An Animation and Chirplet-Based Approach to Developing a PIR Sensing Intrusion Detection System for an Outdoor Setting

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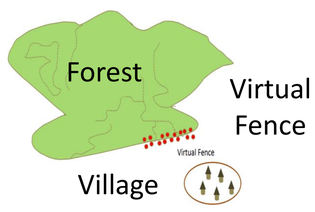
Mitigation of Human-Wildlife Conflicts


Recent leopard attacks in India.

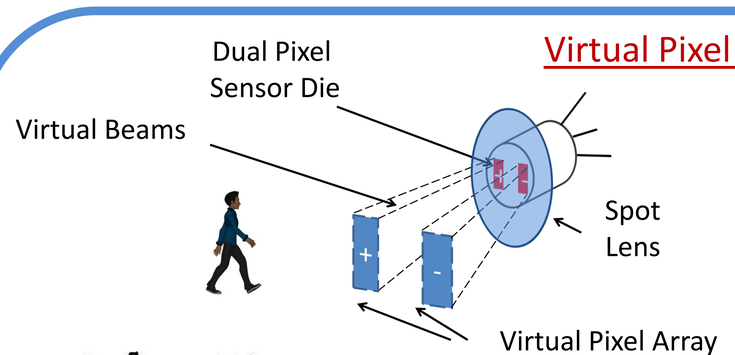
Tiger and leopard skins seized in Delhi.

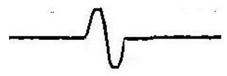


- Animal excursions (killing of livestock and destruction of crops)
- Human intrusions (poaching and forest destruction)

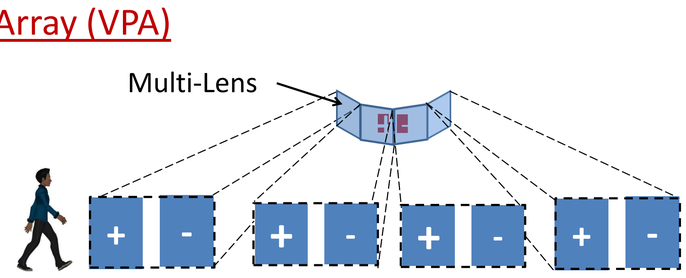
Goal: Investigate efficacy of WSN-based early warning systems to manage human-animal conflicts

Virtual Pixel Array (VPA)





Signal output for an object moving across the VPA of spot lens



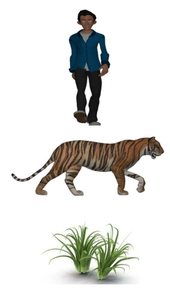
Signal output for an object moving across the VPA of multi-lens

Field of View (FoV): Set of virtual beams along which radiation is received
VPA associated with a plane: Intersection of FoV with the plane
Signal generated when an object enters and exits the pixels

PIR-Based Sensor Platform for Intruder Classification

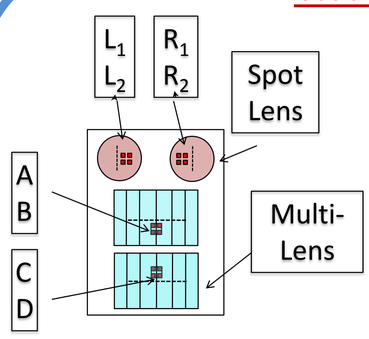
PIR Sensor Tower Platform

Support Vector Machine Classifier



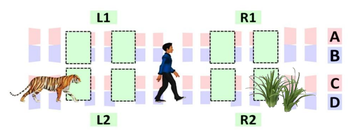
Designed and developed Indigenous sensor platform using inexpensive commercially available components
Assumptions
- Intruder moves in straight lines at a uniform velocity
- No multiple intrusions
- Only intrusions from humans, dogs, leopards, tigers and wolves

VPA Design

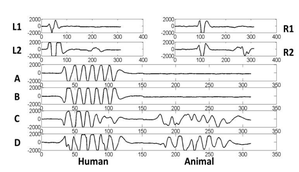


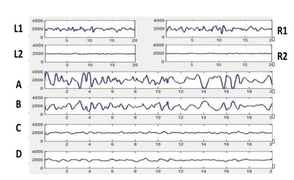
Sensor-lens arrangement

Indigenous sensor platform developed



VPA generated





Waveforms for human, animal and clutter

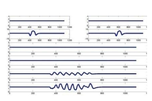
ASPIRE: Animation-Based Simulation of PIR Sensor

Collada (Animated 3D Model)

VPA Associated with Intruder Plane

ASPIRE
$A_{proj}(t)$: 2D Projection of 3D model on VPA

Animation Display



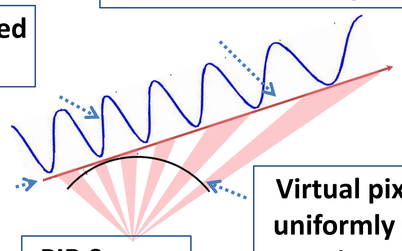
Output Signal: v(t)=w(t)*h(t)

w(t) : Radiation
$w(t) \propto A_{proj}(t)$
h(t): Impulse response of PIR

Chirplet-Based Model For Intruder Detection

Spacing between pixels on the intruder path increases to the right

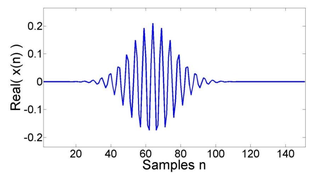
Resulting chirped signal



Intruder path

PIR Sensor

Virtual pixels are uniformly spaced along the circumference



Example chirplet

- Chirplet

$$x(n;m,\omega,c,d) = (2\pi d^2)^{-\frac{1}{4}} \exp\left\{-\frac{(n-m)}{4d^2}\right\} \times \exp\left\{j\frac{c}{2}(n-m)^2 + j\omega(n-m)\right\}$$

- Complex analytic representation of signal

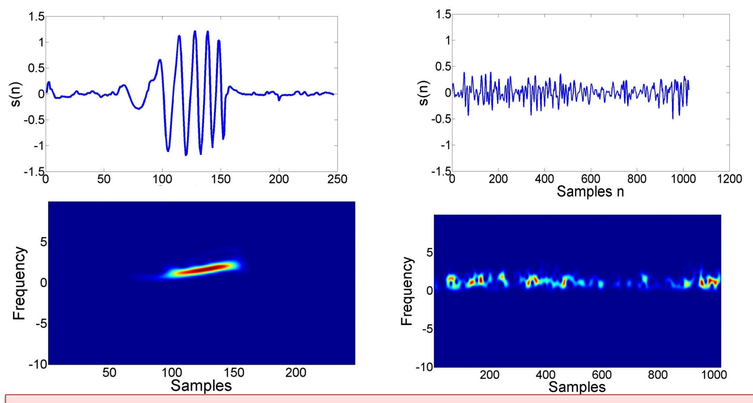
$$s_a(n) = s(n) + j\hat{s}(n)$$

- Intruder signal well approximated by sum of 3 chirplets:

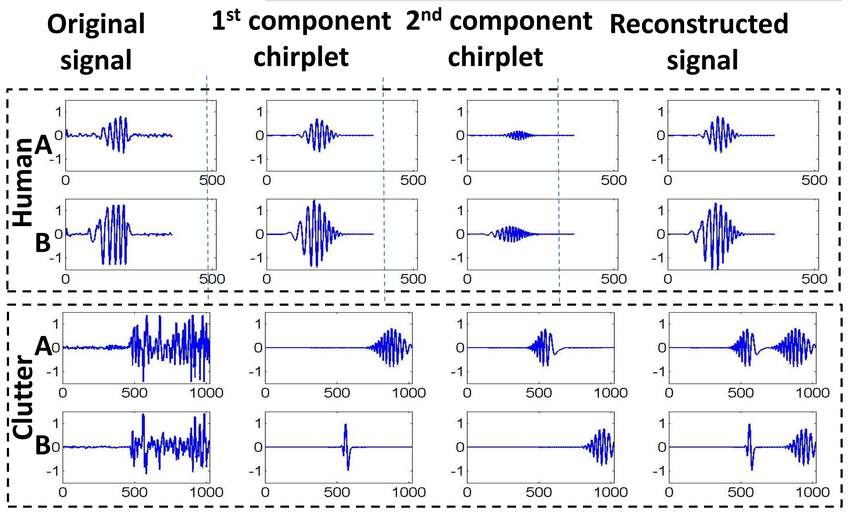
$$s_a(n) = \sum_{i=1}^{3} a_i e^{j\phi} x_i(n; m_i, \omega_i, c_i, d_i)$$

- Chirplet–based feature vector C_{60} : Append ML estimates corresponding to 3 chirplets

Intruder signal in sensors A,B,C & D exhibits chirp

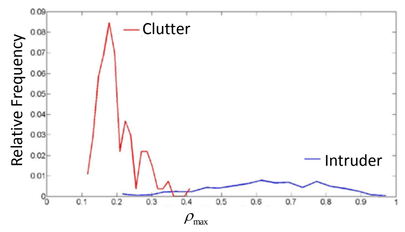


Intruder and clutter signals & the corresponding STFT



Example chirplet decomposition

Energy and Correlation Based Features



Histogram of ρ_{max}

A	B	C	D	Signal Indicates
0	0	0	1	Short animal at 5 m
0	0	1	0	Animal at 10 m
0	0	1	1	Animal at 5 m
0	1	1	0	Human at 10 m
0	1	1	1	Short human at 5 m
1	1	1	1	Tall human at 5 m
(All other combinations)				Clutter or combination unlikely

Inference Drawn from Sensor Combinations Triggered

Feature Performance on Real-World and Simulated Data

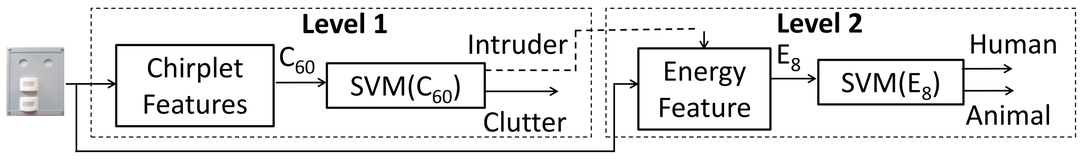
Features			Minimum Accuracy %						Average Accuracy %					
E_8	ρ_{max}	C_{60}	Intruder		Clutter		Total		Intruder		Clutter		Total	
			RWD	SD	RWD	SD	RWD	SD	RWD	SD	RWD	SD	RWD	SD
✓			94.2	88.6	96.3	87.0	94.8	88.0	97.4	92.9	96.3	92.6	97.1	92.8
✓	✓		95.6	96.2	96.3	87.0	95.8	92.5	97.4	95.0	97.8	94.1	97.5	94.6
		✓	98.6	97.5	100	98.2	99.0	97.8	99.7	99.2	98.5	99.3	99.4	99.3

Intruder vs Clutter

Features	Minimum Accuracy %			Average Accuracy %		
E_8	Human	Animal	Total	Human	Animal	Total
RWD	95.0	96.7	95.7	98.4	99.3	98.8
SD	100	100	98.8	100	99.5	99.8

Human vs Animal

Final Two-Level Classifier



	Real-World Data		Simulated Data	
	Minimum Accuracy	Average Accuracy	Minimum Accuracy	Average Accuracy
Clutter	96.3	98.3	96.4	99.2
Intruder	100	98.6	98.7	99.2
Human	95.0	98.0	100.0	100.0
Animal	100.0	99.5	100.0	100.0
Overall	98.8	99.9	99.4	99.9

Reference : J. C. O'Neill, P. Flandrin and W. C. Karl, "*Sparse representations with chirplets via maximum likelihood Estimation*"