Poster Abstract: PipeProbe: Mapping Hidden Water Pipelines

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Abstract

We propose PipeProbe, a mobile sensor system for mapping hidden water pipelines inside cement walls or under floor coverings. PipeProbe works by dropping a sensor capsule into the source of the water pipelines. As the PipeProbe capsule traverses the pipelines, it gathers water pressure and accelerometer readings. Given the pressure sensor readings, we can identify the height of PipeProbe. Accelerometer is used to recognize different types of water pipeline shape when PipeProbe travels through. The PipeProbe system is non-intrusive and requires no alteration to the water pipeline infrastructure.

Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous

General Terms

Design, Experimentation, Performance

Keywords

Water Pipe, Pressure Sensor, Accelerometer

1 Introduction

When indoor water pipes are hidden inside cement walls or under floor coverings, diagnosing them without direct inspection becomes difficult. Especially, when the original diagram of the pipeline layout is also missing, searching for the pipeline locations becomes guesswork and often requires brute-force methods such as knocking down cement walls or ripping up floor coverings. This creates an opportunity for the development of a mobile sensing probe, called PipeProbe, which can be dropped into the source of water pipelines. During its traversal of pipelines, the PipeProbe collects the sensor readings necessary for the reconstruction of the 3D spatial layout of the traversed water pipelines. In comparison to the traditional brute-force approach, the PipeProbe system is a non-intrusive method of mapping and locating indoor water pipelines that requires no alteration to the water pipeline infrastructure.

Two recent projects that apply wireless sensor network technologies for monitoring water pipes include the NAWMS project [2] and the PIPENET project [3]. The NAWMS project detects and locates pipe leaks by attaching vibration sensors to the pipe surface. Similarly, the PIPENET project monitors water flow and detects leaks by attaching acoustic and vibration sensors to large bulk-water pipelines and pressure sensors to normal pipelines. In contrast to these projects, the PipeProbe system does not assume that water pipe surfaces are exposed and accessible for sensor module attachment. In the general domain of environmental sensing, both wireless and wired sensor network technologies [1]x have been used extensively, and a wide variety of inexpensive sensor nodes have been created with different sizes, sensor combinations, computational power, battery power, and radios. Our work focuses on a novel mobile sensor system for mapping indoor water pipelines.

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2 The PipeProbe System

We produced a preliminary prototype of our PipeProbe capsule using the Taroko sensor module. Taroko comes with a built-in MSP430 microprocessor, Zigbee radio and 10KB memory. Additionally, a tiny pressure sensor module MS5541C from Intersema and 3-axis accelerometer module ADXL330 from Analog Device have been added to the Taroko module. The whole system components are shown in Figure 1. When submerged in water, the pressure sensor measures water pressure ranging from 0 to 14 bars at a resolution of 1.2 mbar and the accelerometer measures acceleration with a minimum full-scale range of 3g at a resolution of 300 mV/g. The whole package is fit into a rectangle shape and sealed waterproof with glue and acrylic.

Figure 2 shows how the PipeProbe capsule is used for the mapping (i.e., for the reconstruction of the 3D spatial layout) of indoor water pipelines. We assume a common home scenario where a single water input source (e.g., a water tank) is connected to several water output faucets through a network of water pipelines with0020multiple forks. The PipeProbe system works as follows. (1) A PipeProbe capsule is dropped into the water input source. When a water faucet is opened, the force of the resulting water flow pushes the capsule through the different forks and sections of the water pipelines. When the capsule flows out of the open water faucet, one mapping trip is complete. The capsule is then retrieved for reuse in subsequent mapping trips. (2) While the capsule is flowing inside a water pipe, it gathers pressure and accelerometer readings along its path of traversals. These sensor readings can be saved in its flash memory or transmitted to a wireless reader. After the capsule leaves the water faucet, its sensor readings are transferred from its flash memory to a PC for postprocessing. (3) By alternating among different open water faucets and repeatedly re-inserting the PipeProbe capsule into the water input source for multiple mapping trips, the capsule gathers multiple sensor readings spanning the entire pipeline network. All of the sensor readings are aggregated on a PC for post-processing.

3 Preliminary Results

Preliminary data from the pressure and accelerometer sensors are presented below. Table 1 shows various pressure readings and the converted heights of a 30 cm water pipeline filled with water and held vertically. The average error is 4.35%.

Figure 3 shows the patterns from the accelerometer sensor when the PipeProbe is making a right turn on the horizontal plane inside an L-shape water pipe fork. The circulation of water is driven by a water pump at the flow rate of 12 L/min. Around the 5th second, the PipeProbe is making the right turning; thus produced an increased acceleration on the x-axis and decreased acceleration on the y-axis.

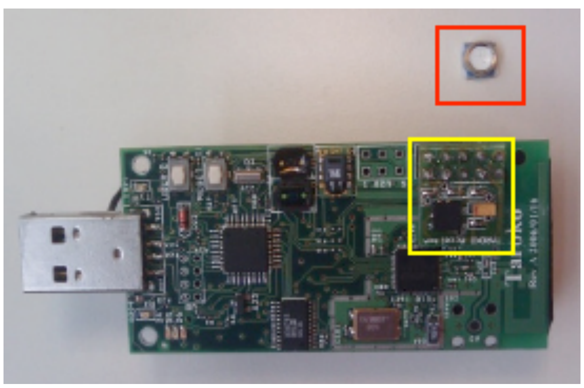

Figure 1. PipeProbe system with accelerometer module and pressure sensor module. The yellow rectangle marks the location of accelerometer module, and the red rectangle marks the pressure sensor module.

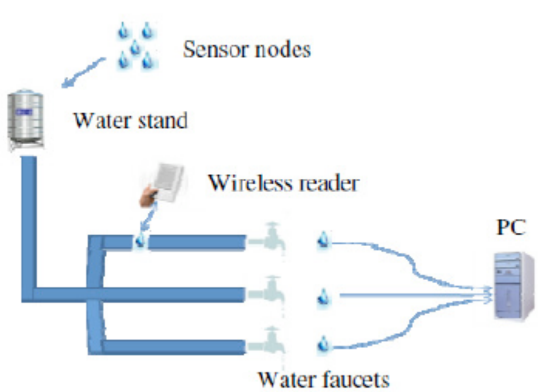

Figure 2. Sensors move through the pipeline.

Table 1. Pressure reading results in centimeter. The average error is 4.35.%

Actual height(cm)	Measured height (cm)	Error rate (%)
5	5.6	12 %
10	10.7	7.1%
15	15.3	2%
20	20.9	4.5%
25	24.95	0.2%
30	30.1	0.3%

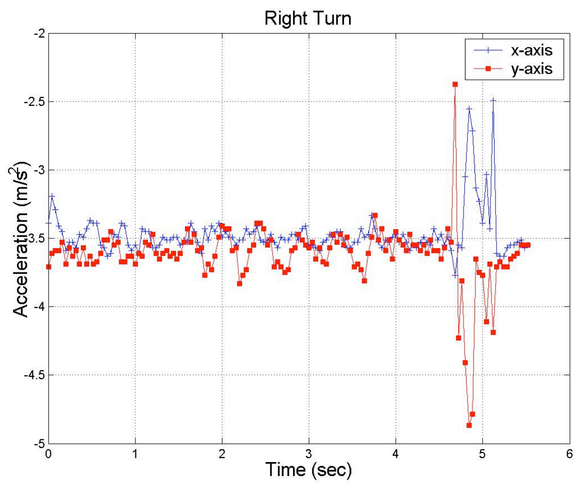

Figure 3. Acceleration data when the PipeProbe is making a right turn in an L-shape pipe fork. The right turn occurs around the 5th second.

4 Future Work

We are currently implementing the PipeProbe system and look forward to evaluating its positioning accuracy.

5 References

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