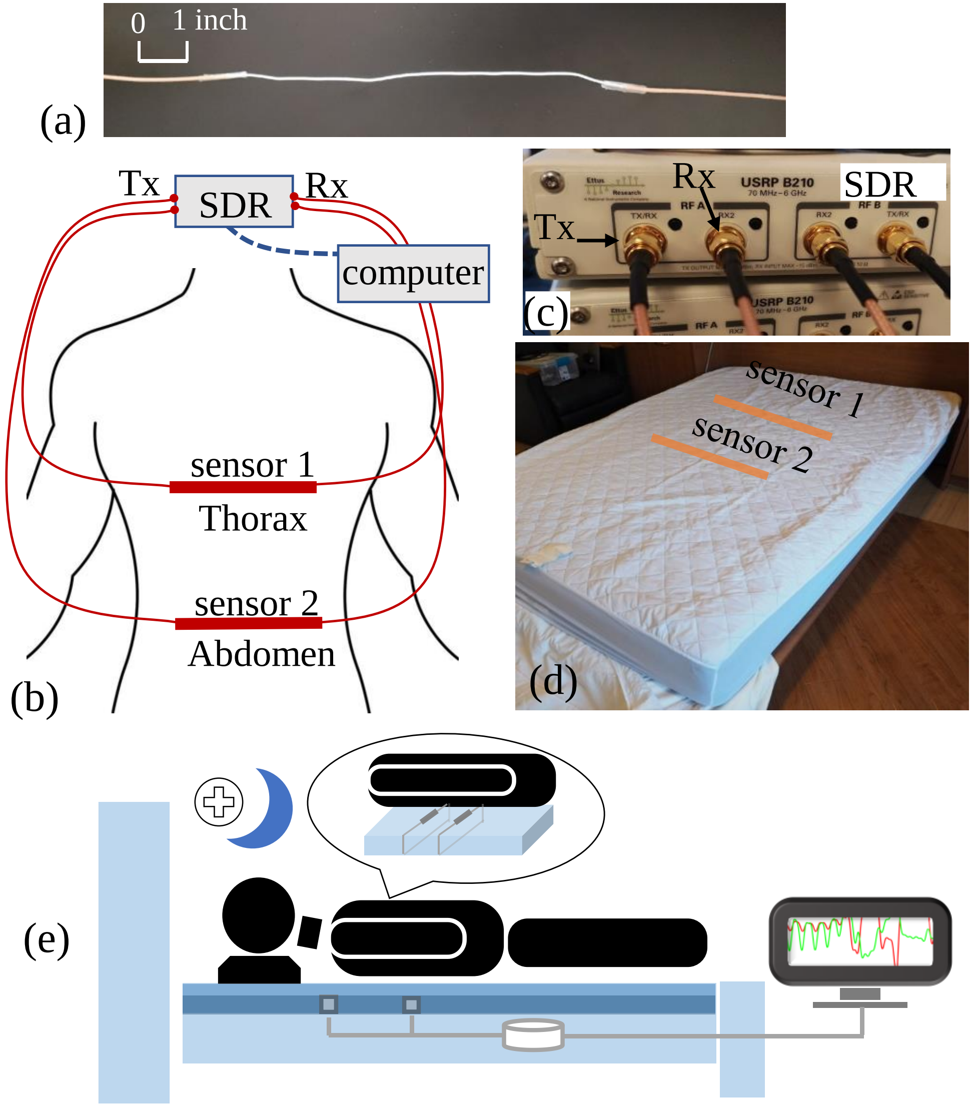
Experimental Setup in sleep center



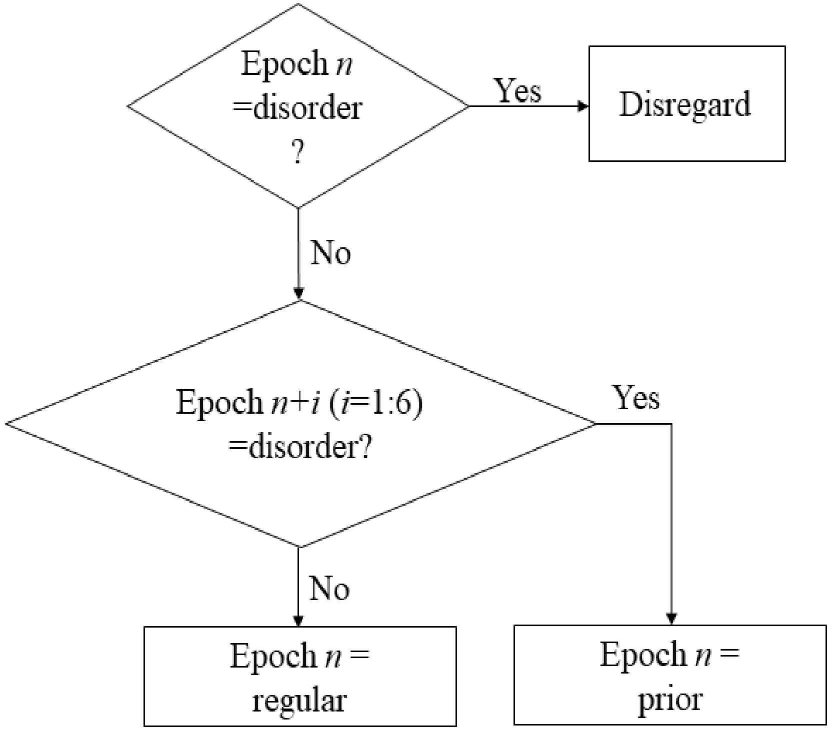
Overnight recordings collected from 27 patients in the Weill Cornell Center for Sleep Medicine.

Invisible sensing:
Notched transmission line sensor
under the mattress pad.

Current technology:
Polysomnography
(PSG)

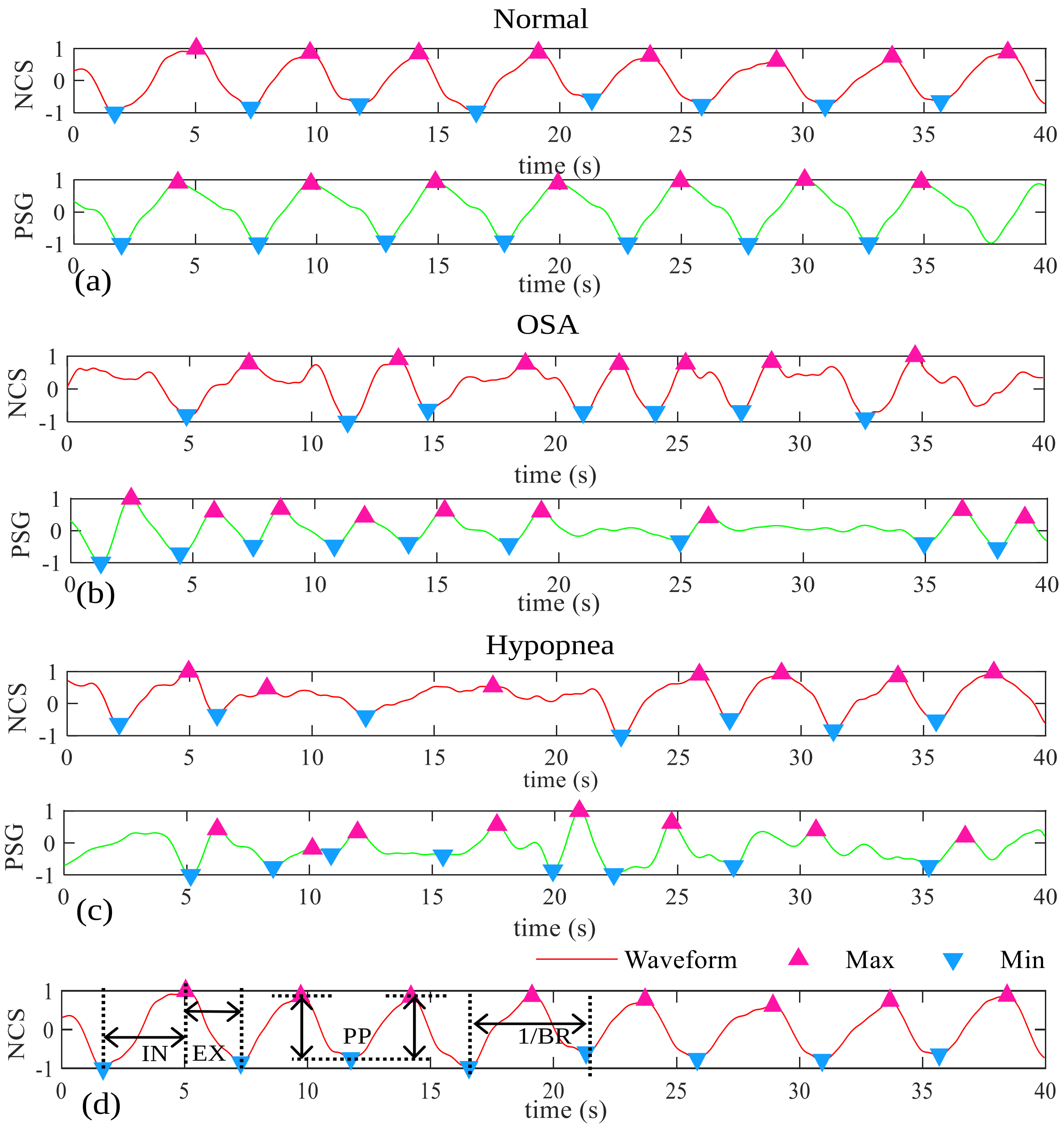
Signal processing procedures

- Down sample and synchronize NCS and PSG.
- Filter and smoothing (0.05-2 Hz).
- Segment waveform (T_{epoch} = 40s, T_{slide} = 15 s).
- Label operator annotation.
- Extract features in epoch.
- Select epochs by signal quality.
- Output to the ML model.



The prediction labelling criterion.

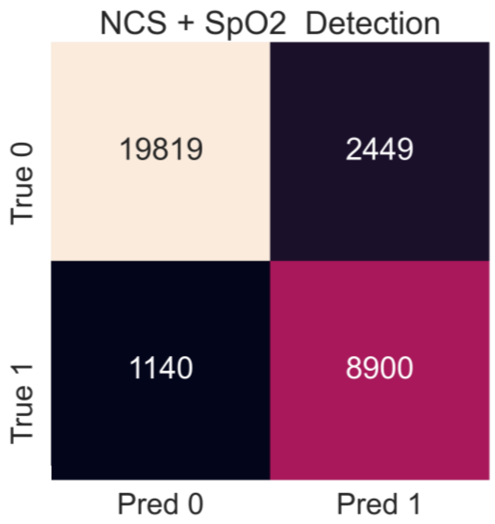
Waveform examples

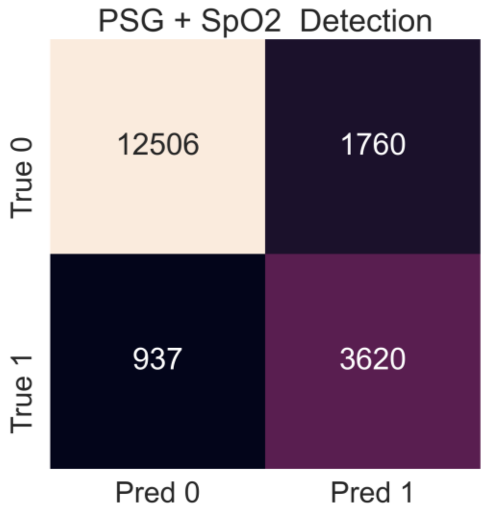


Normal

Disorders

Detect sleep disorders using ML model





5-fold Cross Validation

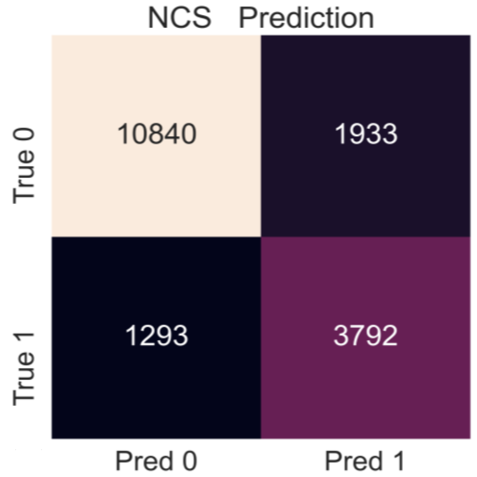
Normal (0) Disorders (1)

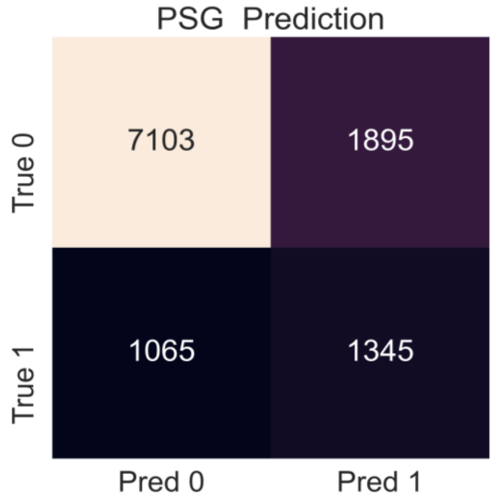
Model: Random Forest

Data set	NCS + SpO2	PSG + SpO2
Accuracy(%)	**88.9**	85.2
Sensitivity(%)	**88.6**	78.3
Specificity(%)	**89.0**	87.4
Feature importance	σ_{SpO2} (0.58)	σ_{SpO2} (0.36)
	σ_{PP} (0.14)	η_{SpO2} (0.05)
	σ_{BR} (0.08)	μ_{BR} (0.05)
	CoV_{PP} (0.04)	σ_{PP} (0.05)

SpO2 : Oxygen saturation level

Predict sleep disorders using ML model

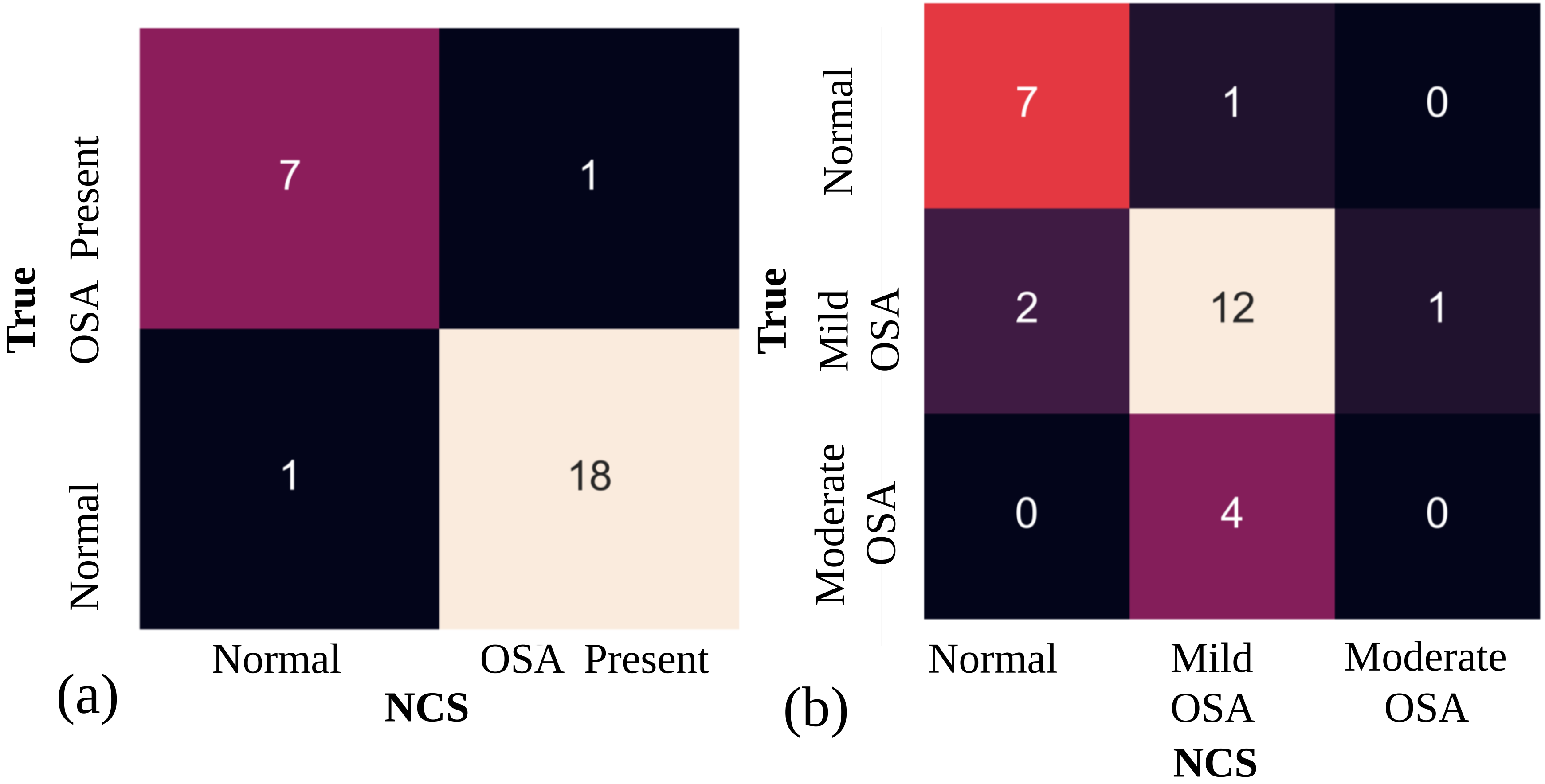




5-fold Cross Validation
Normal (0) Disorders (1)
Model: Random Forest

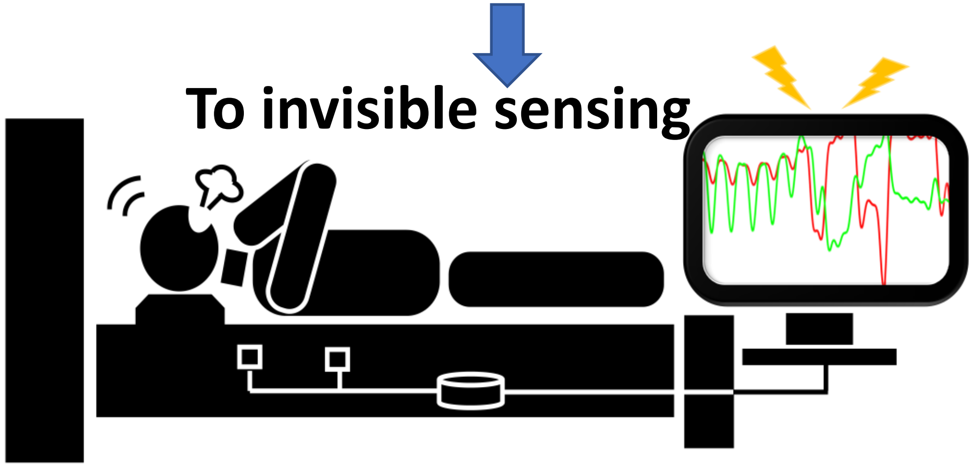
Data set	NCS	PSG
Accuracy(%)	81.9	74.1
Sensitivity(%)	74.6	55.8
Specificity(%)	84.9	78.9
Feature importance	η_{p0} (0.31) σ_{PP} (0.30) CoV_{PP} (0.19) σ_{BR} (0.13)	σ_{PP} (0.21) min_{PP} (0.17) CoV_{PP} (0.10) μ_{PP} (0.09)

AHI, calculated by the number of apnea and hypopnea events per hour of sleep



binary AHI classes
AHI ⩽ 5 Normal
AHI > 5 as OSA Present
accuracy = 0.93

the three AHI classes :
AHI ⩽ 5: Normal;
5 < AHI ⩽ 15: Mild OSA;
15 < AHI < 30: Moderate OSA,
accuracy = 0.70.



Automatic respiratory disorders detection using non-invasive sensors integrated into bed.

The current sleep apnea diagnosis platform was mostly based on PSG, which remained expensive in terms of hardware and operators, uncomfortable from body electrodes, and time-consuming for deployment. The ability to predict upcoming SDB events by PSG was also limited.

In the future, our covert detection and prediction system could expedite intervention, and improve diagnosis and therapy for respiratory disturbance during sleep.