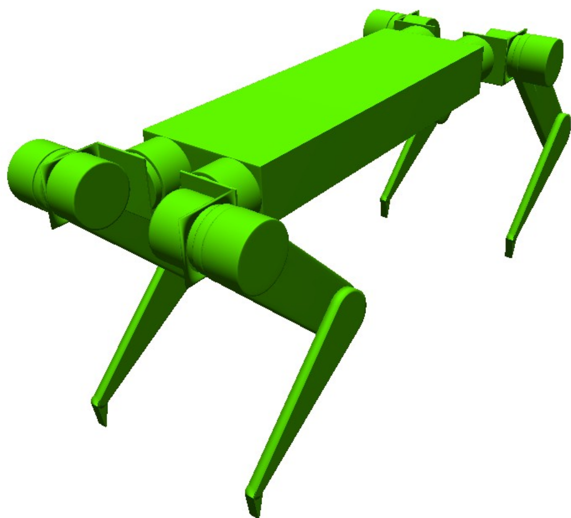
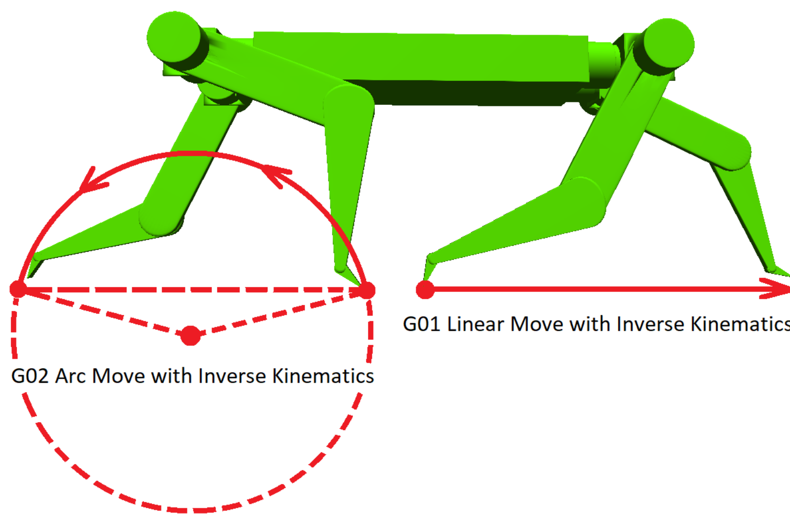
Programming Guide

Servosila Motion Controller

Revision D (December 2023)





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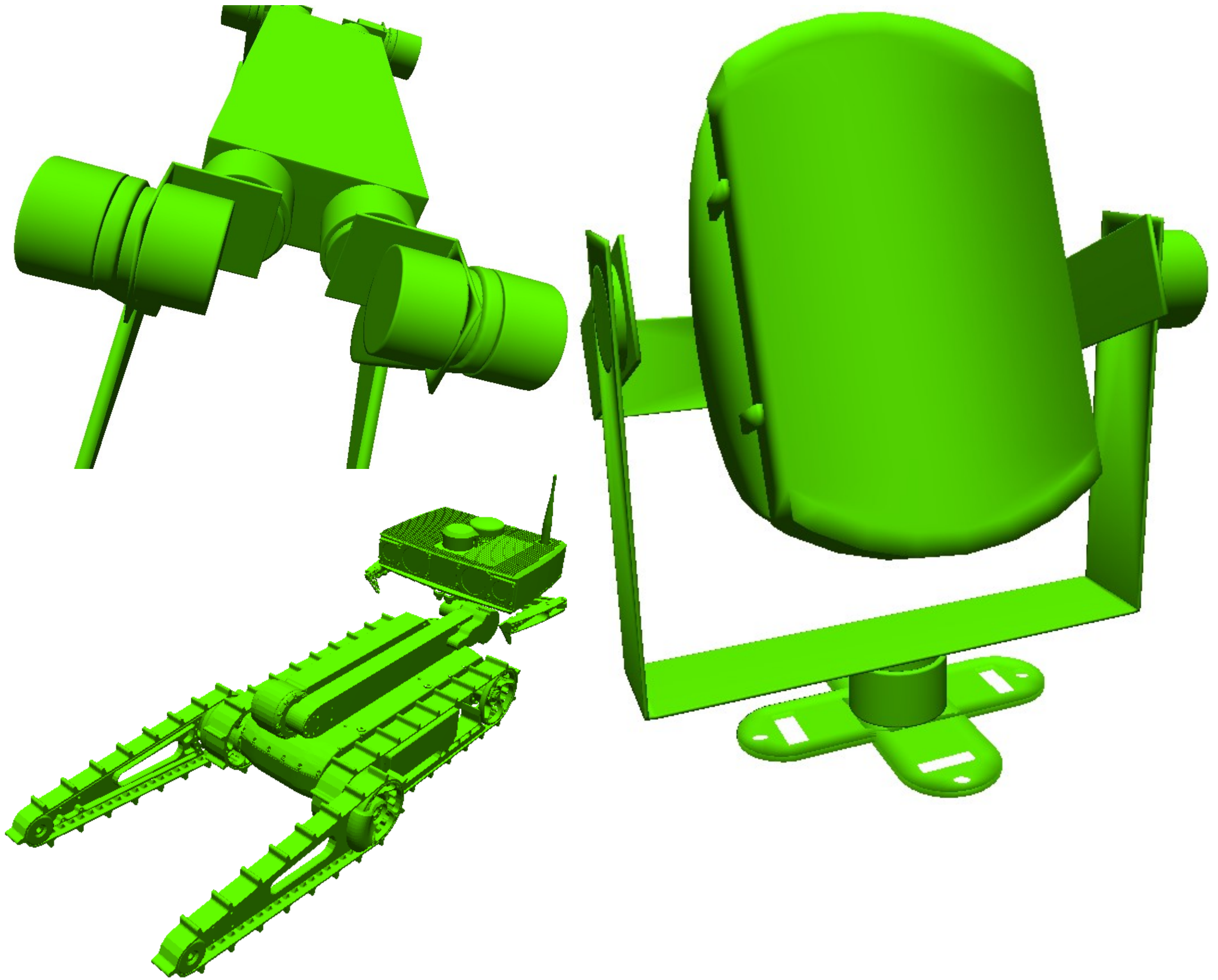
About Servosila Motion Controller

Servosila Motion Controller is embedded software for controlling motion of modern multi-axis robotic systems. The software runs on Linux, Windows or as a firmware on embedded MCUs.

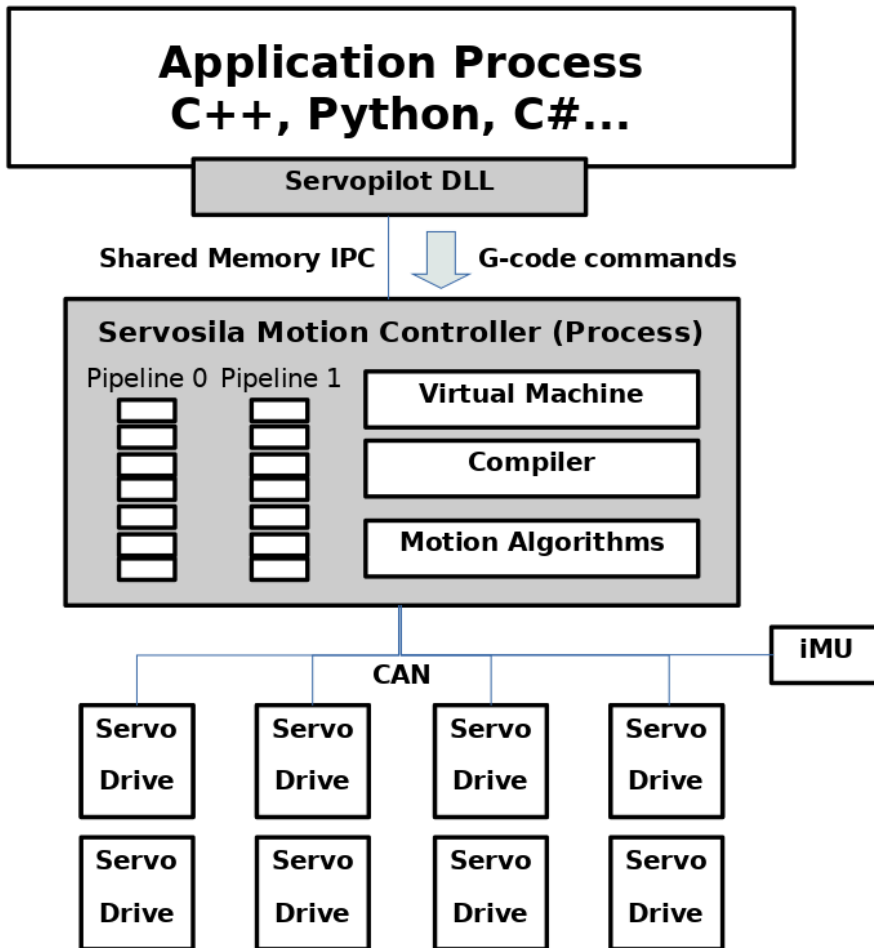


Servosila Motion Controller uses **G-code** for the following **purposes**:

- as a way to define **geometry** of coordinated motions in a text format,
- as a high-level communications **protocol** between the Motion Controller and higher-level user applications,
- as a simple **scripting language** for programming multi-axis robotic systems,
- as a target language for generative AI and LLMs.

Software Architecture

Servosila Motion Controller, shown as a gray box on an architecture diagram below, runs as a background process in Linux or Windows. The process communicates to *servo drives* via CAN or USB network. The *Motion Controller* process provides a low-latency shared memory interface for inter-process communication with a single *Application Process*, shown as a white box on the diagram. In order to abstract away complexities of the shared memory interface, a dynamically linked library called *Servopilot DLL*, is provided with the *Motion Controller*. The “thin” *DLL* exposes a much simpler API (as compared to the shared memory interface) for submitting G-code commands to the *Motion Controller* and for receiving telemetry and status information back. The DLL API is described in this document.



Internally, *Motion Controller* process has a *Pipeline 0* and a *Pipeline 1* for receiving G-code commands from an *Application Process*. The pipelines are cyclic buffers of a fixed size. There are two pipelines so that two independent streams of G-code commands could be executed in parallel if needed. When submitting a new G-code command, an *Application Process* may choose to append the command to one pipeline or the other, or to replace commands in a pipeline with a new set of commands.

The G-code commands are executed by a *Virtual Machine*, an internal component of the *Motion Controller* process. Since G-code commands are submitted by an *Application Process* in a text form, there is an internal *Compiler* that translates the text into an internal binary code understood by the *Virtual Machine*. It is possible to submit a single-line G-code command as well as a text of a complete G-code program. The *Compiler* processes the texts line-by-line and pushes the commands into *pipelines* for execution by the *Virtual Machine*. The *Virtual Machine* processes the pipelines on a “first in, first out” basis (FIFO).

The *Motion Controller* has a configurable *control loop frequency* (e. g. 500 Hz) that governs performance of the entire motion control system.

A single *Application Process* is allowed to attach to a single *Motion Control* process only. It is possible to run multiple *Motion Control* processes by assigning them unique `shared_memory_id`’s.

The *Servopilot DLL* API is not thread safe or re-entrant.

The application programs can be written in any programming language that supports loading dynamically linked libraries (DLL). The typical choices are C++, Python, C#, MATLAB, LabView.

Servopilot DLL API

Connecting to Motion Controller

```
extern "C" bool connect(int shared_memory_id);
```

```
extern "C" bool disconnect();
```

The `connect()` function attaches *Servopilot DLL* to a shared memory segment used for interprocess communication between an *Application Process* and the *Motion Controller* process. The *Motion Controller* process has a unique `shared_memory_id`, a preconfigured integer number. The function takes this ID as the only argument. The function returns `true` if a shared memory segment with the given identifier has been successfully attached to.

The `disconnect()` function detaches *Servopilot DLL* from the shared memory segment. Calling this routine at the end of an *Application Process* is optional.

Submitting G-code commands to Motion Controller process

```
extern "C" bool gcode(const char* program_text);
```

```
extern "C" bool gcode_replace(const char* program_text);
```

```
extern "C" bool execute (const char* program_text);
```

```
extern "C" bool execute_replace(const char* program_text);
```

The `gcode()` function pushed a G-code command or multiple commands to the pipelines of the *Motion Controller* process. All previous G-code commands that have been sitting in the pipelines are preserved. A pipeline is FIFO cyclic buffer. The new commands are appended to the pipelines to be executed after all the previous commands from the pipeline have been executed. The function does not wait for the commands to be actually executed; it just pushes the commands to the pipelines and returns.

The `gcode_replace()` function first clears all the pipelines and then pushes new commands into the pipelines for priority execution. As a result, the Motion Controller interrupts all ongoing motions and immediately continues with new motions defined by a newly received set G-code commands. Such a replacement can be done with the speed of *control loop frequency*, e. g. for torque-based control. The function does not wait for the new commands to be actually executed.

The `execute()` function is the same as `gcode()` except that the function's call returns only once the new G-code commands have been actually executed. Note that all previous commands that have been already sitting in the pipelines are executed first. An advantage of `execute()` over `gcode()` is in a simplicity of application control flow. A disadvantage is that an `execute()` call may stall the

Application Process for an extended period of time, for as much time as it takes to execute all G-code commands from all the pipelines.

The `execute_replace()` function is the same as `gcode_replace()` function except that the function's call returns only after the newly submitted commands have been actually executed.

	Clears the pipeline of previous G-code commands	**Waits until the new commands are actually executed thus stalling the *Application Process***
`gcode()`	No	No
`gcode_replace()`	**Yes**	No
`execute()`	No	**Yes**
`execute_replace()`	**Yes**	**Yes**

All the functions return `true` if the new G-code commands have been successfully submitted to the pipelines of the *Motion Controller* process for execution.

Process Synchronization

```
extern "C" int synchronize();
```

The `synchronize()` function allows the *Application Process* to wait until the *Motion Control* process finishes executing all previously submitted G-code commands. The function's call stalls until all pipelines are empty. This call may stall the *Application Process* for an extended period of time, for as much time as it takes to execute all G-code commands from all the pipelines.

Process State Management

```
extern "C" bool pause();

extern "C" bool resume();

extern "C" bool reset();

extern "C" int  get_mode();
```

This functions manage the state of Motion Controller process.

The `pause()` function temporarily suspends execution of G-code commands by the *Motion Controller* process. This function is used to pause operation of a robotic system. The operation is restarted using a `resume()` call.

The `reset()` function performs a "soft reset" of the Motion Controller. This includes:

- Clearing out all G-code pipelines. All previously submitted commands are lost.
- Resetting all error latches in the Motion Controller process.

The `get_mode()` function returns an indication of the current mode of operation, an internal state, of the *Motion Controller* process. The returned values are as the following:

Result of a `get_mode()` call	**A corresponding mode of operation of Motion Controller**
0	OFF
1	PAUSED
2	FAULT
3	RUNNING

Axes Telemetry

```
extern "C" double get_axis_cursor(int axis_number);
extern "C" double get_axis_position(int axis_number);
extern "C" int get_axis_work_zone_count(int axis_number);
extern "C" int get_axis_fault_bits(int axis_number);
extern "C" bool is_axis_online(int axis_number);
```

The `get_axis_cursor()` function returns a rotary or an angular reference position that the Motion Controller transmits as a commanded position to the axis at a particular moment. In contrast, `get_axis_position()` returns an actual telemetry position of the axis, where the axis physically is at a given moment. Since axes have physical inertia, the G-code program's virtual "cursor" axis position is usually ahead of the physical axis' actual position. The results of both `get_axis_cursor()` and `get_axis_position()` are returned in **millimeters** or **degrees** depending on the axis type (linear or rotary).

The `get_axis_work_zone_count()` function returns telemetry axis position in **encoder counts**.

The `get_axis_fault_bits()` function returns a Fault Bits data received from the axis via telemetry. Refer to your servo drive's Device Reference for information how to interpret the returned value. Zero (0) means "No Fault". Non-Zero (!=0) means some sort of a fault in the axis.

The `is_axis_online()` function tells whether or not the axis' servo controller is broadcasting telemetry on the CAN or USB network.

Example Application in Python

```
# This is a sample program that accompanies Servopilot PLC software for Servosila Brushless Motor Controllers.
#   https://www.servosila.com/en/motion-control
#

import ctypes
import time

# Before running this program:
#   1. Make sure the script is located in the same directory as servopilot-client.dll, or change the path to the DLL in the code below.
#   2. Make sure a Servopilot process is running and is connected to the same network (CAN or USB/Serial)
#           that your servo drive (axis) is connected to.
#   3. The Servopilot process
#       a) must have its Shared Memory Server API enabled in its configuration, so that the DLL could connect to the Servopilot process.
#       b) must have at least 1 axis (servo drive) added to the configuration.

# First, load Servopilot Client DLL.
#   If this fails, check the path to the DLL.
servopilot = ctypes.CDLL("./servopilot-client.dll")

# Second, connect the Servopilot Client DLL to the running Servopilot process via its Shared Memory API.
#   The only parameter (Shared Memory ID) must be the same as configured in the running Servopilot process.
#   If this fails, make sure that a Servopilot process is running, that Servopilot has its Shared Memory API enabled,
#       ...and that the Shared Memory ID in the call below matches the one configured in the process.
#   Returns false (0) if there is a problem, or true (1) if the connection attempt is successful.
connection_result = servopilot.connect(1)

#Handling connection result
if (connection_result==0) :
    print("Cannot connect to the Servopilot process. Connection result is "+str(connection_result))
    quit()

#Example starts here
#
#Gradually increase speed from 0 RPM to 3000 RPM.
for rpm in range(0, 3050, 50):
    # Formulating a G-code string that commands speed.
    #   For example, G1030 [0]1000 means "send Electronic Speed Control 1000 RPM command to Axis 0"
    command = "G1030 [0]"+str(rpm)
    print(command)
    # This line submits the G-code command to the Servopilot process for execution,
    #   ...but does not wait until the command is actually executed.
    # Note that the string's encoding needs to be changed to ASCII
    #...before submitting the string to the DLL as that is how the DLL wants it to be encoded.
    servopilot.gcode(command.encode("ascii"))
    # Letting the motor run for 1 second at the commanded speed before looping and increasing the speed again.
    time.sleep(1)

# This (optional) G-code de-energizes and resets all axes (motors).
#   Otherwise, the motor just keeps running after the program's execution is finished.
#   Note the symbol "b" before the string.
#   The symbol tells Python that the string constant needs to be encoded as ASCII binary array of characters.
#   This is how the DLL wants it to be encoded.
servopilot.gcode(b"G1000")

#The End :-)
```

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and

YouTube: http://www.youtube.com/user/servosila