

Pipeline integrated monitoring system applying unmanned aerial vehicle

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Abstract. The paper presents a complex approach for monitoring linear ground pipes. A generalized structure of an integrated monitoring system for pipeline is elaborated. A mobile system structure, which is an on-board part of an unmanned aerial vehicle, is elaborated as well. An algorithm of system performance including a case-based reasoning method for a stationary system part and application of fuzzy logic mathematics for controlling UAV flight is developed.

1. Introduction

A relevant task nowadays is to elaborate an integrated monitoring system (IMS) for pipeline, which includes external pipe observation and internal observation – identifying multiphase liquid flowing through a pipeline. A structure of a complex system for three-dimensional pipeline monitoring is shown in figure 1.

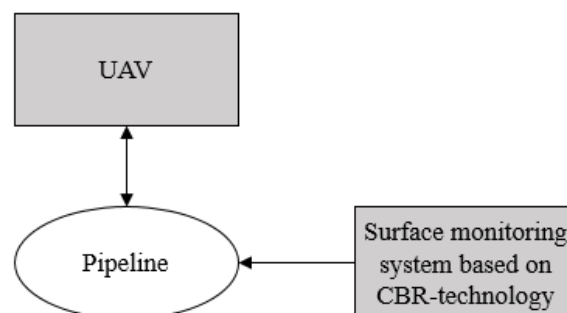


Figure 1. Structure of an IMS for pipeline

Previously developed system with a mechanism of decision-making on multiphase liquid feature [1] serves as a base for internal monitoring. The system includes Case-Based Reasoning (CBR) method [2-8]. Features of a multiphase liquid flowing through a pipeline and liquid flow are determined as a set of S , R and M vectors:

$$C = \langle S, R, M \rangle,$$

where S is a vector in a space of pipeline parameters, R is a meta-description of multiphase flow, M serves as references to the cases from Case Base (CB), associated with current case.

An external monitoring is an essential supplement in solving the issue, and it allows controlling pipeline external surface. It is to be implemented by a mobile system, based on using unmanned aerial vehicles (UAV).

The system is to be highly accurate, highly automated and to perform external object observation for revealing defects (leaks, cracks, buckles and other surface faults), especially in hard-to-reach area.

Performance of a range of automated scanning devices includes a photometric method, which uses so-called Moire effect [9-12]. The effect is obtained by projecting a grid of alternating light and dark fringes over the surface of the studied object. The picture of these fringes lays over another grid, rotated at a set angle. The Moire picture obtained this way provides with an information about object topology, but obtaining and analyzing the picture are labor intensive and does not show enough resulting accuracy.

2. Materials and methods

The present study examines the issue of elaborating the mobile system for determining the configuration and the topology of linear ground pipes applying up-to-date highly accurate contactless methods. The main part of the system is a unit for measuring the distance to the point of observation or measuring linear movements. Data from this converter-scanner allow determining localized defects of a technological object and surface defects as well.

An undertaken analyze of the measuring device (MD) showed that laser and ultrasound MD often serve as range sensors. The devices use triangulation or time-of-flight method. Laser MD are characterized with higher accuracy in comparison with ultrasound ones: laser MD measurement accuracy is 0,1 mm, and maximum distance to the object is hundreds of meters, while the corresponding parameters of ultrasound MD are 1 mm and 20 mm.

A laser scanning is a technology, which provides with constructing a digital three-dimensional model of an object by representing it as a set of points with three-dimensional coordinates. The technology is based on using new devices – laser scanners, which measure coordinates of the points with a high speed of dozens of thousands points per second. A set of points obtained is called a “point cloud” and may thereafter be represented as a three-dimensional model of an object, a two-dimensional drawing, a set of cross-sections, and a surface.

Laser three-dimensional scanning provides with an opportunity to undertake a continual object survey with a high speed and allows one to perform many things within a short period of time with different objects, including:

- buildings and constructions;
- enterprises with complicated structure, for instance, chemical factories, oil and gas processing production etc.;
- motorways, railways and road objects, including bridges, viaducts, surrounding area;
- quarries and places of underground mining;
- places of rugged topography.

Air laser scanning allows recording absolutely all of surface features, obtaining three-dimensional visualization of hard-to-reach objects quickest possible. Scanning technology is connected to installing a laser scanner on a flying vehicle.

3. Results and discussion

The UAV on-board system hardware structure is presented in figure 2.

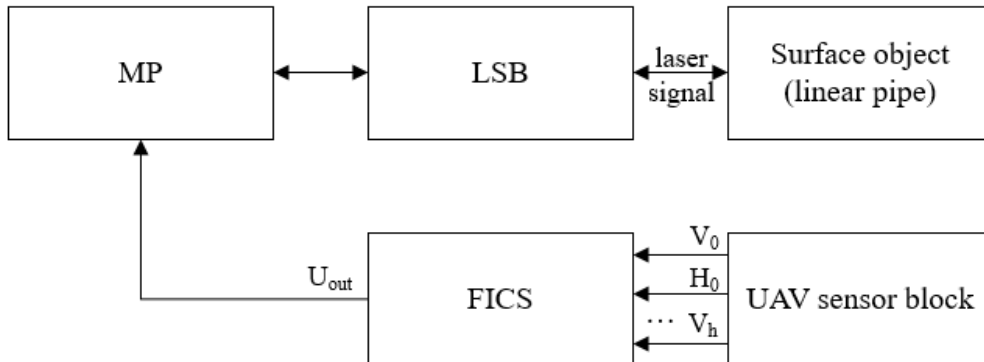


Figure 2. UAV on-board system structure

UAV consists of a microprocessor (MP), a laser scanning block (LSB), a sensor block. Output signals of these UAV elements are input signals of the fuzzy intellectual control system (FICS). A set of these signals may be presented as follows:

$$U_{in} = f(V_0, H_0, Ang_{att}, Ang_{az}, V_h, Z),$$

where V_0 is a reference velocity, H_0 is a reference flight height, Ang_{att} is an attitude angle, Ang_{az} is an azimuth angle, V_h is a rate of flight height change, Z is a set of essential parameters of velocity, height and flight trajectory.

In this case, a set of output signals, which are considered while UAV control, may be presented as follows:

$$U_{out} = f(V, H, W_z, Ang_{az}, Ang_{bank}, Ang_{att}, \lambda, W_x, W_y),$$

where V is a current velocity; H is a flight height, α is an incidence angle; W_z is an angle rate relatively to Z-axis; Ang_{az} is an azimuth angle; Ang_{bank} is a bank angle; Ang_{att} is an attitude angle; λ is a gliding angle; W_x is an angle rate relatively to X-axis; W_y is an angle rate relatively to Y-axis.

The fuzzy UAV regulator structure and a diagram of the fuzzy control system algorithm are known [13, 14]. The regulator consists of velocity, height and direction guidance loops. The FICS fuzzification block performs transforming a complex of input parameters into fuzzy values of linguistic variables. The defuzzification block performs backward transformation from linguistic variables values to certain parameters of velocity, height and direction.

FICS performs the same way when applied with fuzzy logic mathematics for determining the distance to scanning points on the pipeline surface considering destabilizing factors: UAV bank and vibration, object luminance, environment transparency, etc.

The IMS performance algorithm is presented in figure 3. It consists of two procedures: the first is for scanning sensors; the second is for processing data, decision-making and forming control signals. After system run and initialization, the UAV is launched, and repeating scanning of sensors for controlling its flight is undertaken. Scanning sensors of the surface monitoring system and forming corresponding control signals and essential solutions on identifying liquid and flow feature take place as well.

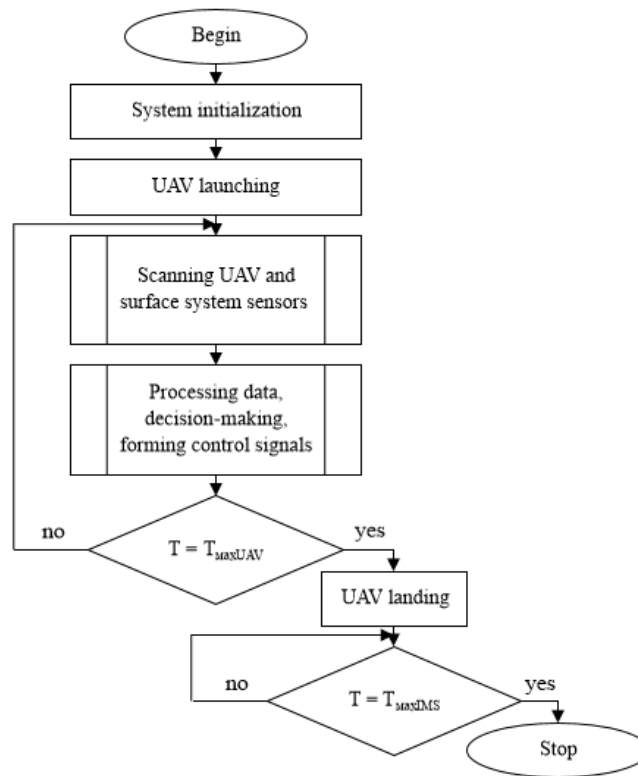


Figure 3. Generalized system performance algorithm

After a set period of UAV flight time (T_{maxUAV}), its landing is implemented. The IMS system performance stops thereafter in case if current time (T) exceeds system operation time T_{maxIMS} .

4. Conclusion

Thus, the approach of constructing the integrated monitoring system for the linear ground pipe is presented. The elaborated system includes a stationary part and a mobile part, based on the UAV on-board system. Identification multiphase liquid parameters apply CBR-technology, and controlling UAV flight applies fuzzy logic mathematics.

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