**Objective:**
- To enable accurate occupancy sensing/tracking and automatic 3-D reconstruction of spaces using a new, low-cost fisheye stereo camera system

**Problem:**
- Occupant presence and position are required for localized advanced control options
- Space reconstruction and occupant positioning through computer vision techniques can expedite calibration of parameters and minimize commissioning needs

**Expected Results:**
- A new low-cost, calibrated, programmable stereo-fisheye camera system
- Continuous automated 3D geometry retrieval and real-time detection of occupant presence, position and posture –direct inputs to building models and control logics
- Reduced cost for controls and commissioning
- Extensions to occupant behavior learning through vision-based, non-invasive techniques

**Approach:**
- Using a small stereo camera on the ceiling, retrieve 3-D space geometry as well as occupant tracking
- Pixel matching, edge/line/depth estimation; machine-learning and pattern recognition techniques can be embedded in calibrated, programmable camera
- Real-time communication through Raspberry Pi to BMS – occupant presence, posture, behavior –controls

**Schedule**
1. Development, calibration and testbed installation of fisheye-stereo camera system: **Jan-Mar**
2. 3-D geometry retrieval of testbed office: **Mar-Jun**
3. Occupant sensing (presence & position) and implementation of control algorithms in testbed office: **Jun-Nov**
4. Extensions to occupant behavior and demonstration in open plan offices (LL): **Oct-Dec**

**PIs:** Thanos Tzempelikos
Michael Kim
Automated 3-D Space Reconstruction and Occupancy Detection (Presence and Position) to Enable Efficient Building Controls Using a Low-Cost Stereo Camera System

**Overview of approach**

- **Pi stereo camera system**
- **Object detection-segmentation**

**Pi stereo camera system**

- Advanced control implementation based on the building model

**Vision-based occupant learning and control**

- Continuous automated 3D-geometry retrieval
- Occupant sensing (positioning and posture tracking)

**Human posture detection & tracking**

**PIs:** Thanos Tzempelikos, Michael Kim

**Overview of approach**

- Automated stereo-vision sensor installation
- OpenCV
- TensorFlow
  - Automated Computer Vision & Deep Learning Approaches
- Python
- MATLAB

**Object detection-segmentation**

- Triangulation
  - Main objects in 3-D cartesian coordinates

**Vision-based occupant learning and control**

- Latent human variables
  - Comfort
  - Preference
  - Distraction
  - Productivity

**Human environment (thermostatic quality)**

**Overhead stereo-camera**