DSM: Short Guide for User

Version 1.0

4th January 2019

Contents

Chapter 1

Introduction

1.1 Getting Help

The latest version of `DSM` and documentation can always be found at `https://github.com/echkon/dsm-deverlopers`.

1.2 Citation

We ask that you acknowledge the use of `DSM` in any publications arising from the use of this code through the following reference

[ref] L. B. Ho,

For the method, It would be appropriate to cite the original articles:

L. B. Ho, Improving direct state measurements by using rebits in real enlarged Hilbert spaces, Phys. Lett. A **383**, 289 (2019).
L. Maccone and C. C. Rusconi, State estimation: A comparison between direct state measurement and tomography, Phys. Rev. A **89**, 022122 (2014).
G. Vallone and D. Dequal, Strong Measurements Give a Better Direct Measurement of the Quantum Wave Function, Phys. Rev. Lett. **116**, 040502 (2016).

1.3 Credits

The present version of `DSM` was written by Le B. Ho (Kindai University, JP).

`DSM` is based on the Fortran 90 codes written for improving direct state measurement by Le B. Ho

Acknowledgements:

Licence

Chapter 2

Parameters

2.1 Usage

In this version, `dsm` can be run in serial only

For serial execution, go to /obj directory and use: `./dsm`

2.2 `input.in` File

The `DSM` input file `input.in` contains some controlled parameters. This file is free-style to write in any way. However, some keywords must be provided exactly. The following are keywords and description.

2.2.1 `string :: qu_state`

Name of quantum state.

Syntax:

```
qu_state   name_n1_n2
```

where

- `name`(string) can be one of the following: `random`, `GHZ`, `W`, and `Dicke`.
- `n1` (integer): the dimension of the state if `name` is `random`, the number of qubits if `name` is `GHZ`, `W`, `Dicke`.
- `n2` (integer): only valid if `name` is `Dicke` describes the number of excited qubits.

For example

```
qu_state   Dicke_5_2
```

generates a Dicke state with 5 qubits including 2 spin-up qubits and 3 spin-down qubits, i.e., $|\texttt{Dicke}\rangle = |\uparrow\uparrow\downarrow\downarrow\downarrow\rangle$.

2.2.2 Other keywords

The other keywords are listed below:

Keyword	Type	Description
`qu_noise`	Real	set of white noise
`qu_status`	String	can be `pure` or `mixed`, option for random state only
`job`	String	can be `strong` or `weak`
`theta`	Real	interaction strength from 0 to $\pi/2$
`num_copies`	Integer	number of copies
`num_iter`	Integer	number of iteration
`plot_his`	Logical	Plot histogram if .true.
`check_cdf`	Logical	Plot histogram of cdf if .true.
`plot_N`	Integer	number of data need to plot
`plot_min`	Real	minimum bound for histogram
`plot_max`	Real	maximum bound for histogram

Table 2.1: `input.in` file keywords defining the system and some controlled parameters.

Chapter 3

Code Overview

The structure of `DSM` can be viewed as below:

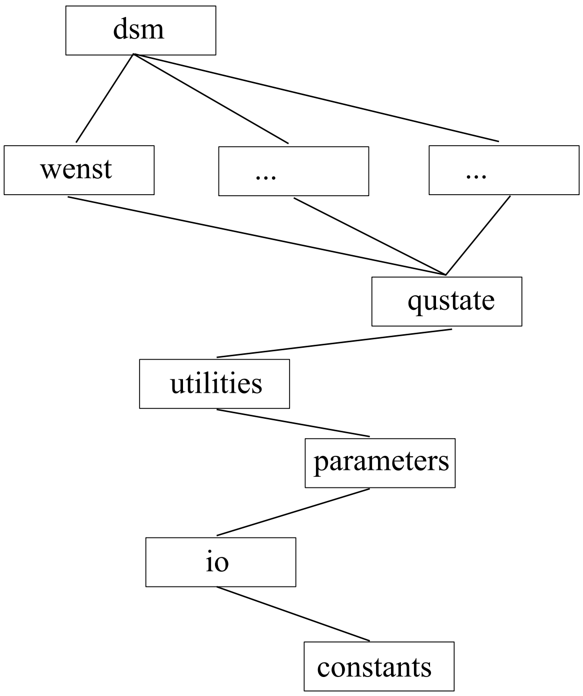

Figure 3.1: Schematic overview of the module structure of `DSM`. Upper modules can use data and subroutines from lower modules. Some of modules $\cdots$ are missing in this version.

Chapter 4

Sample Input Files

4.1 Input file: `input.in`

The input file is stored in /obj directory.

```
Input the information of the true state

qu_state  GHZ_3
qu_noise  0.15 # qu_noise = 0.0 for pure
qu_status  pure # option for random state only

Input the control parameters

job  weak
theta  0.001         # multiply by pi
num_copies  100
num_iter  100

Option plot_his for plot histogram random numbers

plot_his   F
check_cdf   T
plot_N  1000
plot_min  0.0
plot_max  1.0
```

Chapter 5

Check cdf: The cumulative distribution function

To run the check cdf, turn `check_cdf` in the `input.in` in to T

Run `./dsm`

Then plot file `hist_out`

5.1 Background: The CDF method

The simulation method used in `DSM` is based on the cumulative distribution function. Assume that the probability distribution of a measurement is $p(x)$, in general, a function of x. The CDF function is defined to be

$$F(y) = \int_{-\infty}^{y} p(x)dx. \tag{5.1}$$

Given a uniform random variable $r \in (0, 1)$ then $y = F^{-1}(r)$ is distribute as $p(x)$.

5.2 Example

To illustrate, let us choose $p(x) = e^{-x}, x > 0$, and therefore the cumulative distribution is $F(y) = 1 - e^{-y}$. Then, for a random number r, the corresponding y yields:

$$y = -log(1 - r). \tag{5.2}$$

In the figure below, we plot $p(x)$ and the histogram of y.

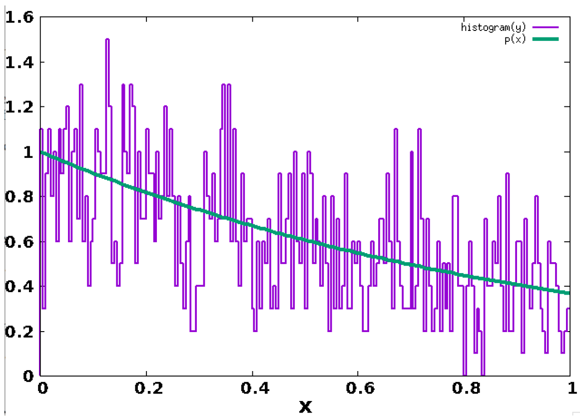

Figure 5.1: Plot of $p(x)$ and histogram of y.