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Underwater docking of an under-actuated autonomous underwater vehicle: system design and control implementation

Key words: Underwater vehicle (AUV); Docking systems; Current estimator; Current compensation; Docking control

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Motivation

1. Underwater docking greatly facilitates and extends operation of an autonomous underwater vehicle (AUV) without the support of a surface vessel.

2. The presence of unknown ocean current makes the docking problem more complicated, and thus an online current estimator and a current compensator are necessary.

3. All the docking algorithms should be tested in the field, therefore a docking system is designed and tested.

Main idea

1. The current estimator can evaluate both horizontal and vertical current velocity components, based only on the measurement of AUV's velocity relative to the ground.

2. A control scheme is developed, which has been embedded with an online current estimator/compensator.

3. A docking system is designed and implemented.

4. All the proposed algorithms are validated by simulations and sea tests.

Method

1. The current estimator and compensator are designed using the principle of speed synthesis and decomposition.

2. A control scheme of a three-hierarchy structure of control loops is developed, which has been embedded with an online current estimator/compensator. The vision guidance is used in the terminal stage.

Major results

Docking system design

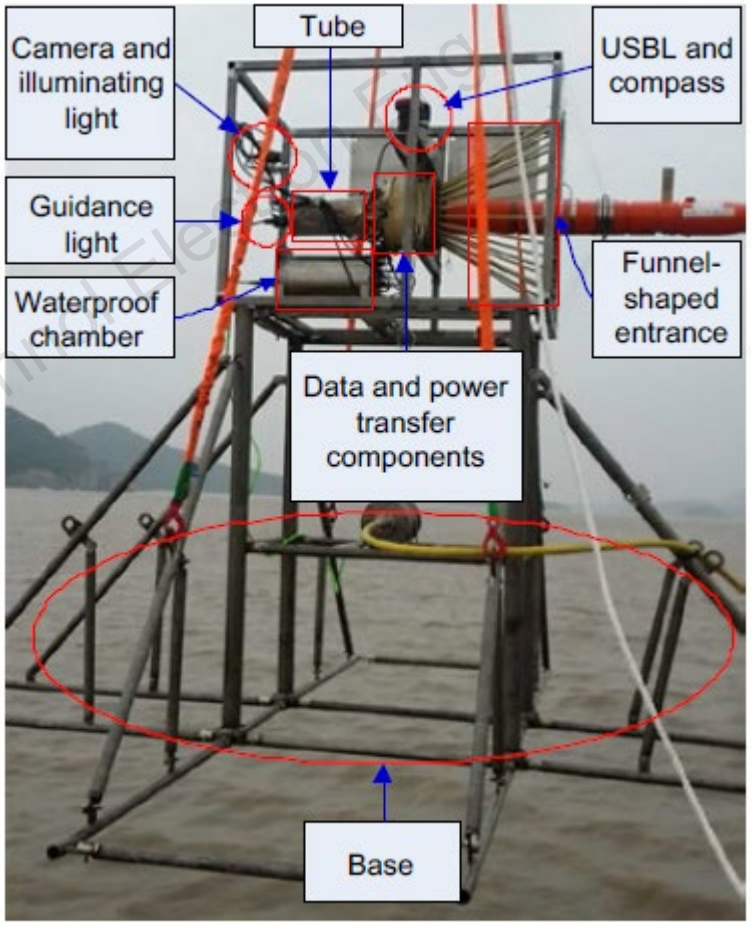


Fig. 1 Photo of the designed docking system

Major results (Cont'd)

1. Current estimation results in sea trials

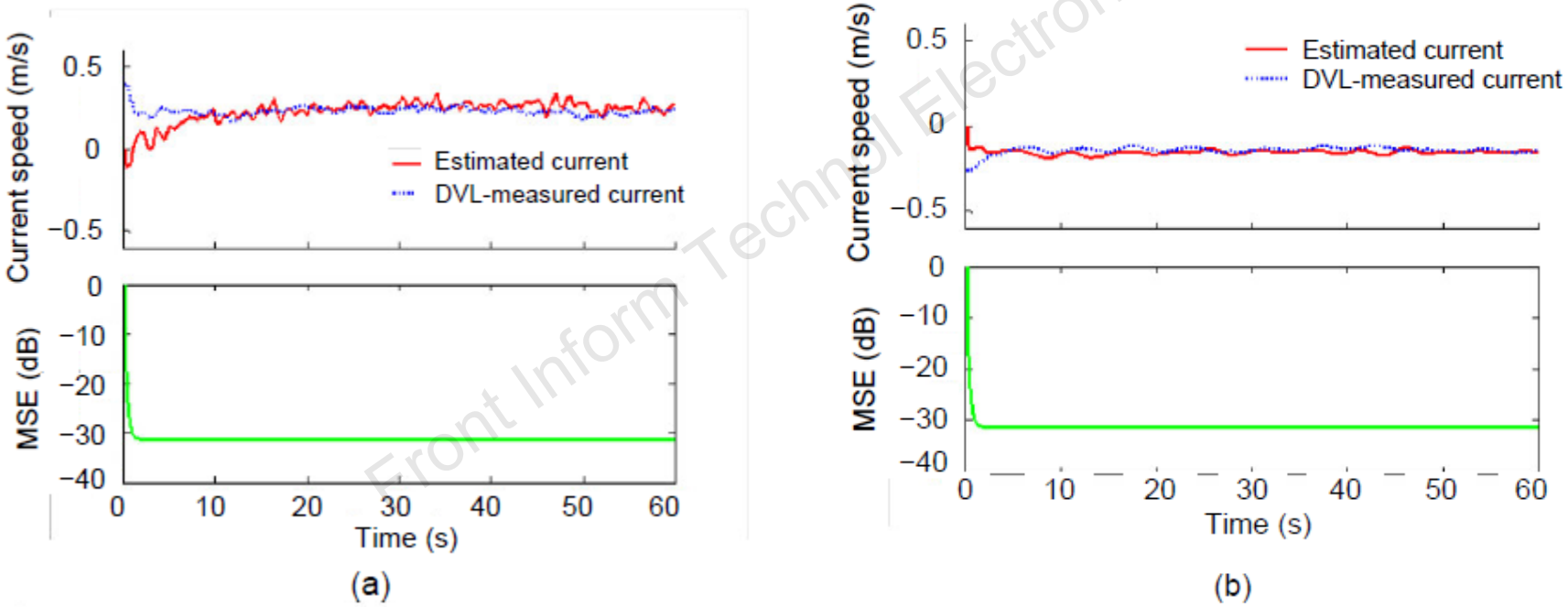
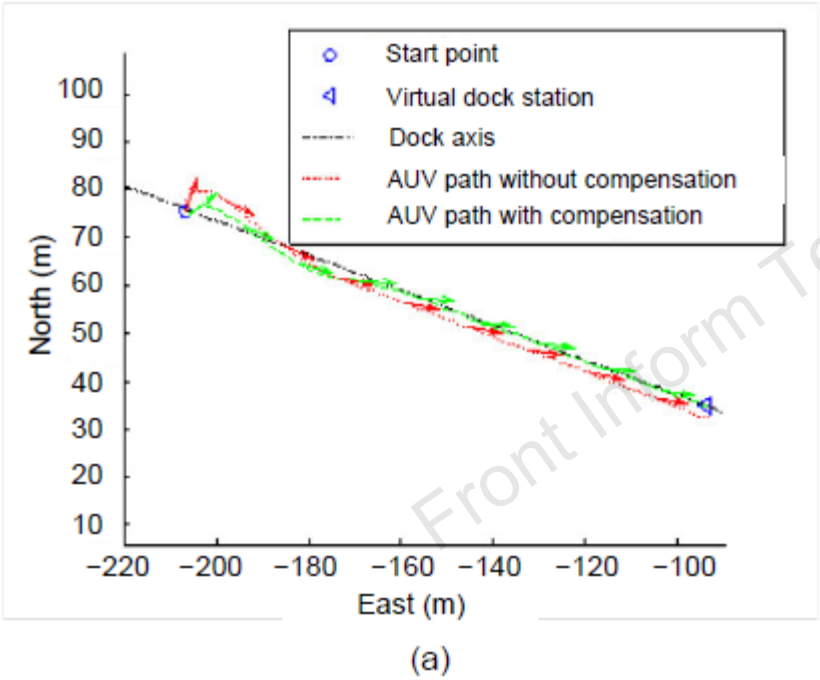


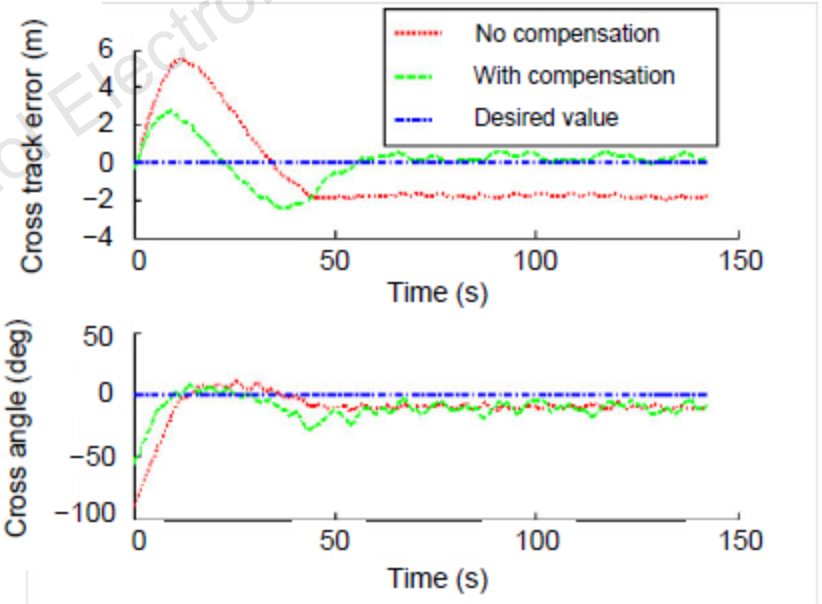
Fig. 17 Current estimation results in sea tests: (a) current estimation results on the surface; (b) current estimation results in a depth of 10 m

Major results (Cont'd)

2. Current compensation results in sea trials



(a)



(b)

Fig. 19 Docking experimental results in currents with or without compensation: (a) vehicle track; (b) corresponding cross-track error and cross angle

Major results (Cont'd)

3. Sea test results

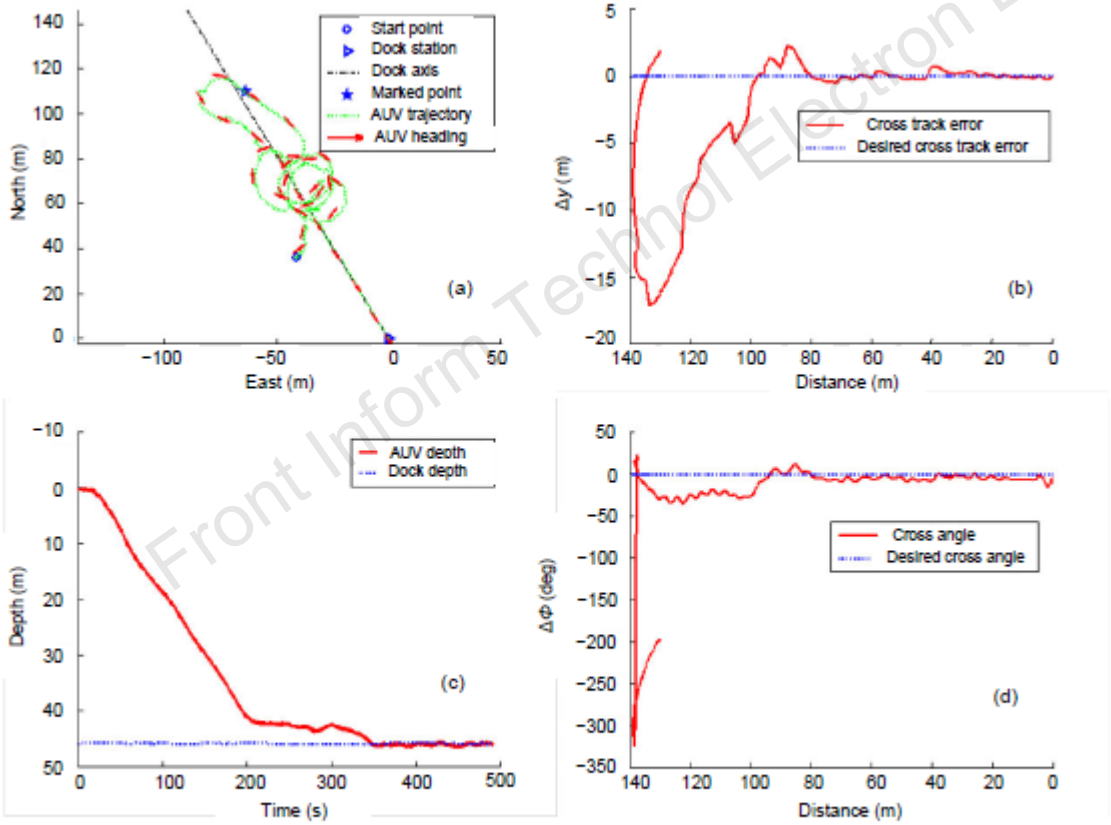


Fig. 21 One successful docking trial in depth of 50 m: (a) AUV track in docking process; (b) cross-track error; (c) depths of the AUV and the dock station; (d) cross angle

Conclusions

1. A prototype underwater docking system is designed, including the dock station, docking AUV, and docking algorithms.

2. A novel control approach that can handle current disturbances via an online current estimation/compensation is presented.

3. Through simulations and sea trials, the control strategy and the current estimator/compensator are thoroughly analyzed and verified.