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PresenceSense: Zero-Training Algorithm for Individual Presence Detection based on Power Monitoring

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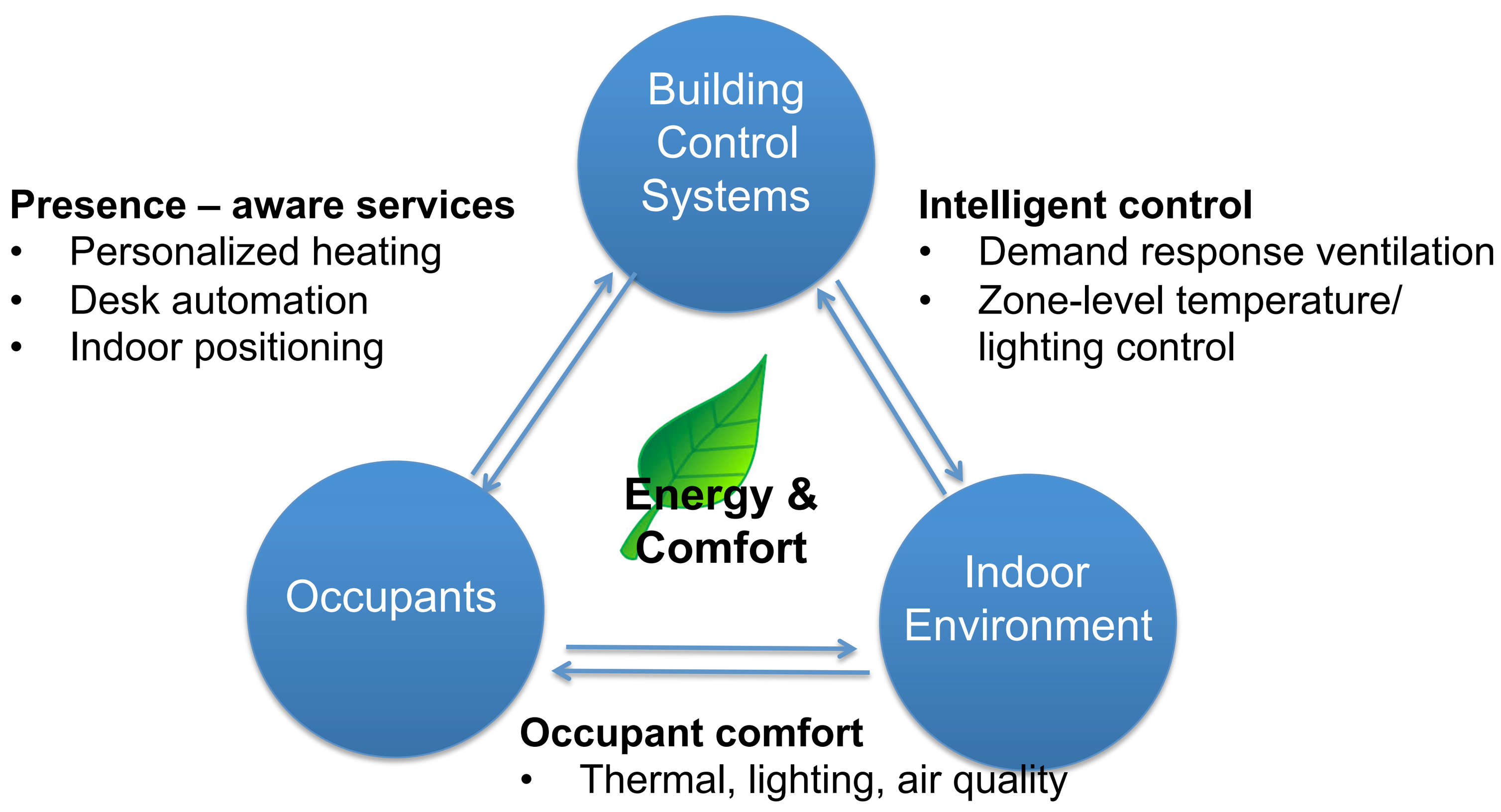
Motivation



Building ~ 40% of energy usage in the US:

- Plug loads ~ 20% - 30% of building energy.

Benefits of individual presence:

- Improve energy efficiency of demand response, thermal comfort by personalized heating

Experiments

Ultrasonic: measures distance to nearest obstacle

- For elapse time $\Delta t, d = \frac{1}{2} v_{\text{sound}} \Delta t$

Acceleration: detects chair motion

- Feature $std(\bar{a}(t))$ where $\bar{a}(t) = \sqrt{a_X(t)^2 + a_Y(t)^2 + a_Z(t)^2}$

WiFi: detects smart phone presence

- Access points detect emitted signal: binary 0 or 1

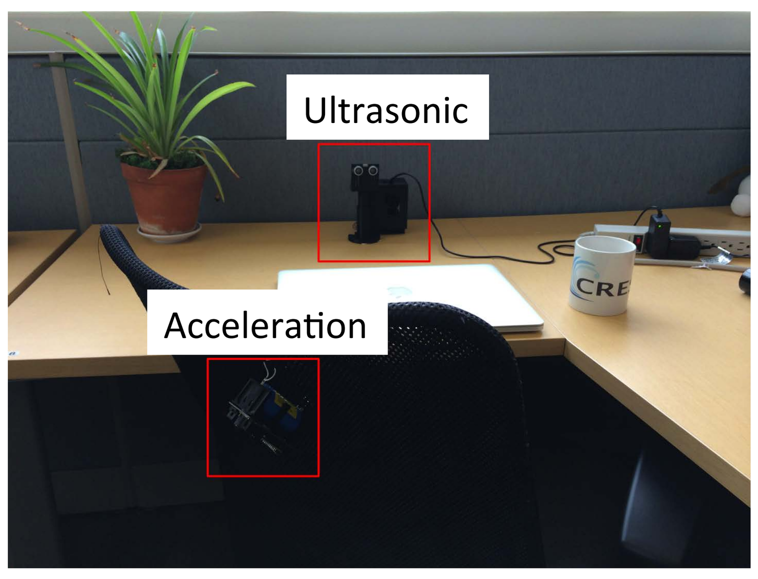


Figure: Placement of the ultrasonic sensor and acceleration sensor

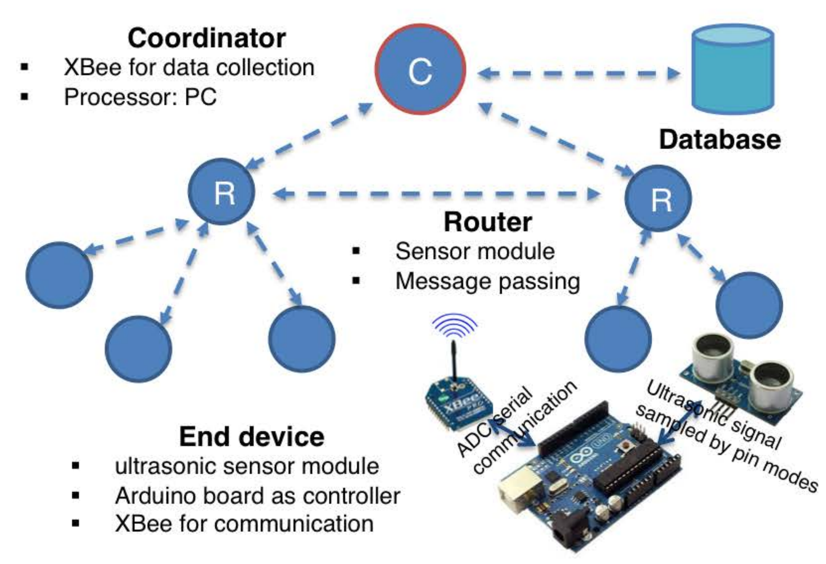


Figure: Network configuration of ZigBee for ultrasonic sensors

Results and Discussion

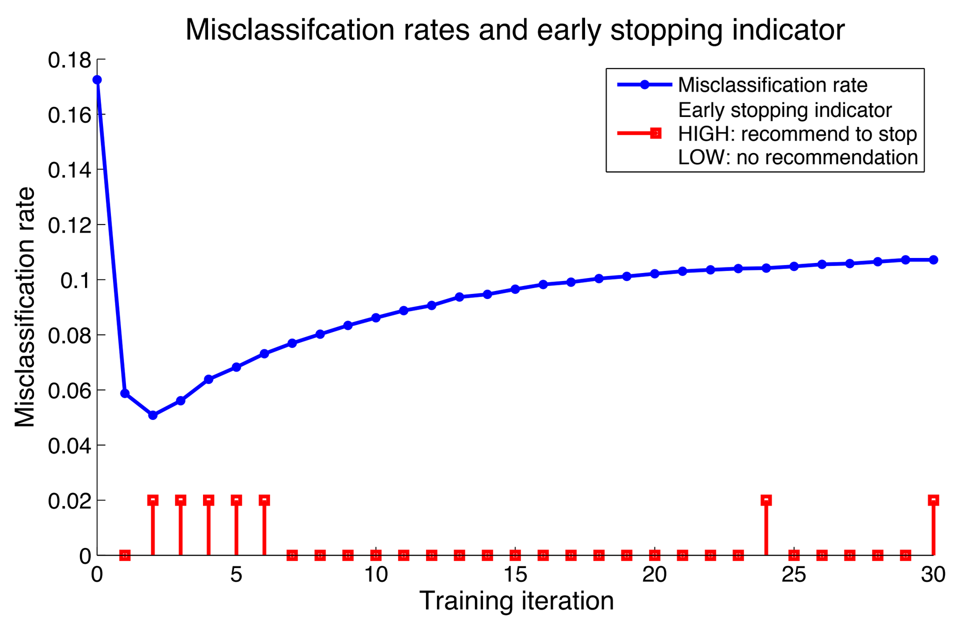
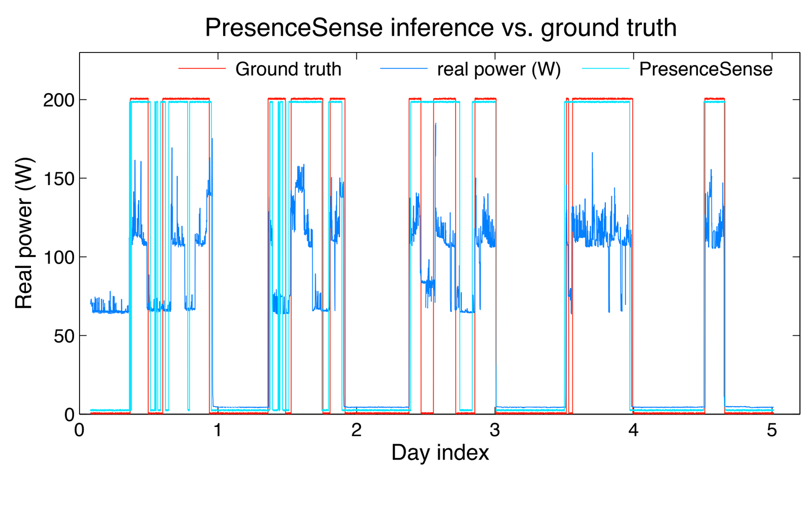


Figure: Misclassification rate after iterations

- ❖ Achieves optimal after only 2 iterations, deteriorates afterwards.
- ❖ Stopping indicator (marked in red) fires at 2 and frequently during degradation.
- ❖ Good indicator for early stopping.



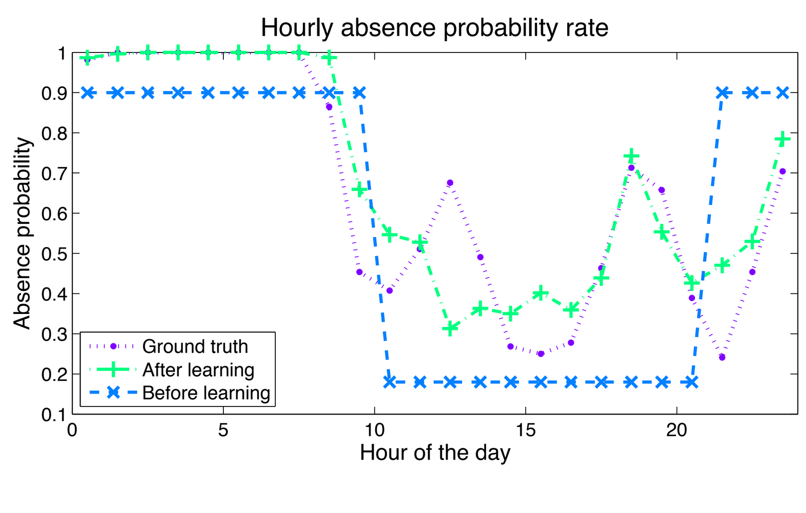


Figure: (left) Ground truth vs. PresenceSense. (right) Learned hourly presence pattern

- ❖ User might leave desktop ON when absent.
- ❖ Power change and std. dev. (ripple effect) are useful features.
- ❖ The presence profile is correctly captured by PresenceSense.

id	Chg/Th	Abs/Th	Prc/Th	PSense
8	.87/.36/.72	**.97**/.62/.86	.79/.45/.69	**.97/.71/.89**
17	.69/.64/.68	**.92**/.76/.86	.83/.49/.71	**.92/.77/.87**
20	.67/.67/.67	**.94/.69**/.86	.87/.40/.72	**.94/**.68**/.87**
26	.80/.14/.62	**.99**/.66/.90	.87/.15/.67	.96**/.84/.93**

★Entry **a/b/c**: detection rate when user is absent/present/overall.

Table: Comparison of accuracy with other popular models

❖ PresenceSense outforms in most cases (2nd place power threshold model).

PresenceSense Algorithm

Algorithm 1 Pseudo-code of PresenceSense

1: **function** PRESENCESENSE_LABELING(X, $Prior$, $MaxIter$)
2: **Initialization:**
3: $L_1^0, L_2^0 \leftarrow Prior(X)$
4: $stopCond \leftarrow false$
5: $k \leftarrow 0$
6: $\eta_0 \leftarrow 0.5$
7: **Main program:**
8: **while** $\neg stopCond \wedge k < MaxIter$ **do**
9: $YMat \leftarrow emptyMatrix(n, v)$
10: **for** $v_{ind} \in \{1, ..., v\}$ **do**
11: $EstModl \leftarrow ModelEstimation(X^{v_{ind}}, L_1^k, L_2^k)$
12: $YMat(\cdot, v_{ind}) \leftarrow ModelPredict(EstModl, X^{v_{ind}})$
13: **for** $s_{ind} \in \{1, ..., n\}$ **do**
14: $Y(s_{ind}) \leftarrow MajorityVote(YMat(s_{ind}, \cdot))$
15: $L_{i,n}^k \leftarrow getSet(Y)$
16: $L_i^{k+1} = \{L_i^k \cap L_{i,n}^k\} \cup Sample\{L_i^k \Delta L_{i,n}^k; \alpha_i\}$
17: $\eta_{k+1} \leftarrow EstEta(L_{1,2}^k, L_{1,2}^{k+1}, \alpha_1, \alpha_2, V^{est})(*)$
18: $stopCond \leftarrow checkStop(L_{1,2}^k, L_{1,2}^{k+1}, \eta_{k,k+1})(*)$
19: *(Optional)* search α_1, α_2 such that $stopCond \leftarrow false$ by repeating (*) steps
20: $k \leftarrow k+1$
21: **Outputs:** $L_1, L_2 \leftarrow L_1^k, L_2^k$

Idea: Start from common knowledge, iteratively relabels data based on power features

Procedure:

1. (L:3) Initialize with presence during office hours (8am–6pm) and the rest with absence

2. (L:11-14) Train and relabel by all power classifiers based on the majority rule

3. (L:15-16) Update labeled set by the rule which guarantees convergence (Corollary 1)

4. (L:17-20) Checks stopping condition and reiterate

For more details regarding convergence and stppping rule, please refer to:

Jin, Ming, et al. "PresenceSense: zero-training algorithm for individual presence detection based on power monitoring." BuildSys'14

Conclusion and Future Work

- Evaluated several presence detection methods: ultrasonic sensor, acceleration sensor, WiFi
- **PresenceSense:** non-intrusive based on individual power consumption
- Extension to occupancy estimation by sensor fusion
- Adapt to other problems such as indoor positioning without training labels

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