Test-Driven Automation:
Adopting Test-First Development to Improve Automation Systems Engineering Processes

Dietmar Winkler Stefan Biffl Thomas Östreicher

Institute of Software Technology and Interactive Systems,
Vienna University of Technology

dietmar.winkler@tuwien.ac.at

http://qse.ifs.tuwien.ac.at

Motivation

- Added value of automation systems with software components:
  - Required flexibility of automation systems.
  - Increased complexity of software components in automation systems products.
  - Increased product quality by systematic software engineering approaches during development and operation.

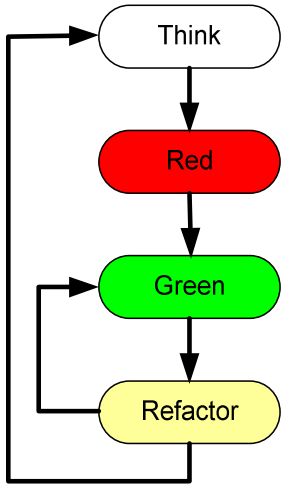
- Observations in Automation Systems Development Practice:
  - Functional, testing, and diagnosis aspects are scattered over the code and hinder efficient (automated) systems testing.
  - Limitations in a systematic development process approach.

- Challenges & Goals:
  - Need for functional, testing, and diagnosis aspects during development and operation within a hierarchical systems design.
  - Efficient (automated) testing strategies.
  - Need for flexible and systematic systems development processes.
  - Application of Best-Practices learned from business IT software development in the automation systems domain (e.g., test-first approach and model application).

Test-First Development in Business IT Software Development

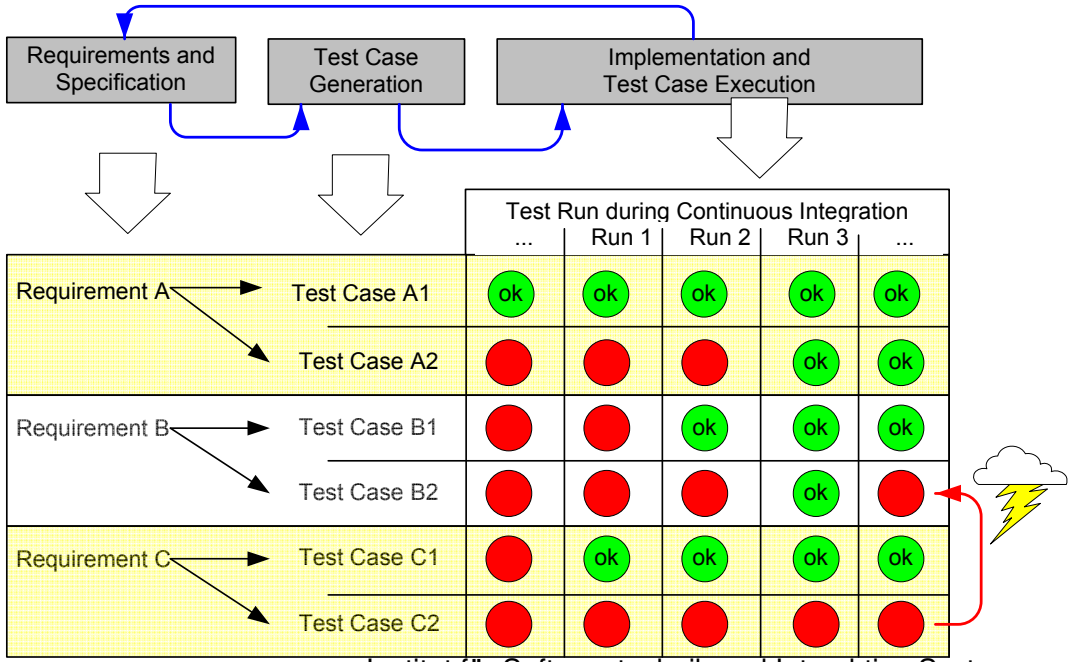
Test-Driven Development Steps:

1. Think. (a) selection of new requirements and (b) test case definition.
2. Red. Implementation and execution of test cases (failed).
3. Green. Implementation of functionality and test case execution until all tests are successful.
4. Refactor existing code without modifying functional behaviour and test case execution. Continue at step 1.



→ Continuous Integration and Test:

- Frequent test runs
- Immediate Feedback on test results (e.g., daily builds)
- Efficient regression testing.
- Automation and Tool support



Research Approach

- Need for flexible systems development and efficient testing approaches in the automation systems domain lead to:
  - Strict separation of functional, testing, and diagnosis aspects.
  - Application of test-first development to increase testing efficiency.

- Enriched automation systems development by systematic software engineering approaches, applying
  - Lessons learned from business IT software development.
  - Test-first development (TFD) in the automation systems domain.
  - Model-support to foster “test-first” in systematic systems development.

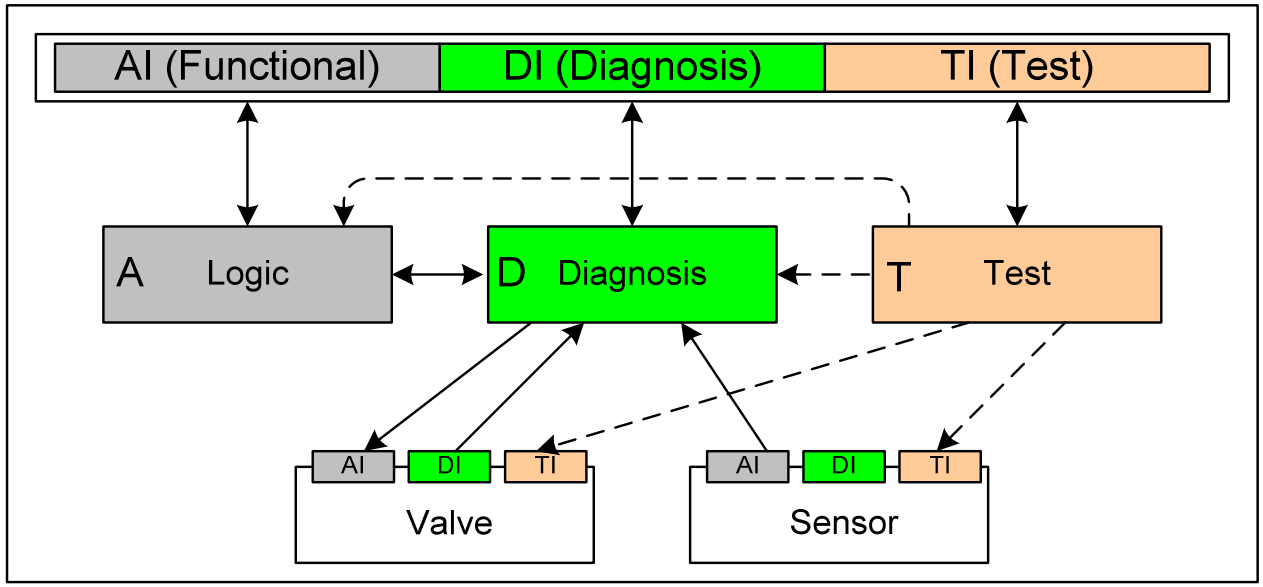
- Solution approach:
  - Concept for a test-driven automation component (TDA component).
  - Test-First development based on a systematic process approach (W-Model).
  - First evaluation in a prototype study: bottle sorting application.

Concept of a TDA Component

- Strict separation of functional, diagnosis, and test components.
- Interaction via defined interfaces within the TDA component and to lower-level and upper-level TDA components.
- Hierarchical systems design of typical automation systems.

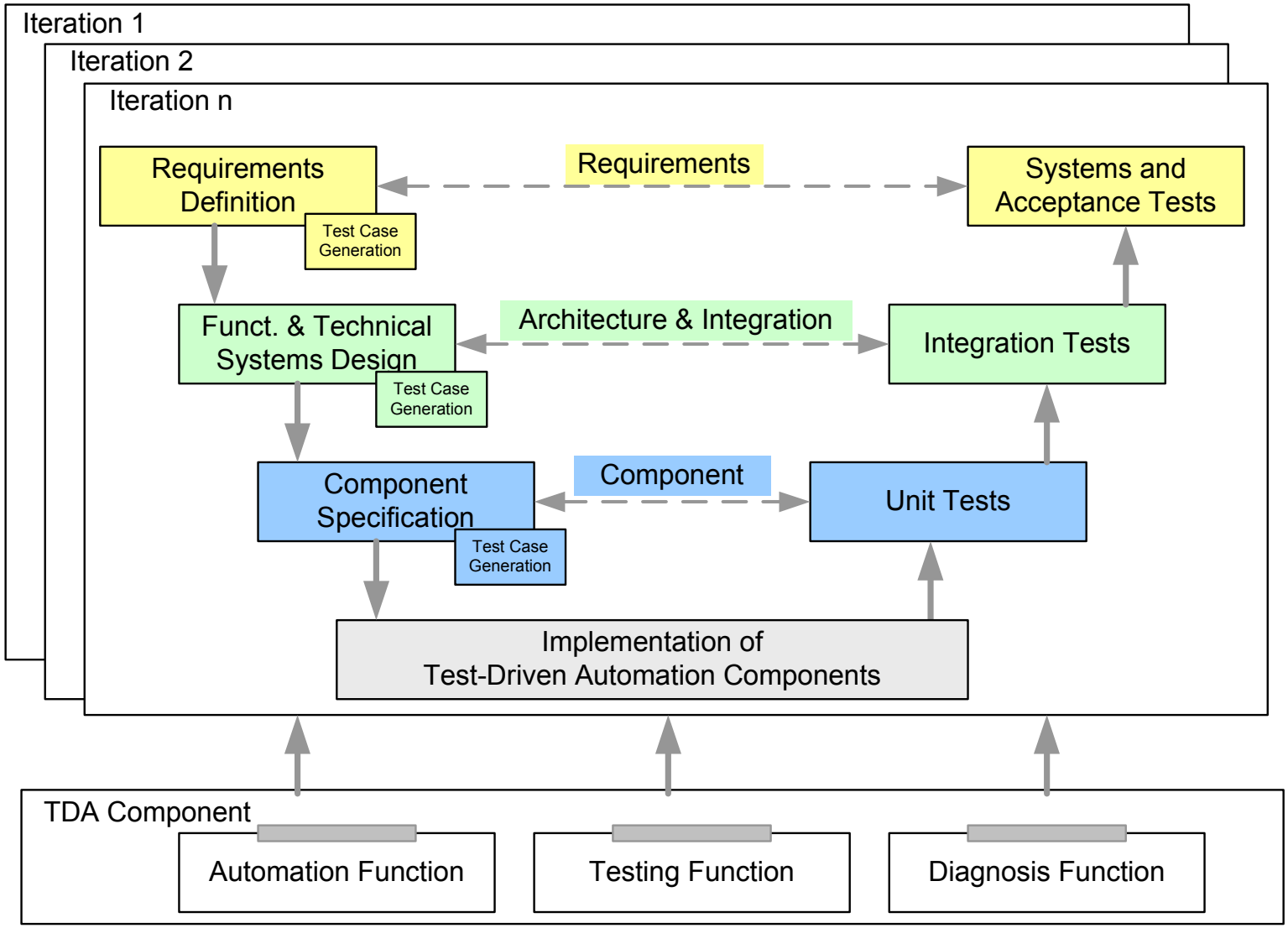
Component structure:

- Logic: Represents functional aspects.
- Diagnosis: (a) Pass messages from logical aspects to lower-level components and (b) monitor systems responses.
- Test: Set system in a certain state (functional behaviour) including tests of systems states which should not be reached (e.g. an error state).



Test-First in Software Development

- Based on the W-Model (Baker et al, 2007) or V-Modell XT (Biffl et al, 2006).



Test-Levels in TDA

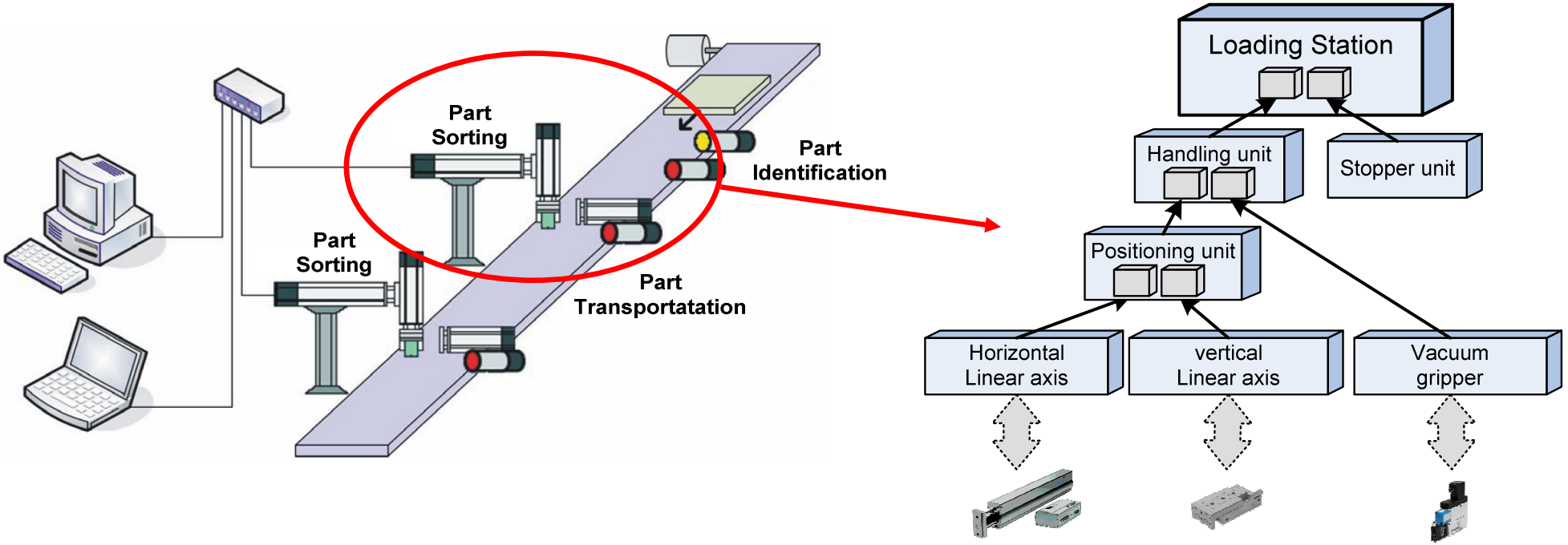
- Based on the W-Model focusing on
  - Requirements based test cases.
  - Test cases based on architecture, design and integration.
  - Component-based test cases.

- Test case definition on every level
  - Help Identifying success-critical issues on different levels.
  - Addresses individual stakeholder groups.

Phase	Deliverables	Test Level	Stakeholders
Requirements Definition	Use Cases	System / Acceptance Testing	Customer, Factory Setting
Functional and Technical Systems Design	Component diagrams State-Charts	Architecture / Integration Testing	Engineering Team
Component Specification	State-Charts	Component Testing	Individual Engineer
Implementation of TDA Components	Function Blocks	Developer Testing	Individual Engineer

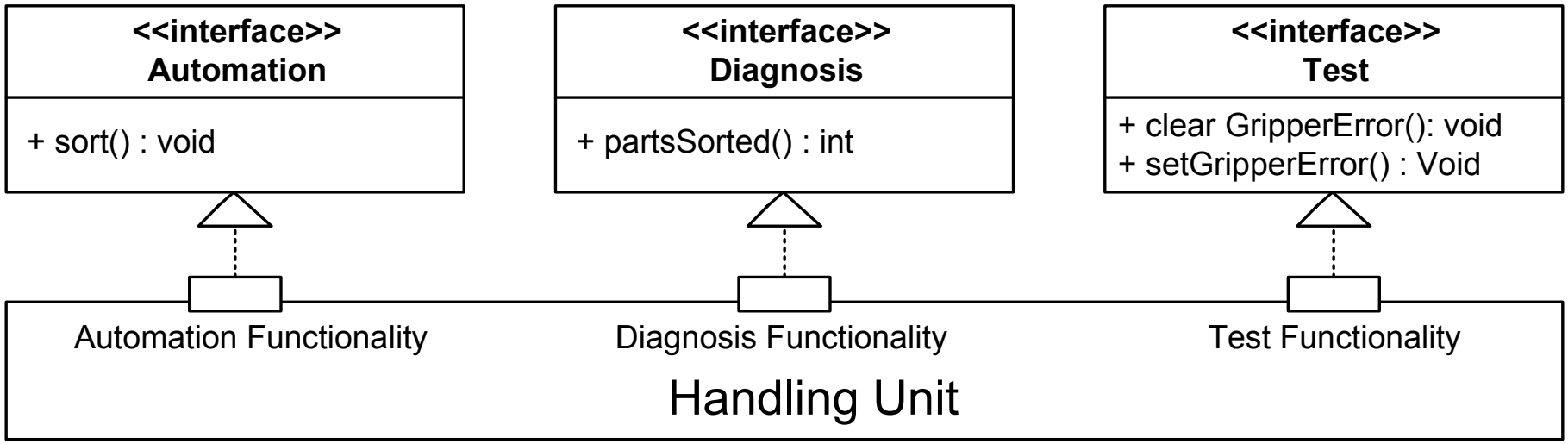
Sorting Application Prototype

- Bottle sorting application to illustrate TDA component application.
- Basic requirements:
  - Identification of individual items on a conveyor.
  - Stop at the appropriate loading station (stopper unit).
  - Grapping of the item (vacuum gripper) and moving the item into a box.
- Component Structure.



TDA Component Structure

- TDA component encapsulates functional, diagnosis, and test aspects.
  - Automation control via automation interface (e.g., sorting call)
  - Diagnosis: reporting the sorting status for (a) higher-level diagnosis components and (b) handling unit automation control unit.
  - Test control to set the system in a certain state, e.g., an error state (set/clear gripper error). Observation of system response via diagnosis and system reaction via automation aspects.

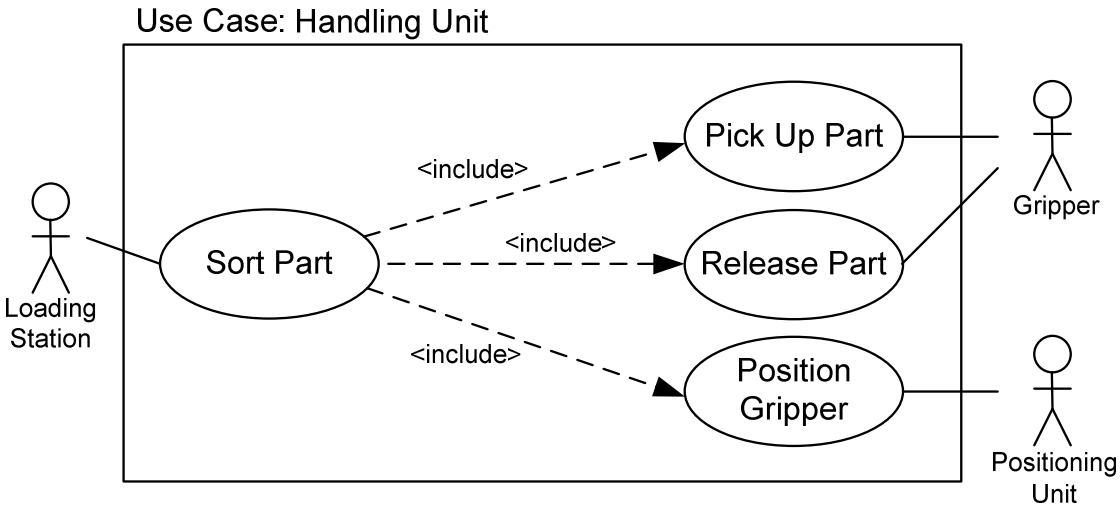


System Level Test

- Expected user behaviour on requirements level.
- Test Cases based on use case models and requirements from user perspective.

Advantages:

- Common "language" between different disciplines.
- Early defect detection.
- Enhanced understanding of the customer requirements.
- Test cases as vehicle for communication between stakeholders

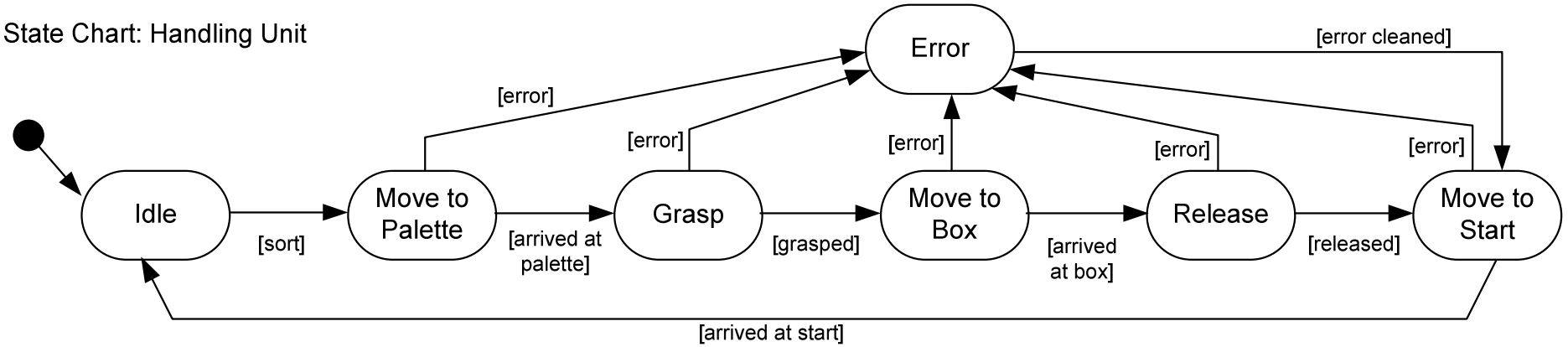


No	Desc.	Level	Type*	Pre-condition	Input	Expected Result	Post-condition
1	Sorting a Part	System	NC	Handling Unit in idle Position	Command to sort part	Handling Unit in idle Position and part sorted	Handling Unit in idle position
2	Through-put	System	NC	Handling Unit in idle Position	Command to sort part	Part has been sorted in less or equal than 10sec.	Handling Unit in idle position

* Definition of test cases (type) according to (a) normal and regular cases (NC), (b) special cases (SC), and error cases (EC).

Integration & Unit Tests

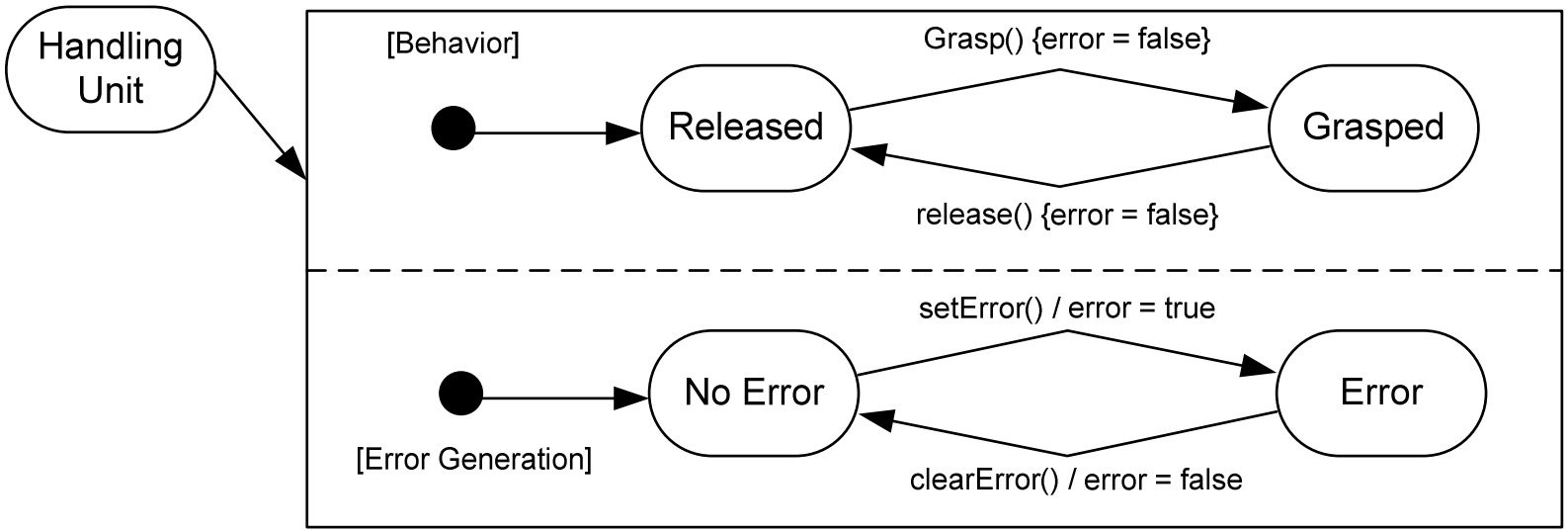
- State charts are common practices in the automation systems domain.
- Ability for automated code generation.
- Modelling of state charts including error states.
- Example: handling unit on component level.



No	Desc.	Level	Type*	Pre-condition	Input	Expected Result	Post-condition
1	Gripper move to Pos	Comp.	NC	Handling Unit idle	Sort part	Gripper moved to intended position	Gripper is in intended position
2	Axis got stuck	Comp	EC	Handling Unit in idle Position	Sort part error after 3s	Positioning Unit reports an error; Handling Unit idle	Handling Unit in idle position

Mocking with State Charts

- Mocking is necessary to
  - Simulate missing systems behaviour, i.e., code which is not available so far.
  - Simulation of hardware behaviour.
  - Simulation of error cases, i.e., system states which cannot be reached during regular machine behaviour.
- State charts support modelling error states for testing purposes.



Lessons Learned & Future Work

- Increased flexibility and (software) complexity in the automation systems domain lead to new challenges in software construction.
- Lessons learned from business IT software development can help systems engineers in constructing high-quality products in short iterations.
- The concept of “Test-Driven Automation” applies:
  1. Systematic software engineering process in the automation systems domain.
  2. Test-first development on various levels of details to systematically increase product quality in short iterations.
  3. A strict separation of functional, test, and diagnosis aspects (TDA component structure) enables systematic product development including interaction over clearly defined interfaces.
- Lessons learned from a pilot application showed the expected benefits in a small show case application.
- Future work includes
  - Refining the process model and the TDA structure including diagnosis functions.
  - Investigating the scalability of the TDA concept in a larger project context.
  - Elaborating on a larger pilot application with industry partners with focus on data collection to empirically investigate the expected benefits of the novel TDA concept.

Thank you for your Attention

Test-Driven Automation:
Adopting Test-First Development to Improve Automation Systems Engineering Processes

Dietmar Winkler

Vienna University of Technology
Institute of Software Technology and Interactive Systems

http://qse.ifs.tuwien.ac.at
Dietmar.Winkler@tuwien.ac.at

Referenzen

- Baker P., Dai Z.R., Grabowski J.: Model-Driven Testing: Using the UML Testing Profile, Springer, 2007.
- Beedle M., Schwaber K.: Agile Software Development with Scrum, Prentice Hall, 2008.
- Biffl S., Winkler D., Höhn R., Wetzel H.: Software Process Improvement in Europe: Potential of the new V-Modell XT and Research Issues, in Journal Software Process: Improvement and Practice, Volume 11(3), pp.229-238, Wiley, 2006.
- Damm L.-O., Lundberg L.: Quality Impact of Introducting Component-Level Test Automation and Test-Driven Development, Proc. EuroSPI, 2007.
- Drusinksy D.: Modeling and Verification using UML Statecharts, 2006.
- Duvall M.P., Matyas S., Glover A.: Continuous Integration: Improving Software Quality and Reducing Risk, Addison-Wesley, 2007.
- Karlesky M., Williams G.: Mocking the Embedded World: Test-Driven Development, Continuous Integration, and Design Patterns, Proc. Emb. Systems Conf, CA, USA, 2007.
- Sünder C., Zoitl A, Dutzler C.: Functional Structure-Based modelling of Automation Systems, Jounal of Manufacturing Research, 1(4), pp405-420, 2007.
- Vyatkin V., Christensen J.H., Lastra J.L.M.: OOONEIDA: An Open, Object-Oriented Knowledge Economy for Intelligent Industrial Automation, IEEE Trans. on Industrial Informatics, vol. 1, pp. 4-17, 2005.
- Zhang W., Diedrich C., Halang W.A.: Specification and Verification of Applications Based on Function Blocks, Computer-Based Software Development for Embedded Systems (LNCS 3778), Springer Verlag Berlin Heidelberg, pp. 8-34, 2005.