PPEM016 – “Intelligent Power Management for Autonomous Vehicles”
WP3 – Quantitative Assessment

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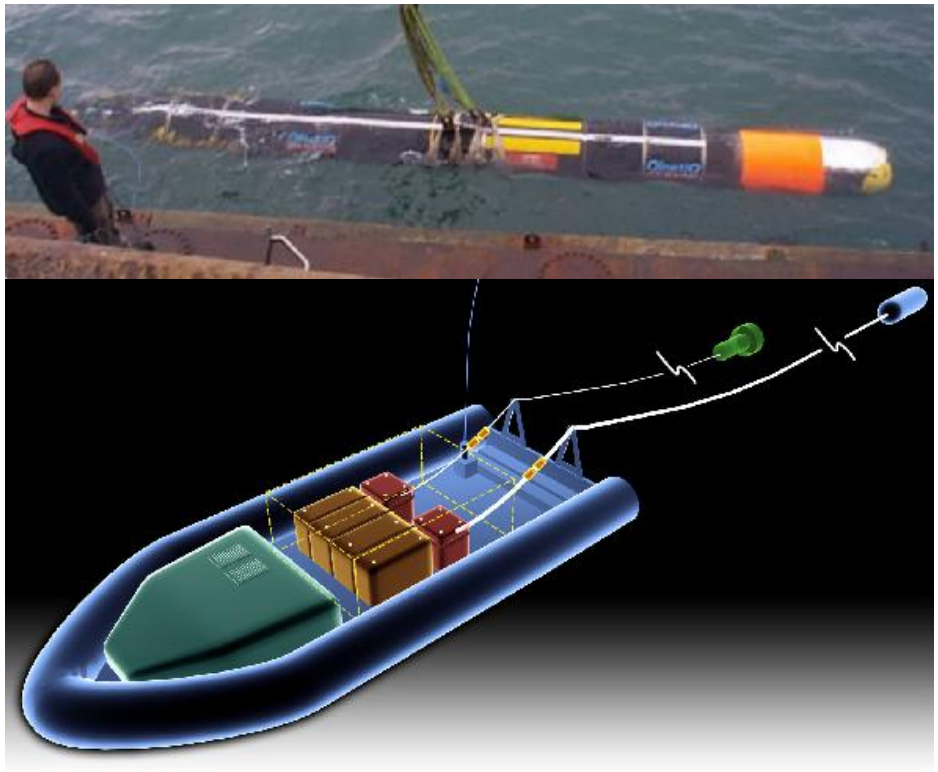

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Contents

1 Objectives

PPEM016 Objectives

- To investigate how power systems requirements can be accommodated in future autonomous systems

WP3 Objectives

- To ensure we can assess the quantitative benefits of intelligent power management algorithms

What we aimed to achieve by end of Phase 1 project

- Generic assessment framework defined, and suitable (software and hardware) demonstration environments identified
- This has been achieved, with a focus on the underwater environment (UUVs)

2 Assessing IPM Algorithms in Software

Assessment of IPM algorithms is needed to quantify the effect on platform endurance, cost, mission effectiveness and other metrics of performance

- Future autonomous systems will increasingly optimise missions, schedule actions, coordinate with others and re-plan in the face of an unexpected event
- The effectiveness of the integration of autonomous planning with the platform's power management system can also be considered.

Advantages of using software based simulations for assessment are:

- Usually cheaper
- Can perform many more assessment runs, as often in faster-than-real-time
- Can easily perform identical runs of system under assessment against a baseline system

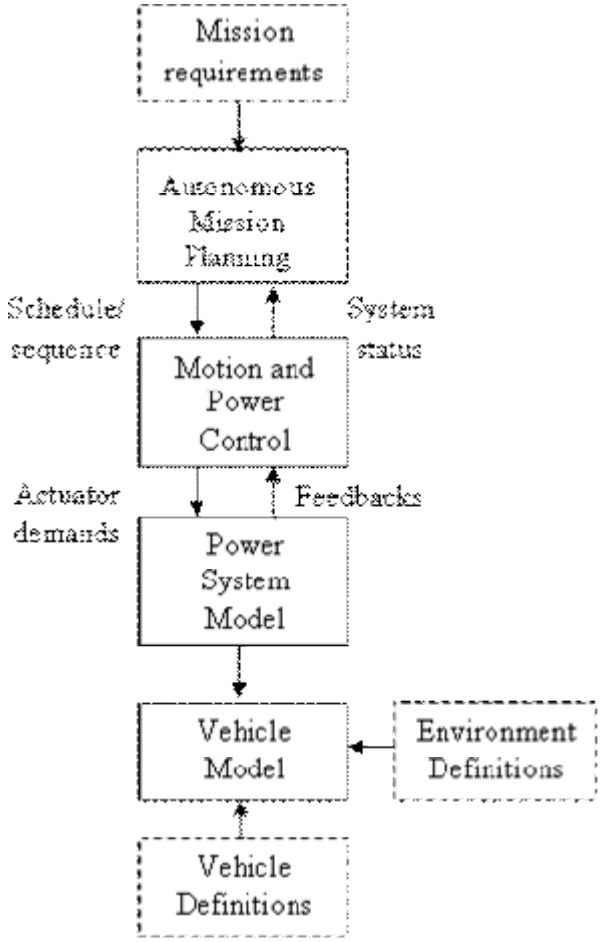
Disadvantages are:

- Often quite difficult and expensive to validate, so usually perform final assessments in hardware

2 Assessing IPM Algorithms in Software

Our approach

- Define a generic framework for pulling together existing models of a vehicle, an environment model and a mission definition, such that a mission can be simulated at the platform level and performance metrics calculated
- Required models are:
  - Platform dynamics;
  - Power systems (steady-state);
  - Low-level power and motion control;
  - Autonomous mission planning algorithms (actual system)
- It is likely that these last two will be combined



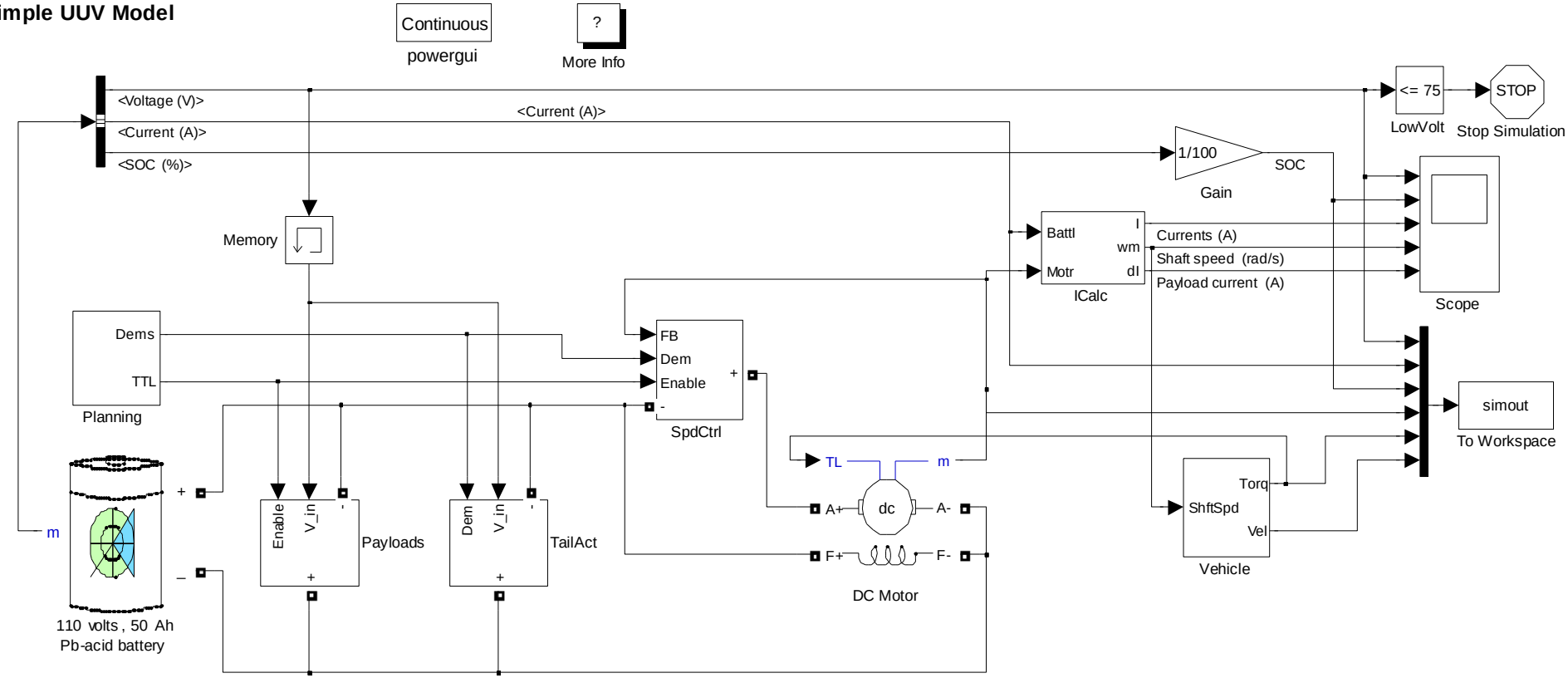
2 Assessing IPM Algorithms in Software

Other issues explored:

- De-risked use of Simulink as modelling ‘glue’ for assessment framework
  - Also the established tool for producing simple models (e.g. steady-state power) for novel platforms
  - Different modelling paradigms can be catered for
  - (see next slide)
- Software → Hardware
  - Use of validated software models with the actual hardware sub-system interfaces de-risks migration to hardware demonstration

2 Assessing IPM Algorithms in Software

Simple UUV Model



3 Assessing Operational Benefits

Claim:

- *"Significant platform-level benefits of IPM do not necessarily result in significant operational benefits"*

Explanation:

- We expect IPM to produce benefits such as "UAV endurance increased by 10%" or similar
- However some missions are designed top-down – an increase in endurance may not benefit the mission directly
- Exceptions are where the platform-level improvements mean the mission can be performed in a fundamentally different way, or with fewer assets
  - Potential example: Number of UGVs needed to search area reduced ***only if*** average area covered over time increased by *x*% ***only if*** UGV endurance increased by *y*%

3 Assessing Operational Benefits

This suggests linking OA tools or similar to the platform-centric assessment tool

Key observations:

- Top-down analysis of mission requirements, resulting in analyses like the earlier example, can be used as targets for future research
- Analysis tools for UUV missions (specifically mine countermeasure) exist
  - Top-down goals may include
    - areas to be searched/de-mined;
    - level of risk (to future traffic) to be achieved;

4 Applications to UUVs

The applicability of IPM research to the underwater domain is promising:

- Suitable platforms for experimentation exist (e.g. the Marlin UUV)
- Suitable vignettes exist with scope for power-related optimisation (future MCM capability)
- Suitable software models of the environment, vehicles and systems already exist
  - Can focus specifically on the development and assessment of new algorithms

Marlin UUV

- This vehicle has been identified for potential use in future underwater IPM demonstrations, as it is an experimental workhorse with rapidly reconfigurable payloads
- Note: usual set-up (for mine countermeasure operations) has predominantly low power loads, with power considerations dominated by the propulsion system
  - Significant platform-level improvements (e.g. endurance) are only likely through better propulsion systems, or use and management of additional power-hungry loads

4 Applications to UUVs

Future MCM Capability

- Current mine countermeasure operations use fairly low power loads and limited scope for autonomy
  - Vehicles leave mother ship for mined area, perform sensor sweeps, and return to mother ship, after which they may need to be sent out again
- Future capabilities include the use of deployable comms buoys, possibly increasing endurance by reducing the need to transit back and forth
  - However such systems are power-hungry (~1kW to winch buoy), and may not need to be deployed
  - This trade-off may depend on situational awareness (e.g. likely performance of sensor sweeps)
    - High autonomy is needed to perform the trade-off
    - High autonomy may be needed to provide the situational awareness
  - Future systems may reason in general about achieving sensor coverage to the required confidence level more efficiently, potentially requiring integrated sensor management, mission and route planning capability, and higher power usage

5 Conclusions

The means to assess IPM benefits in simulation has been identified.

- Through a model-based assessment framework and methodology
- Performance metrics are extracted at the platform system level
- Requirements can also be fed in and/or analysed in conjunction with operational analysis tools

There is considerable potential in applying IPM algorithms to UUV missions, in particular those involving future MCM capability.

Future work is recommended to take the assessment framework forward by instantiating it for a realistic and operationally relevant vignette.

- Initial emphasis would be on de-risking and assessing specific IPM algorithms
- In general any mission planning algorithms (e.g. route planners) ought to be assessed in this framework to understand the impact on power and energy considerations.

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