Improving the performance of a position localization system based on infrared pattern recognition.

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Abstract.
In this paper, an improvement regarding the speed of a recently developed system that uses infrared (IR) sensors in order to estimate the position of a moving vehicle is presented. This system, that is made up of IR sensors, a microcomputer controller and assisting hardware and software components is proven very effective in locating the position of a moving target on a grid plane. A high frequency signal carrier is used in order to speed up the system performance. Results are presented were the error in the calculation was minimised using proper correction techniques. The presented system can be used in a number of automation, robotics, virtual reality and ubiquitous applications.

Keywords: Infrared sensors, system design, position recognition and localization, indoor navigation system, pattern recognition, noise, error reduction, signal carrier.

1 Introduction.

Several approaches have already been proposed in order to locate the position of a moving target in an indoor area, which is a significant issue for applications in Robotics, Automation and Ubiquitous/Pervasive Computing [1-3]. Passive infrared sensors are often used for the indoor navigation of moving vehicles like robots in order to avoid obstacles or detect the presence of intruders in the region they are responsible for. Infrared sensors detect obstacles in short distances, while ultrasonic waves are used for the navigation in longer distances from walls and obstacles.

In a recently published work of ours [4-6], we presented a new method, based on a system that uses IR sensors and makes use of the statistical processing of digital infrared patterns. This method has the advantage of low cost due to the use of commercial infrared LEDs and sensors. The coordinate estimation time depends on the desired position location accuracy and could be derived in less than 1 sec in the lab.

In this paper, after a short review of the above work, the design and implementation of a high frequency signal carrier which speeds up the performance of the system is presented. The full details of the whole system are further explained and analyzed in the provided relevant literature [4-6].

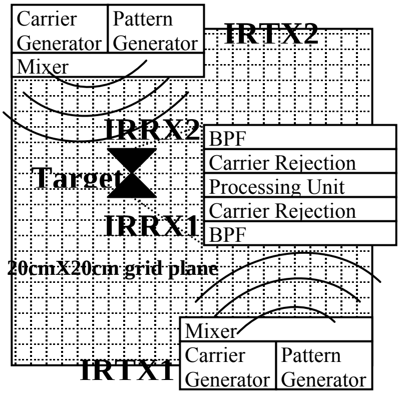

Figure 1. The system.

2 System components and architecture.

Figure 1 depicts the sensors system architecture and the relative hardware components. The basic unit is the infrared pattern transmitter (IRTX). A control unit generates the digital pattern signal. This signal is mixed with the carrier and the amplified output drives the infrared emitting diode. The carrier can be generated either by the control unit or by an external square wave generator. The power dissipation and the beam angle of the emitting diode is a significant issue since it is desirable to cover a wide enough area. In order to achieve this goal, more than one diodes can be connected in parallel, positioned in a circular arrangement. If more than one IRTX devices are used they may share the same control unit if wiring is not an issue. The principle of the system is simple and it is the following: The statistical processing of digital infrared patterns that are received by the target has recently proven to be an efficient solution in the indoor localization problem [4-6]. These patterns are sent by at least two transmitting devices placed in a proper topology around the covered area. The number of infrared patterns of a specific type that were received by the pair of infrared sensors placed at the receiver at opposite directions, is compared to the number of the expected ones (success rate). This comparison can provide an indication of the position of the target. The cost of such a localization system is very low since no accurate measurements are required. Several types of patterns are defined and they are recognized with scalar difficulty at the target.

The interference of other infrared sources like sunlight is suppressed by transmitting the patterns over a carrier. The frequency of the carrier drastically affects the speed of the position estimation. In the following paragraphs, we provide a speeding up procedure based on the carrier signal frequency properties [5,6].

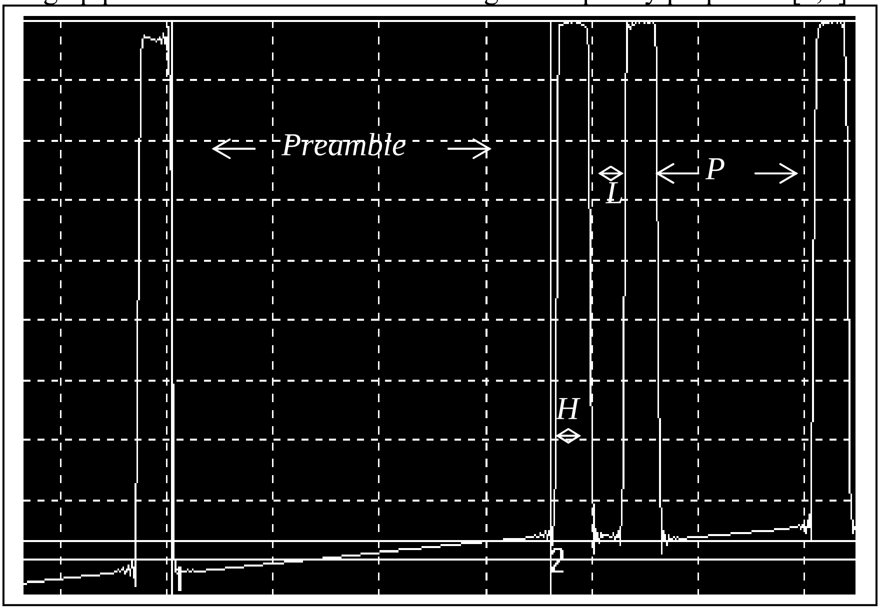

Figure 2. The structure of an infrared pattern

3 System improvement and results

The operation of the system can be described as follows: A preamble is transmitted first by an IRTX device consisting of a single pulse and a relatively long low interval (Fig. 2). As a next step, *M* identical codes are transmitted, each one consisting of *i* long pulses. The type of each one of these codes will be denoted as MOD*i*. Pause intervals of a specific duration *P* separate the successive codes. Another set of *M* identical codes is then transmitted. This second group of codes consist of *j* pulses shorter than the ones of the MOD*i*. When all the supported MOD*i* pattern groups are sent, the procedure is repeated by transmitting a new preamble. The patterns MOD3, MOD4, MOD7 and MOD8 are transmitted by IRTX1 and MOD2, MOD5, MOD6 and MOD9 are transmitted by IRTX2. The MOD*i* patterns are generally recognized easier and cover longer distances than MOD*j* if *i*<*j*. Nevertheless, they are received with no error if the target is close enough to the IRTX device. On the other hand, MOD*j* patterns fade closer to the transmitter and can be used to estimate shorter distances. The aforementioned hypothesis is valid if the scrambling caused by the reflections and the transmitting device interference is not important. Using the parameters shown in Fig. 2 the pulse period (*H*+*L*) should be a multiple of the carrier frequency period (k/F_c). Different *k* values for different MOD*i* patterns should be used in order to achieve different success rate dimensions for each MOD*i* type. Thus, the time needed to read a single MOD*i* pattern is

$$T_i = i\frac{k_i}{F_c} \qquad .1$$

The total time T_s needed between the transmission of two successive preambles is

$$T_s = M\sum_{MOD_i \in S}\left(i\frac{k_i}{F_c} + P\right) + T_{pre} \qquad .□$$

where *M* is the number of successive identical patterns separated by low intervals (*P*), T_{pre} is the preamble duration and *S* is the set of the supported by a single IRTX device, MOD*i* patterns.

In order to make it feasible for the receiver to distinguish between the beginning and the end of a pattern from a preamble, the value of T_{pre} is longer than that of *P* and the value of *P* is longer than the *H* and *L* values. A safe margin is achieved by choosing $P=2 \cdot H$ and $T_{pream}=2 \cdot P$. If a non-standard carrier frequency is used in order to increase the position estimation speed a custom bandpass filter and a carrier rejection circuit has to be implemented. A low cost IRRX receiver consisting of the infrared sensor diode and a Multiple Feed Back Filter (MFBF) at 1MHz followed by a carrier demodulator is demonstrated in Fig. 3.

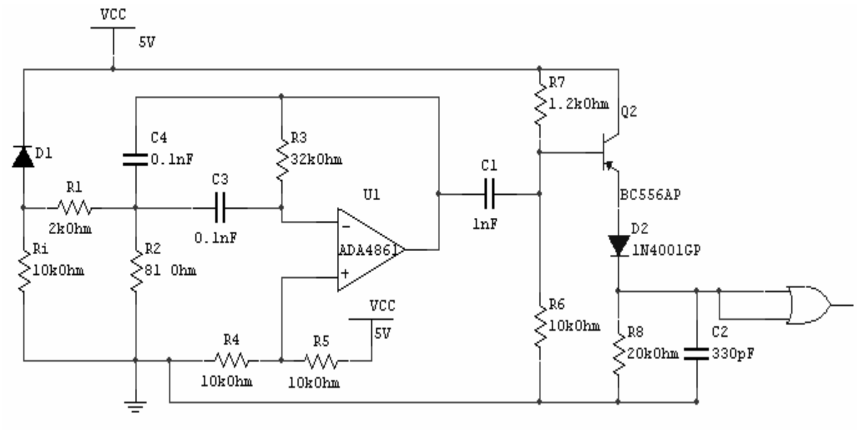

Figure 3. The 1MHz Infrared Carrier Receiver

The infrared diode D1 (SFH203) is inversely biased allowing a current of less than 50uA in the dark and more than 80uA when infrared light is present. The resistor *Ri* adapts the voltage at the input of *R1* to the desired filter sensitivity. Resistors *R1, R2,* and *R3* in combination with C3, C4 determine the center frequency (F_c), the quality factor (Q) and the gain (G) of the MFBF filter. The Q factor is defined as follows:

$$Q = \frac{F_c}{B} \quad .$$

where B is the desired bandwidth of the filter limited by the points where the signal is attenuated by –3dB compared to the central frequency. It is well known [9] that for higher central frequency filters the factor Q should be kept as small as possible and the operational amplifier should preferably be working at unity gain (G=1). Slightly higher values ($Q=10$ and $G=8$) have been chosen though, in order to reduce the cost by avoiding higher order filtering and amplification. The *R1,R2, R3, C3* and *C4* values are estimated as a function of the parameter Q [9].

Implication of all of the above into the initial system and successful test runs resulted in the following: Using a 38KHz carrier, the time needed for the estimation of a position by the target is 1.263sec if equation (3) is used. If a carrier of 1MHz instead of 38KHz is used and the relations between H, L, P, T_{pream} remain the same then the estimation time is reduced to 48ms.

5 Conclusions

The effect of the carrier frequency to the speed of an indoor localization system that is based on the quality of infrared pattern reception was studied in this paper. The infrared patterns are transmitted over a carrier in order to minimize the interference of other infrared sources. An active filter and a carrier rejection circuit was presented for the case of a 1MHz carrier. The localization speed is more than 25 times higher if a 1MHz carrier is used instead of a standard 38KHz frequency.

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