ENERGY MANAGEMENT FOR THE TELEPRESENCE SYSTEM TSR

R. Brockers, M. Botte, B. Mertsching
{brockers, botte, mertsching}@upb.de
GET Lab, Faculty EIM, University of Paderborn, Germany

Abstract: Mobile robot action planning in telepresence applications is strongly limited by the availability of high-performance power resources. While by definition no manual maintenance to replace discharged accumulators can be provided, adequate energy management becomes highly important for using all present resources with highest efficiency. In this paper we introduce an energy management system, following the Smart-Battery-System¹ standard to implement a multi-accumulator power supply for the telesensory robot TSR. The system provides global composite resource information giving a base for robot action planning under different configurations.

Keywords: Mobile Robot, Energy Management, Smart Battery System, Telepresence, Robotics

1. INTRODUCTION

The operating range of a mobile system is highly influenced by the availability of the internal power supply. Power consumption, together with available power resources like accumulator batteries, limits the operating time in which a system can interact with its environment. This is a crucial point that becomes even more serious when dealing with operator controlled manipulation robots utilized in hazardous areas like in space or in contaminated surroundings where no manual recharging or refreshing of the power supply is possible. Designing electrical power supplies for a mobile robot system has to cope with this problem. The supply has to provide the

system with all present power resources while discharging accumulators at the optimal operating state to raise efficiency.

In this paper we introduce a power supply design for a mobile robot for telepresence applications. The special topic of a telepresence system focuses on the explained situation because the robot generally acts as a manipulator in a far-off surrounding, radio controlled via an operator with the help of an adapted human machine interface. Especially, far-off in this formulation does not only mean distant places. A telepresence system is by definition designed to overcome a physical barrier which, generally, cannot be passed by the human operator. This can be the distance, but also scaling, dangerous surroundings or a different medium. In these applications a manual surveillance of the power supply like changing the accumulators or connecting to a power charging station is mostly impossible, which raises the importance of an optimal power management solution.

The presented power supply follows the Smart Battery Standard¹ that was introduced in 1998 by the Smart Battery System Implementers Forum (SBS-IF), a consortium of different companies working in the field of mobile energy supply components. In contrast to standard solutions our design focuses on the telepresence application implementing an on-board energy planning instance to estimate global power resources depending on different activation levels of the mobile system. This gives the possibility of energy dependant action planning with different robot configurations that can be switched by the human operator or, in a later stage, by the semi-autonomous mobile system to maximize operating time.

In this contribution we concentrate on the description of the TSR hardware part of the implemented power manager forming the basic data source and the primary instance for battery surveillance.

In the following we give a short overview of the used telesensory robot for which the energy management system was designed. In the third section we explain the realized Smart Battery System providing some tested results in section four. A short preview of future work completes the paper.

2. TSR – A MOBILE ROBOT FOR TELEPRESENCE APPLICATIONS

Telepresence together with the associated topics Telesensorics and Teleactorics are recently investigated topics in today's robotics research. In a telepresence system, a manipulator like a mobile robot is controlled by a human operator with the help of an adapted human-machine-interface providing him with as much sensorial information as possible to facilitate a realistic interacting with a remote environment. In the optimal case the

operator himself feels totally immersed into the far-off environment and interacts as located on-site.

At GET Lab, a new robot system called TSR was developed for telesensory application to explore telepresence topics².

Figure 1. The telesensory robot TSR developed at the GET Lab

The system consists of a 4WD mobile robot that is radio controlled by a human operator via an operator PC, realizing the human-machine interface (figure 1). To achieve an immersion as deep as possible the data acquisition on the robot is adapted to the human perception together with a suitable presentation of the information: For example the most important human sense, visual perception, is realized by a 2 DOF stereo camera head, which is controlled by the head movements of the operator recorded with a head tracker on top of a head mounted display that visualizes the acquired stereo images.

Figure 2. Main components of TSR mobile platform

Other feedback loops take advantage of several sensor information as e.g. vibration, distance to obstacles or pan-and-tilt angles of the robot to implement a haptic interface with the help of force feedback input devices.

The main components of the robot are shown in figure 2. There are four main categories integrated on the mobile platform: the sensors for information acquisition, actuators for robot control, a communication module and an embedded PC board for the execution of semi-autonomous tasks, e.g. realizing a homing process.

All sensory information except the visual and audio information are digitalized by micro controllers and passed via I²C interface to a Master Controller unit that collects available data and provides it to the operator PC and the internal embedded PC via RS232 links.

The Master Controller is the center of communication. It controls all sensor configurations and the information flow between operator and robot. To provide power supply information to the whole system, the later described power management system has to connect to the Master Controllers I²C interface, making it possible to easily integrate the new component into the communication system.

3. ENERGY MANAGEMENT SYSTEM

The mobile platform power supply is divided into a motor supply path, providing energy for the driving engine with its power, and a second power path to supply all other TSR components like the embedded PC, the servo actuators or the sensor and communication components (see fig. 3).

Figure 3. TSR power supplies (schematic): a) system supply, b) drive supply

In this paper the realization of a Smart Battery System for the system supply is described, which is the critical instance limiting the functionality of the mobile platform due to the high energy demand of the controlling hardware.

An energy management has to deal with the following objectives:

- extending accumulator discharge time by implementing simultaneously discharging which reduces power loss
- electronically switching battery packs to guarantee system stability during accumulator change
- charging battery packs with hot plugged AC-adaptor automatically
- providing global run-time-to-empty and remaining-capacity data

To implement the desired functionality a complete Smart Battery System has to be installed.

3.1 Smart Battery System (SBS)

A Smart Battery System (fig. 4) consists of one or more Smart Batteries connected to a Smart Battery Selector and a Smart Battery Charger. The selector chooses the system power supply which can be a connected accumulator or a AC-DC-power adapter plugged to the electricity network. The Smart Battery Charger controls the charging of the Smart Batteries when the power adaptor has been detected.

Figure 4. Smart Battery System. Overview ⁴

Finally a system host supervises the whole system. It can request the battery data or status via SMBus and reacts to reported critical events.

3.2 Implementation on TSR

The primary objective of the TSR battery management system is to get access to specific battery data for run-time planning and robot configuration. To provide this information system-wide, we have to set up an energy manager following the full SBS standard. First the battery packs have to be extended by supervising ICs that monitor the implicit battery parameters like voltage, current and remaining capacity, turning them into Smart Batteries.

The selector/charger combination is realized with a SBS-Manager connected to two Smart Battery Packs and an additional microcontroller representing the system host.

3.2.1 Smart Battery

According to the Smart Battery System specification every accumulator pack is equipped with a BQ2060A gas gauge IC (Texas Instruments) to measure all accumulator specific data. The IC supports SBS Smart Battery Data Specification v1.1⁵. It monitors and provides all required battery parameters and maintains an accurate record of the available charge. All data, including the battery's remaining capacity, temperature, voltage, current, and remaining run-time predictions, can be addressed via 2-wire SMBus interface. The BQ2060A works with an external EEPROM, which stores all configuration information such as the battery's chemistry, number of cells, self-discharge rate or design voltage and capacity. As an additional feature a 4- or 5-segment LED display can be connected to the BQ2060A for remaining capacity indication. Connected permanently to the battery pack we achieve a Smart Battery, which can be directly connected to any SBS-Manager within a Smart Battery System.

3.2.2 Smart Battery Manager

The SBS is managed by a LTC 1760 Dual Smart Battery System Manager (Linear Technology) which implements a SBS charger/selector for two Smart Batteries. The IC controls both selecting the system power source by a proprietary power path architecture and automatic charging of battery packs when a power adaptor is present. Fast autonomous power source selection ($<10\mu\text{s}$) guarantees a stable system power supply even during hot plug events like connecting or disconnecting of batteries or a wall adaptor during operation.

A main advantage of the LTC1760 is the support of simultaneous charging and discharging of both batteries which extends the typical battery run-time up to 10% while charging times are reduced by up to 50%⁶.

Figure 5. TSR energy management system for the system supply (overview)

The chip implements all elements of a Smart Battery System Manager version 1.1¹ except for the generation of composite battery information. It communicates with the attached Smart Batteries and a connected SBS host via SMBus and manages proper operation with only a few additional components. The power switches are implemented with external FETs while the battery charger is realized with a synchronous buck charger, both directly driven by the chip⁶.

3.3 System Host

The SBS-system is controlled and monitored by a PIC16F877 microcontroller (Microchip) to provide battery information to the TSR system and compute composite battery information like global power prognoses. The controller communicates with the SBS-system via SMBus interface and is connected to the TSR system via I²C following the standard sensor protocol on TSR. Doing so, the whole energy management unit appears as a configurable sensor unit, whose information is propagated system-wide on the internal sensor bus making it accessible to a controlling instance on TSR and, via radio link, to the human operator.

Beside monitored single battery information like available charge, current, voltage or error, global power prognoses are reported to the TSR system. Due to the computational limits of the used microcontroller it was focused on approximate values to estimate global power reserves. The following global values are calculated by the SBS-host:

Global-Remaining-Capacity [Wh]

The global remaining capacity appears as the sum of the particular capacities.

$$GRC = C_{rem,BAT1} + C_{rem,BAT2}$$

Global-Relative-State-Of-Charge [%]

The relative value is related to the particular full charge capacity.

$$GRSOC = 100 \cdot GRC / (C_{full, BAT1} + C_{full, BAT2})$$

Global-Measurement-Error [%]

Each Smart battery provides an error measurement to assess its estimation quality that depends on the number of calibration cycles in which the gas gauge IC learns the capacity of the connected accumulator. To simplify error propagation, we take the maximum error of the connected batteries as the global estimation error:

$$GError = \max\{err_{max, BAT1}, err_{max, BAT2}\}$$

Global-Run-Time-To-Empty [min]

The Global-Run-Time-To-Empty is computed on a power basis for several robot configurations with different power consumption (see table 1).

$$GRTTE_{act} = 60 \cdot C_{rem, corrected} / P_{act}$$

$$GRTTE_{55} = 60 \cdot C_{rem, corrected} / 55W$$

$$GRTTE_{30} = 60 \cdot C_{rem, corrected} / 30W$$

$$GRTTE_{17} = 60 \cdot C_{rem, corrected} / 17W$$

The remaining capacity $C_{rem, corrected}$ is the overall value of both batteries corrected with the error estimates to provide the minimum remaining capacity. P_{act} is the momentary required power:

$$C_{rem, min} = C_{rem, BAT1} - err_{max, Bat1} C_{full, BAT1} + C_{rem, BAT2} - err_{max, Bat2} C_{full, BAT2}$$

$$P_{act} = I_{BAT1} U_{BAT1} + I_{BAT2} U_{BAT2}$$

Global-Time-To-Full-Charge [min]

According to the discharge case, the LTC1760 charges the batteries simultaneously with a current proportional to their missing capacity to full charge, so both packs are fully charged at the same time. To provide a global waiting time until full charge is reached, the maximal time-to-full of each battery is used:

$$GTTF = \max\{t_{to\_full, BAT1}, t_{to\_full, BAT2}\}$$

Table 1. Power consumption for different TSR configurations

Configuration	Symbol	Consumed power
Full scale with maximal power (embedded PC, framegrabber, video, all sensors)	P_{55}	55W
Telepresence mode (embedded PC switched off)	P_{30}	30W
Reduced telesensory mode (actuator control via RS232 link, reduced sensors)	P_{17}	17W

4. RESULTS

To evaluate the intended prolongation of the accumulator run-time we show the measured discharge curves for simultaneous and separate discharging. Figure 6 shows the accumulator voltage during discharge at TSR standby operation. The run-time was extended by about 10% in the dual discharging mode compared to the successive discharging due to lower power loss at the batteries internal resistance.

Figure 6. Accumulator voltage during simultaneous (a) and separate (b) discharging of two Smart Battery packs (BAT1 and BAT2)

Figure 7 shows the provided Global-Run-Time-To-Empty prognosis (GRTTE) for different robot configurations (cp. table 1) together with the individual estimation of each battery pack RTTE(BAT1) and RTTE(BAT2) confronted with the values of the true remaining run-time (true RTTE). The robot was driven with full functionality in a stand-by mode.

Figure 7. Estimated and effective Run-Time-To-Empty (RTTE) for different robot configurations together with the individual RTTE of each battery pack

5. FUTURE WORKS

After implementing an energy management system for the TSR system supply the next step is to implement a semi-autonomous planning instance to configure the TSR depending on the momentary energy state. A possible strategy is a stepwise disconnecting of modules in case of low energy reserves up to the extreme case when the robot is only guided via a single serial radio link allowing the return to a charging station during the remaining prolonged operation time.

REFERENCES

1. Smart Battery System Implementers Forum: Smart Battery System Manager Specification. Version 1.0 (Release B), 8/9/1999, <http://www.sbs-forum.org>
2. R. Stemmer, R. Brockers, S. Drüe, J. Thiem: Comprehensive Data Acquisition for a Telepresence Application. In: International Conference on Systems, Man and Cybernetics, IEEE, 2004, pp. 5344-5349
3. Texas Instruments: bq2060A – SBS v1.1-Compliant Gas Gauge IC. Datasheet # SLUS 500A, May 2002
4. Smart Battery System Implementers Forum: Smart Battery Selector Specification. Revision 1.0, 9/5/1996, <http://www.sbs-forum.org>
5. Smart Battery System Implementers Forum: Smart Battery Data Specification. Revision 1.1, 11/12/1998, <http://www.sbs-forum.org>
6. Linear Technology: LTC1760 – Dual Smart Battery System Manager. Datasheet Rev. 1760f, 2003