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Paper:

Information Assistance for Search-and-Rescue by Intelligent Data Carriers and a Data Retrieval Blimp

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We propose a search-and-rescue information assistance system that consists of an intelligent data carrier for rescue (IDC-R) and a data retrieval blimp (DRB). The IDC provides the environment with information storage, sensing, and processing. We incorporated auditory functionality into IDCs and used them to support search-and-rescue. IDC-Rs in buildings repeatedly call to victims and record their answers independently. A DRB flies over a disaster area and communicates with IDC-Rs to activate them and to obtain data. We have implemented actual devices and describe a feasible motion planning algorithm for a DRB.

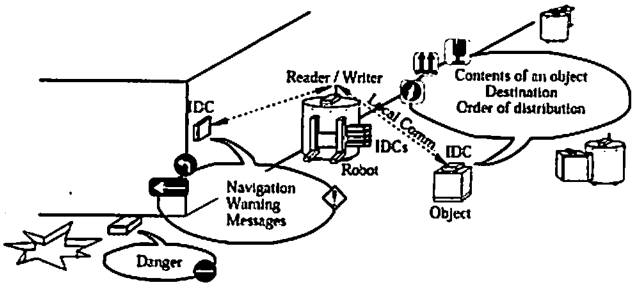


Fig. 1. An overview of "intelligent environment".

Keywords: rescue, information assistance, blimp

1. Introduction

In 1995, the Hanshin-Awaji Earthquake in Kobe killed more than 6,500 people and destroyed 80,000 wooden houses. The contribution of robotics and information technology is expected to mitigate such damage. Researchers are establishing a new research field and solutions of information support in such disasters [1]-[3]. Contests between rescue robots are proposed to encourage interest in rescue robotics research [4]. In earthquakes, an important issue is providing information for action planning in disaster mitigation, search, and rescue. Information may be difficult to transmit, however, due to breakdowns in telecommunication networks. Finding victims is difficult because they are usually widely spread over vast areas and often buried under collapsed housing.

We propose an autonomous, independent, intelligent infrastructure for locating victims. By "intelligent," we mean that it finds and communicates with victims via local communication, which involves an intelligent data carrier (IDC) [5]-[8] that stores and exchanges information with mobile robots (Fig.1).

We propose victim search and rescue using an intelligent data carrier for rescue (IDC-R) and a data retrieval blimp (DRB). The IDC provides the environment with information storage, sensing, and processing. We incorporated auditory functionality into IDC units to search victims. A DRB carries an antenna and its reader/writer (controller). It flies over an area and communicates with IDC-Rs to activate them and obtain data.

In Section 2, we detail the information assistance system configuration. In Section 3, we discuss the IDC-R architecture and operating procedures. In Section 4, we show a DRB and its motion-planning algorithm. Section 5 summarizes the paper.

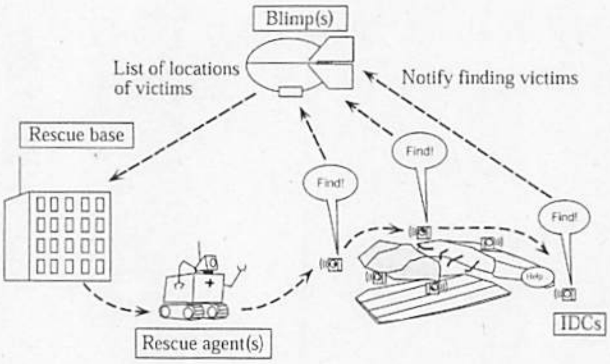


Fig. 2. Overview of information assistance system.

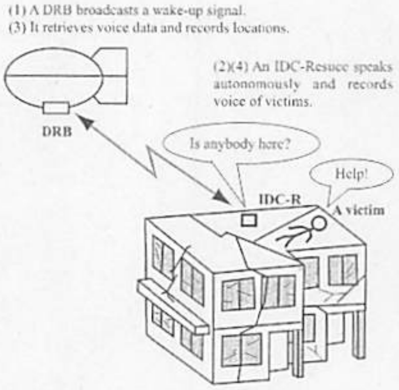


Fig. 3. The procedure of searching victims.

2. System Configuration

On the objective of search and rescue is to locate victims as soon as possible - usually a very difficult task. Rescuers such as rescue personnel and trained dogs sweep an area. This usually involves considerable time and treading.

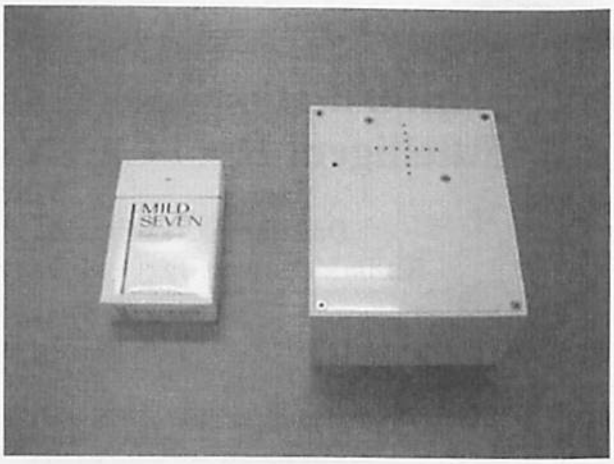
This suggests the usefulness of applying a "distributed" way in searching for victims.

We give "intelligence" to an environment to enable it to help find victims, specify their location, and notify rescuers (**Fig.2**). To do this, we extend local information management using IDCs. Having individual IDCs find victims in a distributed way reduces the load on rescuers.

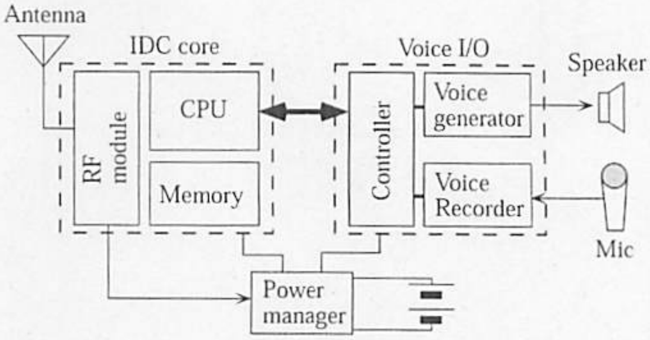
The IDC consists of portable information storage tags (IDCs) and read-write devices carried by robots. A tag has its own CPU, memory, and batteries. We developed IDC-Rs by adding voice I/O and power management to the IDC.

We gather information on victims from distributed IDC-Rs, especially their locations. We use blimps to survey an affected area to send wakeup signals and retrieve data from IDC-Rs, since earthquakes often disrupt roads.

We assume IDCs are already located on ceilings or walls of houses. The next section details the IDC-R system we developed for rescue.



(a) An IDC-R tag.



(b) Block diagram of an IDC-R tag.

Fig. 4. Prototype IDC-R system.

3. Victim Search by an IDC-R

3.1. Search Procedure

To search for victims, we added an auditory function to an IDC. An IDC-R is attached to a wall or a ceiling in advance. If a building or house collapses, it starts calling, "Is anybody there?" and records any victim responses. When we communicate with an IDC-R having voice data, we can determine at least that a victim is within a few meters of the IDC-R.

Victims are searched for as follows (**Fig.3**):

1. A DRB flying over an area broadcasts a wake-up signal to IDC-Rs buried with victims. Once an IDC-R receives this signal, it starts its main CPU and voice I/O.
2. An IDC-R repeats messages to victims and records their voices at intervals.
3. A DRB flying over an area broadcasts a signal to IDC-Rs asking whether they have recorded any voices. An IDC-R having voice records sends location data and voice records to the DRB.

Table 1. Specifications of IDC-R.

CPU	16bit
Memory	1kbit (for location data) 128Kbyte (for voice recording)
Battery	Four NiMH batteries (1600mAH)
Size [mm]	118 × 95 × 61
Weight [g]	650
Frequency	125 [kHz]
Modulation	FSK, PSK

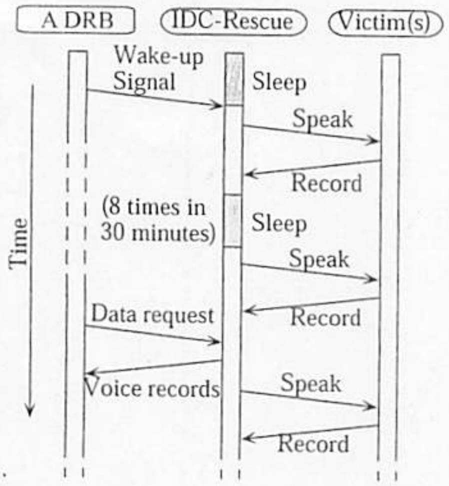


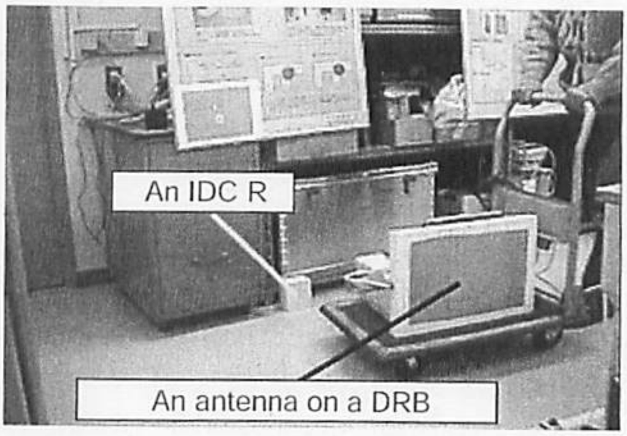
Fig. 5. Communication procedure of IDC-R system.

4. After sending voice records, an IDC-R clears memory and starts calling and recording voices again.
5. The DRB returns to the rescue base and downloads voice records and location data from IDC-Rs. Rescue teams then search for victims based on this data.

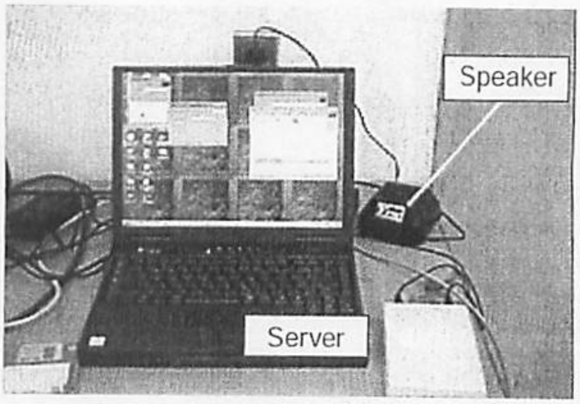
3.2. Implementation of IDC-R

Figure 4(a) shows an IDC-R tag, block diagram of which is shown in **Fig.4(b)**. Specifications of the IDC-R are given in **Table 1.** The IDC-R consists of a core chip, a voice management module, and a power manager. The core chip works without batteries because its RF module generates enough electric power to drive its 12-bit CPU and 1K bit memory. The voice management module has a 16-bit CPU, a voice generator, a speaker, a voice recorder, and a microphone. The module records 4s × 8 times voices in 128K-byte memory.

Figure 5 shows IDCR communication. First, the core chip is activated by a DRB. It then activates the power manager and voice management module. The voice management module speaks a short message such as "Can you hear me?" and it records sound for 4 seconds to receive answers from victims. The power manager repeatedly activates and stops the voice management module 8 times in 30 minutes.



(a) A DRB obtains voice records from an IDC-R.



(b) We can analyse voice data at a rescue base.

Fig. 6. Experiment to search victims.

Table 2. Specifications of a DBR.

Length	6.5 [m]
Width	3.0 [m]
Volume	30.6 [m^3]
Payload	8.0 [kg]
Max. speed	1.5 [m/s]
CPU	Intel DX4-66Mhz

After 8 recordings, the IDC-R remains idle until a DRB contacts it again. When it communicates with the DRB again, it transfers recorded data to the DRB via the RF module. After that, it initializes itself and starts again. Notice that an IDC-R transfers its records anytime it communicates with a DRB even if the voice recorder's memory is not full. A DRB gathers voice records and brings them to a rescue base to provide further information on victims.

3.3. Verification by Experiment

We conducted an experiment using the IDC-R. We wake up an IDC-R from an antenna on a cart (a DRB) (**Fig.6**). Communication distance is about 1.5m. The IDC-R records voice data and sends it to the cart autono-

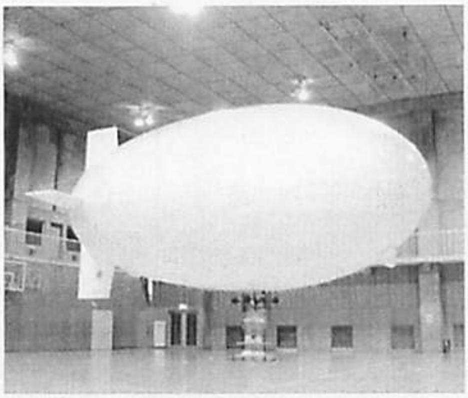


Fig. 7. A data retrieval blimp (DRB).

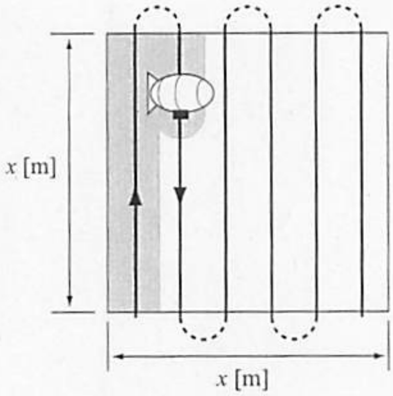


Fig. 8. A direction-parallel path.

mously. The cart transfers voice records to a rescue server (**Fig.6(b)**), on which is heard the IDC-R voice and ID. In the experiment, we confirmed functions of the IDC-R and obtained voice records.

4. Motion Planning of DRB

4.1. Specifications

In this section, we give an algorithm for path and velocity planning of a DRB, which activates IDC-Rs and retrieves data from them. We developed the DRB in **Fig.7**. DRB specifications are given in **Table 2**. It has six fans -- four for propelling and two for stabilizing; an antenna for the IDC-R, and a controller on its gondola.

For a feasible path and optimal flight velocity of a DRB, which must sweep all required areas using its IDC-R antenna, we apply a "direction-parallel" path (**Fig.8**). We then design an appropriate DRB flight velocity.

A blimp can stay in the air a long time because it requires little energy. Disturbance by winds, however, make in necessary to take positioning errors into account. In our blimp model (**Fig.9** and **Table 3**), e_v indicates maximum positioning error along a desired path and e_w positioning error crossing a desired path. Radius r denotes the communication range of an IDC-R. Because a blimp takes τ seconds to establish a communication link with an IDC-R, it communicate with IDC-Rs only in the hatched regions of the figure. Width $s(v)$, a function of velocity v, of the hatched region is valid for sweeping an area. The faster a DRB flies, the smaller $s(v)$ becomes, and it must traverse an area many times.

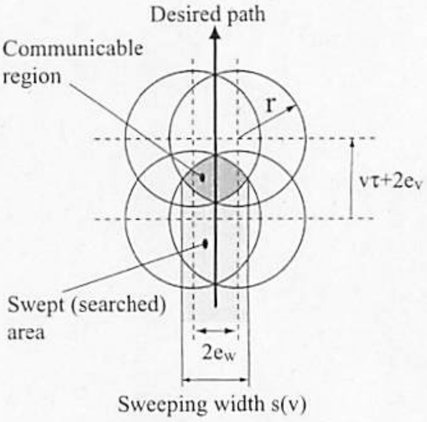


Fig. 9. Parameters of a flying DRB.

Table 3. Parameters for planning of a DRB.

v[m/s]	Velocity of a blimp (to be designed)
$x \times x$ [m^2]	Size of a suffered area
r [m]	Radius of a communication area of IDC-R
τ [s]	Required time to establish a communication link with an IDC-R
η[s]	Required time that a blimp turns 180 [degree]
e_v[m]	maximum position error of going-direction axis
e_w[m]	maximum position error of radial axis of e_v

4.2. Optimal Flight Velocity

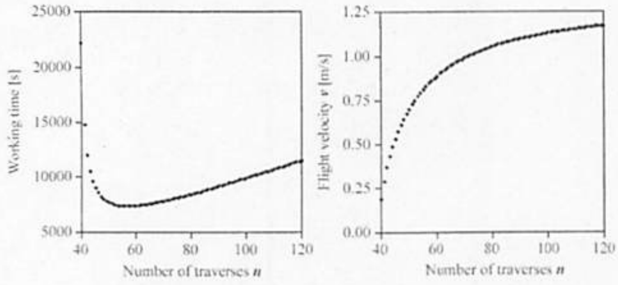
Sweep width $s(v)$ is calculated by (1). Flight velocity v must not exceed constant v_{sup} because $s(v)$ must be positive.

$$s(v) = 2\left(\sqrt{r^2 - \left(\frac{v\tau + 2e_v}{2}\right)^2} - e_w\right) \quad \cdots\cdots (1)$$

$$v < v_{sup} = \frac{2}{\tau}\left(\sqrt{r^2 - e_w^2} - e_v\right) \quad \cdots\cdots\cdots\cdots (2)$$

A blimp must traverse an area n times, derived by (3), where $[a]$ indicates the maximum integer not exceeding $a \in \mathbf{R}$.

$$n = \left[\frac{x}{s(v)}\right] + 1 \quad \cdots\cdots\cdots\cdots\cdots\cdots (3)$$



(a) Working time (b) Flight velocity

Fig. 10. Designing flying velocity.

Table 4. Parameters for the example.

x	100 [m]	η	10 [s]
r	1.5 [m]	e_v	0.2 [m]
τ	2 [s]	e_w	0.2[m]

In general cases, we formulate working time $t(v)$, a function of v, as in (4). Both $v \rightarrow 0$ and $v \rightarrow v_{sup}$ make $t(v) \rightarrow \infty$.

$$t(v) = \frac{x}{v}\left(\left[\frac{x}{s(v)}\right] + 1\right) + \eta\left[\frac{x}{s(v)}\right] \quad \cdots\cdots\cdots\cdots \quad (4)$$

In the optimal case, $\frac{x}{s(v)}$ becomes equal to number of traverses n. In other words, working time t becomes sequence t_n as in (5).

$$t_n = \frac{\tau x}{\sqrt{4r^2 - (\frac{x}{n} + 2e_w)^2} - 2e_v} n + \eta(n-1) \quad . \; . \; . \quad (5)$$

By searching n_{opt} that gives minimum t_n, we determine optimal flight velocity v_{opt} by (6).

$$v_{opt} = \frac{1}{\tau}\sqrt{4r^2 - (\frac{x}{n_{opt}} + 2e_w)^2} - 2e_v \quad \cdots\cdots\cdots \quad (6)$$

We find that t_n has a single minimum value in the above equations, so we apply an appropriate search algorithm to find optimal n for calculating v_{opt}.

4.3. Numerical Example

We apply the motion-planning algorithm to our DRB. Parameters for planning are shown in **Table 4**. **Fig.10(a)** shows the relationship between number of traverses n and working time t_n, and **(b)** shows velocity at n. These results show the optimal flight velocity $v = 0.84$[m/s].

5. Conclusion

We have proposed victim search and rescue and developed an intelligent data carrier for rescue (DC-R) and a data retrieval blimp (DRAB). In searches, we incorporated auditory functionality into IDC units for use in rescue support. We detailed the IDC-R architecture and demonstrated its feasibility. We also showed a DRB and its motion planning. With the proposed method, we determine an appropriate flight velocity for retrieving data on victims from distributed IDC-Rs.

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