개발과정에서의 MATLAB과 C의 연동
(영상처리분야)

Application Engineer
Caleb Kim
Algorithm Development with MATLAB for C/C++ Programmers

- Objectives
  - Use MATLAB throughout algorithm development process
  - Highlight MATLAB external interfaces
  - Move MATLAB algorithm into product

- Design, implement and verify a lane detection system
Algorithm Development Process

Requirements

Research & Design
- Explore and discover
- Gain insight into problem
- Evaluate options, trade-offs

Implementation
- Migrate design to production
- Optimize performance
- Deploy / Integrate / Test

Test & Verification
Representative Tools Used in Algorithm Development

- **General-purpose languages**
  - C, C++
  - Fortran, Java

- **Technical computing languages**
  - MATLAB

- **Specialized and single-purpose tools**
  - Image processing application
  - Speech recognition application

- **Spreadsheets**
  - Excel
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Design

Test

Elaborate

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Design the Lane Detection System

- Process images from actuated camera mounted on vehicle
- Prototype algorithm for identifying lanes in the road
- Elaborate algorithm to process streaming video
MATLAB Capabilities for Algorithm Design

- Interactively develop algorithms
- Edit and debug large programs
- Profile code performance
- Publish reports
- Use application-specific toolboxes
Algorithm Development Process

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Verify the Lane Detection System Harness

- Test the harness using working MATLAB code
- Leverage the MATLAB Engine interface to connect C with MATLAB
Plotting the Data in Your C Project Using the MATLAB Engine Library

- Add header file and libraries to your project
- Package data into MATLAB data structure (mxArray)
- Use engine routines to:
  - Send data to MATLAB
  - Perform computations in MATLAB
  - Plot data in MATLAB
- On Windows, enable MATLAB Automation Server
C Engine Routines: Call MATLAB from C

The Engine Library

The engine library contains the following routines for controlling the MATLAB computation engine. Their names all begin with the three-letter prefix `eng`. These tables list all the available engine functions and their purposes.

### C Engine Routines

<table>
<thead>
<tr>
<th>Function</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>engOpen</td>
<td>Start up MATLAB engine</td>
</tr>
<tr>
<td>engClose</td>
<td>Shut down MATLAB engine</td>
</tr>
<tr>
<td>engGetVariable</td>
<td>Get a MATLAB array from the MATLAB engine</td>
</tr>
<tr>
<td>engPutVariable</td>
<td>Send a MATLAB array to the MATLAB engine</td>
</tr>
<tr>
<td>engEvalString</td>
<td>Execute a MATLAB command</td>
</tr>
<tr>
<td>engOutputBuffer</td>
<td>Create a buffer to store MATLAB text output</td>
</tr>
<tr>
<td>engOpenSingleUse</td>
<td>Start a MATLAB engine session for single, nonshared use</td>
</tr>
<tr>
<td>engGetVisible</td>
<td>Determine visibility of MATLAB engine session</td>
</tr>
<tr>
<td>engSetVisible</td>
<td>Show or hide MATLAB engine session</td>
</tr>
</tbody>
</table>
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Introducing MATLAB Coder
Generate C Source Code
Automatic Translation of MATLAB to C

With MATLAB Coder, design engineers can

• Maintain one design in MATLAB
• Design faster and get to C/C++ quickly
• Test more systematically and frequently
• Spend more time improving algorithms in MATLAB
Implementing the Algorithm

Generate C Source Code

- Integrate algorithm into test harness
- Use MATLAB Coder to generate C source code from MATLAB algorithm
Implementation Constraints

- Polymorphism
- Memory allocation
- Processing matrices & arrays
- Fixed-point data types

7 Lines of MATLAB
107 Lines of C
MATLAB Language Support for Code Generation

- Visualization
- Java
- Nested functions
- Cell arrays
- Graphics
- Sparse
- Variable-sized data
- Struct
- Global
- Complex
- Classes
- System objects
- Fixed-point
- Arrays
- Numeric
- Functions
- Alloc
- Persistent
**Supported MATLAB Language Features and Functions**

Broad set of language features and functions/system objects supported for code generation

<table>
<thead>
<tr>
<th>Matrices and Arrays</th>
<th>Data Types</th>
<th>Programming Constructs</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Matrix operations</td>
<td>• Complex numbers</td>
<td>• Arithmetic, relational, and logical operators</td>
<td>• MATLAB functions and subfunctions</td>
</tr>
<tr>
<td>• N-dimensional arrays</td>
<td>• Integer math</td>
<td>• Program control (if, for, while, switch)</td>
<td>• Variable-length argument lists</td>
</tr>
<tr>
<td>• Subscripting</td>
<td>• Double/single-precision</td>
<td></td>
<td>• Function handles</td>
</tr>
<tr>
<td>• Frames</td>
<td>• Fixed-point arithmetic</td>
<td></td>
<td>Supported algorithms</td>
</tr>
<tr>
<td>• Persistent variables</td>
<td>• Characters</td>
<td></td>
<td>• More than 1100 MATLAB operators, functions, and System objects for:</td>
</tr>
<tr>
<td>• Global variables</td>
<td>• Structures</td>
<td></td>
<td>• Communications</td>
</tr>
<tr>
<td></td>
<td>• Numeric class</td>
<td></td>
<td>• Computer vision</td>
</tr>
<tr>
<td></td>
<td>• Variable-sized data</td>
<td></td>
<td>• Image processing</td>
</tr>
<tr>
<td></td>
<td>• MATLAB Class</td>
<td></td>
<td>• Phased Array signal processing</td>
</tr>
<tr>
<td></td>
<td>• System objects</td>
<td></td>
<td>• Signal processing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Statistics</td>
</tr>
</tbody>
</table>
Supported Functions

- Aerospace Toolbox
- Communications System Toolbox
- Computer Vision System Toolbox
- DSP System Toolbox
- Image Processing Toolbox
- Phased Array System Toolbox
- Signal Processing Toolbox
- Statistics Toolbox

1100+
MATLAB Coder Use Cases

- Hand off C code to software engineers
- Integrate algorithms into C/C++ simulations
- Accelerate user-written MATLAB algorithms (via MEX)
- Migrate algorithms to embedded processors (using Embedded Coder)
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MATLAB Compiler and MATLAB Coder

MATLAB Compiler

for k=1:max
x = fft(dat)
y = 20*log10(x)
end

MATLAB Coder

.c, .cpp

.ex, .lib, .dll

MATLAB Compiler Runtime (MCR)
Implementing the Algorithm
Generate C Shared Library

- Integrate algorithm into test harness

- Use MATLAB Compiler to create C shared library from MATLAB algorithm
Deploying Applications with MATLAB

1. MATLAB Application
2. MATLAB Compiler
3. .dll

End-User Machine

Toolboxes

MATLAB Desktop

MathWorks
# MATLAB Compiler and MATLAB Coder

<table>
<thead>
<tr>
<th></th>
<th>MATLAB Compiler</th>
<th>MATLAB Coder</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output</strong></td>
<td>Executable or software component/library</td>
<td>Portable and readable C source code</td>
</tr>
<tr>
<td><strong>MATLAB language support</strong></td>
<td>Full</td>
<td>Subset</td>
</tr>
<tr>
<td><strong>Additional libraries</strong></td>
<td>MATLAB Compiler Runtime (MCR)</td>
<td>None</td>
</tr>
<tr>
<td><strong>Supported toolboxes</strong></td>
<td>Most toolboxes</td>
<td>Some toolboxes</td>
</tr>
<tr>
<td><strong>License model</strong></td>
<td>Royalty-free</td>
<td>Royalty-free</td>
</tr>
<tr>
<td><strong>Extensions</strong></td>
<td>Builder Products</td>
<td>Embedded Coder</td>
</tr>
</tbody>
</table>
Summary
Reduce Development Time and Cost

- Develop algorithm in MATLAB
  - High level language
  - Existing functions available within the MATLAB product family

- Move quickly to implementation
  - MATLAB Compiler and builders for deployable applications
  - MATLAB Coder for ANSI C code of algorithms

- Distribute your application freely
  - No need for a MATLAB license
Q&A