DATA INTELLIGENCE ENABLES TEST INTELLIGENCE

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ICT Enables the Fourth Industrial Revolution – Intelligentization

Industry trend: Mobility->SDN->Cloud->Storage->Big Data->5G/IoT-> AI

→ Intelligent R&D (DI or AI ??)
What is R&D Data Intelligence?

- Data intelligence is the ability to mine software engineering data to find insightful and actionable solution to solve business problems & Effectiveness.
- Comprehensive data intelligent solutions may consist of software traceability, data mining, data analysis, data query, and data visualization techniques.
- Data intelligent solution may help R&D project stakeholders make informed decision, reduce R&D cost, and even find new business opportunities.
- Industry leaders such as Google and Microsoft are aggressively utilizing R&D data to create applications to solve business problems & R&D Efficiency. Examples of these applications are:
  - Dynamic R&D Adaptive Model
  - Automatic Quality Assurance
  - Feature Impact Assessment
  - Automated TC Generations/Lean Test
  - Domain Experts Recommendation
  - Fault Localization & Resolution
  - Dynamic Resource Allocations
  - Etc....
Updated bugs from the current delivery (code and documentation)

Dev and test bugs

Resolved and unresolved trouble tickets

Test cases, Requirement mapping to test cases

Test case evaluation, Pass rate, Upgrade path validation

Code review status, Checklist and OA&M Doc review status

OA&M Doc completion status, Support resources status

Prioritized release content

Delivery Pass/Fail Report, Specific role reports

Feedback and continuous improvement data

Detailed Milestone Criteria (from process intelligence)
Milestone KPI’s from previous releases
Industry Norm KPI’s

Problem Tracking DB

Problem Tracking System

Code/Doc Review Tool

Test Plan Repository

Test Tool

Test Tool

Inference/Rules Engine

Knowledge Base

Project Management Tool

Project Management DB

Requirements Management
Multiple assets assessable across teams.

- **Env** – Pool of resources dynamically allocated for high reuse and utilization
- **Code** – Source code assessable and searchable by development teams for high code reuse and quality
- **Test** – Strategy, plans, and code assessable by development teams for experience sharing and reuse.
- **Data** – Project, experts, experience, tools, technology information assessable across teams for experience sharing, insight extraction, and intelligent decision making.
Data Correlation Analysis Enables Intelligent R&D Applications
Data Intelligence’s Challenges

- Reusability, Sharing?
  - Lots of issues are common to the various teams, but their original Data Format & standard are different and make it difficult to reuse & share
  - The resolution of some issues may use the same or similar data, can that be shared?
  - How to dig out the different original data and find out the common solution?

- Data? (Type? Attribute? Correlation?)
  - Huge & separated R&D process Data, where do we start?
  - What are the useable R&D Data? Where are they?
  - How are we going to correlate these Data?
  - How to use these to resolve issues & improve overall R&D efficiency?
  - Do we have the complete Data to resolve the targeted issues?
  - How to maintain the integrity of the Data?
What is Intelligent R&D

- Let machine learn to accumulate knowledge and experience to free human brain power for better creativity.
- Provide the right help, to the right person, at the right timing in a timely fashion to facilitate the R&D efficiency & Trustworthiness.

- Service Providers & Integrators’ Paradigm Shift
  - Reactive >> Proactive
  - Tools Centric >> Users Centric (Business Centric)
  - Band-Aid Solution >> Comprehensive Solution
  - Innovation Ceiling >> Innovation Enabler

- Service Consumer’s Paradigm Shift
  - Speculation Decision >> Data/Evidence Based Decision
  - Hidden Risk >> Visible & Traceable Result
  - Resolve Issue >> Prevent Crisis

Key enablers for Intelligent R&D: R&D Data Intelligence
Future R&D Environment

- Anything can be connected will be connected
- Anything can be shared will be shared
- Anything can be integrated will be integrated
- Any Process can be automated will be automated
- Any Data can be correlated will be correlated
- Any Activity can be collaborated will be collaborated
- Anything can be tested will be tested at the 1st available time
## Intelligent R&D Application Scope

<table>
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<tr>
<th>Category</th>
<th>Key Business</th>
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| **Intelligent Platform** | Self adaptive tools chain  
Business intelligent enablement – R&D knowledge graph support  
Data Ocean and software analytics ecosystem  
Expert and artifact recommendation and coordination |
| **Intelligent Management** | Self adaptive R&D Model  
Automatic quality assurance measurement  
Systematic project management  
Efficient & intelligent project resource utilization |
| **Intelligent Architecture & Design** | Automatic architecture recovery and smell detection  
Automatic architecture refactoring/enhancement  
Visualization of software architecture  
Architecture design impact and risk analysis  
Architecture framework/pattern recommendation |
| **Intelligent Development** | Intelligent code search and code insight support  
Intelligent log analysis for distributed system  
Fault localization and automatic bug repair  
Intelligent regression test for new problem resolution |
| **Intelligent Test** | Intelligent test case recommendation  
Intelligent test environment utilization and test execution  
Comprehensive log/data collection  
Risk analysis for un-resolved problems |
| **Intelligent Solution** | Multi-tier intelligent continuous deployment  
Integration simulation and risk prediction  
Muti-vendor device integration solution recommendation  
Muti-vendor dynamic resource management T-DSL |
| **Intelligent Lab** | Strategic lab resource utilization  
E-DSL  
Lab utilization risk analysis and cost estimation  
Project plan and lab utilization conflict resolution |
Industry R&D Models & Engineering Methodology

- Up to now, there is no “One Model or Process can fit it all” for various Products & Solutions
- All the new Models that have introduced so far are still lacking of “Quality Assurance Guideline"
- Service Integration will be a major challenge for the future Cloud & Open Ecosystem

Crafts programming, the “software crisis”
First Software Engineering Conference, "software engineering" was born
The formation of computer-aided design and software for industrial production system
The rapid development of the modern Internet technology, birth of Agile
Lightweight Mixed Mode Processes
Community-based development, open source software ecosystems

Focus on process engineering from a management perspective
Design methodology Analysis

Process dictated by the programming language
Structured Systems Analysis and Design
Computer-aided and object-oriented design
Software architecture, modularity, automation, reusability

Next Generation R&D Ecosystem

Vision: system of tools to enable trustworthiness, efficiency, quality, consistency & evidence-based decisions throughout the product development process

- Expert knowledge and fact-based decisions throughout the process
- Single User Interface for multiple tools on dynamically defined desktops per role
- Workflow-based automation of the product development, verification, packaging, delivery, support
- Increasing Dev Efficiency With Intelligent Tools
- Use of Big Data Throughout Dev & Ops to enable Evidence-based decisions
- Dynamic and efficient allocation of scarce resources

Knowledge based R&D Process Expert System to ensure most-fitted/Self-Adaptive R&D Model、Working Platform、Tools Chain、APIs、Dynamic Resources、Auto-Quality Assurance System、Open Ecosystem
Integrate advanced technologies in the industry and evolving test practices from automation-based to customer-oriented, cloud-based, service-oriented, and intelligence-based.

- **Intelligence-based test design:** Developer can use collaboration and operation platform to efficiently implement one-source design, and collaboration. With intelligent search, and test knowledge graph R&D resource and info is available anytime. Use TDSL/JADL to build efficient, unified test case design domain specific language. All linkages from test cases are completed and managed automatically during design process.

- **Intelligence-based test execution:** With ICT-integrated dynamic resource scheduling, starts the intelligent test pipeline in one click, and completes the associated unit test, function test, system test, DFX test, solution test verification.

- **Intelligence-based test analysis:** Automatically execute product-level test coverage assessment and risk feedback in real-time. Use data analysis platform integrated with data processing, machine learning and artificial intelligence, and integrate data about tools, and logs from product SUT that is generated during design, execution and env resource setup with automatic data collection and test activity analysis to provide efficient solution to problem isolation and localization.
Vision & Mission of Intelligent Testing

- Support future Intelligent R&D
  - Intelligent R&D Model: Design, Modeling, Code Development

- Full scope of Automation & Intelligence
  - Auto-evoke the new code verification of Unit, Functional, System, DFX & Solution (Auto-DevOps)
    - Automatic Test Case Generation
    - Automatic validate the Test Coverage, Code Coverage; automatic Test case generation for untested Code
    - Automatic Quality Evaluation & Gate passing
    - Automatic Test Results Analysis & Fault Isolation
    - Automatic Bugs Retest for automatic bugs resolution

- Intelligent Working & Collaboration Platform to integrate the E2E R&D Activities
  - Facilitate the Design, Development, Test engineers to work seamlessly – including the cross platform/products vertical integration
Intelligent Testing Key Activities

- **Intelligent Test Design:**
  - Development & Test Design collaboration (with the same source)
  - Full scope of TC Correlation -- Unit、Functional、System、DFX、Solution

- **Intelligent Test Execution (Automated DevOPS):**
  - Test Execution Pipeline: Unit → Functional → System → DFX → Solution
  - Test Coverage Validation + Automated TC Generation for Untested Code

- **Intelligent Test Results Analysis、Fault Isolation**

- **Automatic Verification for Defect Resolutions**
Intelligent Test Design

• **What is Intelligent Design?**
  - Parallel Test Design with Development Design: Requirement, Scenario & API analysis
  - Through Intelligent Working System to seamlessly guide the users to input the key data accurately, via the automatic Data Correlation to build the proper Knowledge Graph
  - Correlate the Code & Test suites to set up the Unit test foundation and evolve the E2E Data correlation and Traceability
  - Utilize the services provided by the Knowledge Graph to timely deliver the required data to the users during the Test Design process
  - System provides effective Design verification environment to speedup the design iteration and enhance the Unit test capability

• **Scope of Intelligent Test Design:**
  - Adaptive R&D Working & Collaboration Platform
  - Intelligent Search & Knowledge Graph
  - Development & Test Design Collaboration (with the same source)
  - Correlate the Code iterations with corresponding Unit, Function, System Test cases
  - Enhance the Unit Test Capability: Generation, Correlation & Test cases Management
  - TDSL & Test case Modeling
Intelligent Test Design Overview

Strengthening Unit Testing with 2 methods

- New code modules developed with new unit tests
- Existing code modules are tested by unit tests created from system tests

**System Tests**
(Lots of existing tests)

**Test Design Experimentation**
- IDE-accessible Search (learn)
- IDE-based Test creation (code)
- IDE-accessible Test Runs (Test)

**Unit Tests**
(Light weight, Run fast, High coverage)

**Test Design Experimentation**
- Tester (trainer)
- Developer (learner)

**Laying foundation for engineering transformation**

**Method 1: Unit test creation from system testing**
Tester (trainer)
Developer (learner)

**Method 2: Unit test creation along with SUT source code modules**
Tester (learner)
Developer (trainer)

**Collaborative Test Design**

**Increasing System Test effectiveness and efficiency**

**Field data analytics guided test creation**
- Critical test scenarios/SUT platforms
- Test package design

**Effective test packages**
- Data-driven test design
- Exhaustive test exploration

**Behavior modelling**

**Model-based Testing and DSE**

**Building technology foundation for test design and other applications**

**Mapping test cases to src code enabling coverage-based test design**

**Knowledge graph enabling traceability**
Intelligent Search & Knowledge Graph -- Example

- Requirement Analysis
- Scenario Analysis
- API Analysis
- OAM Design
- Architecture Analysis
- Capacity & Robustness
1. Requirement Description
   i. Feature Description
   ii. Feature Impact
2. Feature Specification
   i. Feature Description
   ii. Feature Impact
3. Use Scenarios
4. Message Flow
5. Feature Interaction Matrix
6. OA&M
   i. Alarms and Logs
   ii. Detail Record
7. Performance Impact
8. High Level Design
   i. Architecture Block Diagram
   ii. Component Message Flow
   iii. Changed Component Description
   iv. New Component Description
   v. Data Design
   vi. API Design
9. Low Level Design
   i. Changed Function
   ii. New Function
   iii. Data Schema
   iv. New API Detail Description
   v. Changed API Detail Description
10. Unit Test Cases
    i. Tested Component/Function
    ii. Scenario Description
11. Mock Testing
12. Functional Test Cases
    i. Tested Feature
    ii. Required Resource
    iii. Scenario Description
13. System Test Cases
    i. Tested Requirement
    ii. Test Environment Design
    iii. Scenario Description
14. DFX Test Cases
    i. Tested Requirement
    ii. Test Environment Design
    iii. Scenario Description
15. Solution/JAD Test Cases
    i. Tested Requirement
    ii. Test Environment Design
16. Appendix (Review Meeting Minutes)
Test Case Centric Data Correlations

- Requirements
- Dev Design
- Test Design
- Modeling
- Coding
- Test Case
- Test Data
- Effects

- Req.-Design - TC Correlation@DTTP
- Modeling-TC Correlation@MBT
- Code - TC Correlation@VBS
- TC - TC Correlation@STEP
- Data - TC Correlation@Log
- Defects - TC Correlation@DREAM

TC Sets
Test Execution System includes services for individual ITEL test case, ITEL test suite, and ITEL traffic model execution.

- ITEL test cases are reused across functional and non-functional test scenarios (capacity, robustness, etc.)
- ITEL test cases leverage the same test infrastructure including the Dynamic Test Resource Manager and existing test technology integration capability.
- ITEL test cases execute on a dynamically built test environment that can be dedicated to specific test activities or shared among test activities.
- The user desktop is dynamic and workflow-based. It integrates functional and non-functional test capability as required by the user workflow.
Intelligent Test Execution

What is Intelligent Test Execution?

- Anytime, Any Place can execute the Test Cases via personal Devices
- Users do not need to worry about the Test Automation Framework & implementation Languages, all languages best practice will be effectively integrated with the system to execute the corresponding Test cases
- Effectively organize & define the TC suite, Test Environment, Test data, Test Data services, Test Logic and can execute in Parallel or sequential in order to fit the test execution strategy
- Effective, sufficient, realistic utilize the Resources & capability, prompt environment set up and maximize the TC execution efficiency
- Automated Test Execution Pipeline: Unit $\rightarrow$ Functional $\rightarrow$ System $\rightarrow$ DFX $\rightarrow$ Solution
- Effective Test Coverage Analysis to facilitate the Automated generate missing Test Cases

Scope of Intelligent Test Execution:

- Intelligent Test Execution
- Effective Test Automation Ecosystem
- Intelligent Test Strategy & Test Cases Selection mechanism
- Intelligent Test Environment set up
- Adaptive Test Execution Pipeline
What is Intelligent Test Analysis?

- Facilitate the testers to collect complete error data and avoid the developers to do it again
- Provide the complete data to help the developers to conduct effective analysis & resolutions
- Search similar bugs and categorize those to avoid duplications
- Automate the Issue Ticket generation process to reduce the testers’ workload
- Record the System & User interaction message flow to ease the reports & issue isolation process
- Correlate the system behaviors to better understand the system E2E status
- Analyze the root cause of the regression issues to identify the trouble Code
- Through the discovery of the system issues to evaluate the Test Effectiveness and better the Test suite

Scope of the Intelligent Test Analysis:

- Fault analysis
- Fault Isolation
- Test Execution Analysis
- Test Coverage Analysis
Intelligent Testing: Key Technology

- Self-Adaptive Working & Collaboration Platform (Projects, Activities, People Collaboration)
- Intelligent Test Design Document Framework & Auto-Verification
- Intelligent Search Service
- Test Knowledge Graph (Requirements, API, Scenarios, Architecture, Reliability, Logs/Alarms)
- Unit Test case Generation, Optimization, Management
- ITEL: Intelligent Test Ecosystem Language
- System Test case Modeling + Test Case Auto Generation + Selections
- Unit, System, Solution Test case Correlation
- Cloud Resource Dynamic Allocation
- Intelligent Test Execution Pipeline: Unit ➔ Functional ➔ System ➔ DFX ➔ Solution
- Via Black box Test cases automatically generate Unit/White Box Test cases
- Automatic Test case generation for Untested Code
- Fault Isolation
- Fault Localization
- Automatic Defect Resolution & Retest
Open & Service Oriented Ecosystem

R&D Data System
- Persistence
- Data Access
- Data Processing
- Storage Mgmt

Standardized R&D Data Center
- Analytics
- KPIs
- BAM/BI
- Predictors
- Historical Data
- NLP

Workflow Framework
- WF Modeler
- Core Workflows
- Ecosystem Workflows

UI Framework
- Management
- Architect
- Developer
- Lab Mgmt
- Solution
- Support
- Test

Workflow Management
- Rqmt Mgmt
- Change Mgmt
- TestCase Mgmt
- Source Control
- Log Correlation
- Auth / Permissions
- User Profile

WF Execution Environment
- Lab Configuration Mgmt
- Resource Mgmt

WF Scheduler

Data Center Management Services
- DCIM
- Virtualization / IAAS
- Utilization Monitoring
- Env Monitoring
- Energy Mgmt

IT & CT Physical Equipment
- Space / Power / HVAC
- Monitoring
- Connectivity
- Networking

Core services
- R&D services
- Custom Tools
- Custom Analysis
- Custom ???

Analytics
- KPIs
- BAM/BI
- Predictors
- Historical Data
- NLP

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Predictors
- Historical Data
- NLP

Historical Data
- NLP

NLP

UI

API Gateway
Thank You!