Article summary

Paper title:

“Applying Compute-Proximal Energy Harvesting to Develop Self-Sustained Systems for Automobiles”

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Introduction

In this article, the authors propose a compute-proximal energy harvesting approach for automotive environments. The main goal is to explore self-sustained systems that harvest power locally, eliminating the need for wiring them into the car’s power supply.
The method involves collecting energy from various sources such as wind, light, vibration, and heat. Then they apply the theoretical knowledge to two prototypes that demonstrate this approach: a thermoelectric energy-based parking assistant attached to the exhaust pipe and a wind-powered external pedestrian display anchored to the front bumper of a car.

The research was conducted using an instrumented sport utility vehicle that was driven repeatedly along a specific route, and various modes of energy harvesting, such as wind and temperature, were measured using commodity sensors and mode-specific harvesters. The evaluation provides both a potential estimate of harvested power by each source and a comparison of what can currently be achieved.

Methodology

The study performs some analytical estimates by placing sensors around the car to measure the potential harvesting power of each source. Therefore they present the Theoretical Model and Limits of Harvesting in comparison with the Practical Harvesting Results.

Wind:

The power available for harvesting is determined by various factors such as air density, the size of the blades in a propeller, the speed of the wind, and the efficiency factor of the wind turbine. A theoretical model is used to estimate the power that can be generated from wind energy, and practical results are obtained through the use of a small wind energy generator. The practical results enumerated in Table 1, show that the roof and side doors of a vehicle are the best locations for wind energy harvesting, with yields of 732 μW and 461 μW at an average driving speed of 13 mph, respectively. The wind turbine used in the study only worked at wind speeds higher than 11 mph and did not generate any harvested energy at the rear bumper of the vehicle.

Heat:

The power that can be generated is determined by the temperature difference between a target area (such as an engine block, front grill, or exhaust pipe) and its surroundings (such as the air around the car). The Seebeck effect, which is a key part of thermoelectric generators, is used to estimate the power that can be generated from heat energy. Practical results are obtained by deploying a thermoelectric generator module to different heat sources on the vehicle. The results show that the exhaust muffler pipe is a highly feasible location for heat energy harvesting, with a yield of 240 μW.

Light:

Light energy harvesting is determined by the amount of light reaching a surface and the efficiency of the solar cell being used. The theoretical model measures the luminous intensity and estimates the performance of light energy harvesting by a simulator. Practical results are obtained through the use of a mono-crystalline solar cell. The results show that light energy is feasible for harvesting power in some contexts, but not in others. The power harvested from all the locations examined in the study ranges from 2.4 to 14.6 mW. The difference between the theoretical estimates and practical results may be due to factors such as temperature, load impedance, wavelength, time of day, or climate.

Vibration:

Energy harvesting from vibration sources is determined by the characteristics of the vibration energy, which can be influenced by factors such as the driver's acceleration and braking style, the curvature of the driving route, and the bumpiness and degree of inclination of the road. The power is converted to electricity through the use of an electromagnetic system, and a compact, coaxial circular coil vibrator is designed and manufactured for this purpose. The results show that the vibrator can generate an average of 11.9 μW. The study found it challenging to measure the theoretical power and therefore only the vibration and the resonant frequency were extracted.

TABLE 1. Summary of theoretical and practical measurements of energy harvesting by mode and location.

Mode	Location					
Wind	Location		W1 (Front Bumper)	W2 (Roof)	W3 (Side Door)	W4 (Rear Bumper)
Wind	Wind (mph) [Avg/Max]		6.2/18.8	15.5/43.6	10.5/36.7	2.6/10.7
Wind	Driving (mph) [Avg/Max]		14/42	13/35	13/41	14/47
Wind	Power (μW)	TE	840	13100	4100	62
Wind	Power (μW)	PM	311	732	461	0
Heat[1]	Location		H1 (Front Grill)	H2 (Engine Cover)	H3 (Exhaust Pipe)	
Heat[1]	Temperature (°C)		43.5	51.7	55.4	
Heat[1]	Power (μW)	TE	8767	13584	16101	
Heat[1]	Power (μW)	PM	19	59	240	
Light	Location		S1 (Front Bumper)	S2 (Side Door)	S3 (Rear Bumper)	S4 (Windshield)
Light	Daytime[2] (lux)		24209	37920	24529	62223
Light	Nighttime[3] (lux)		18.4	18.2	24.4	16.5
Light	Power[4] (μW)	TE	34801	54407	35259	89158
Light	Power[4] (μW)	PM	2390	5173	2541	14603
Vibration	Location		V1 (Arm Rest)			
Vibration	Axis		x	y	z	
Vibration	RMS[5] (g)		0.077	0.072	0.066	
Vibration	Resonance Frequency (Hz)		0.5	23	13	
Vibration	Power (μW)	PM	11.9			

Design guidelines for implementation

A four-step process for designing and evaluating self-sustaining computational systems for retrofitting onto automobiles is described. The steps involve uncovering design opportunities, designing the target system in a power-efficient manner, designing and optimizing the energy harvester, and evaluating the self-sustainability of the system under realistic conditions. The process includes considerations such as the energy demand of the system, energy conversion techniques, and the feasibility of the system in a typical driving scenario. The goal is to design systems that can operate without the need for wiring into the car's power supply, using locally harvested energy instead.

The authors identified several locations around a car where energy could be harvested, including the exhaust pipe, wind around the front bumper, and sunlight on the roof. They also developed two prototypes that demonstrated the feasibility of this approach: a device called RearSense, which was attached to the exhaust pipe and used heat energy harvesting, and a wind-powered device called PedDisplay, which was anchored to the front bumper. Both prototypes used a common core platform with shared functions, including a dc-dc boost charger, a rechargeable energy storage device, a battery gauge, a processor, and a communication module. They found that the energy harvesters they developed had a longer lifespan than a comparable battery, and they suggest that this approach could be used to simplify the installation process for devices on vehicles.

Discussion, limitations, and future work

The authors discuss the use of alternative power sources for automotive computing devices through the process of energy harvesting, rather than relying on the car's main battery. They provide a framework for understanding the potential of energy harvesting in the automotive domain and discuss the gap between what is theoretically possible and what is currently practically achievable. They also demonstrate two prototypes, RearSense and PedDisplay, which utilize energy harvesting in order to function. The authors suggest that the computer-proximal energy harvesting approach can be applied to other domains and that as the field matures, more ready-made solutions may emerge.

The current energy harvesting techniques result in relatively low power budgets, limiting the sophistication of the computational solutions that can be supported. They suggest that further research on materials and optimization is needed to improve energy harvesting efficiency and that more plug-and-play components and how-to guides are needed to support creative exploration and design in this field.

Conclusion

This research explores the use of energy harvesting methods to retrofit automobiles with intelligent devices, rather than solely focusing on recharging the main battery pack. By examining possible energy sources in and around a vehicle, and presenting examples of prototype systems, the authors hope to inspire further exploration and expansion of the use of harvested energy in different locations. The goal is to introduce computation in various environments with reduced constraints on installation and maintenance costs.

References

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