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-developers.

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 the 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:

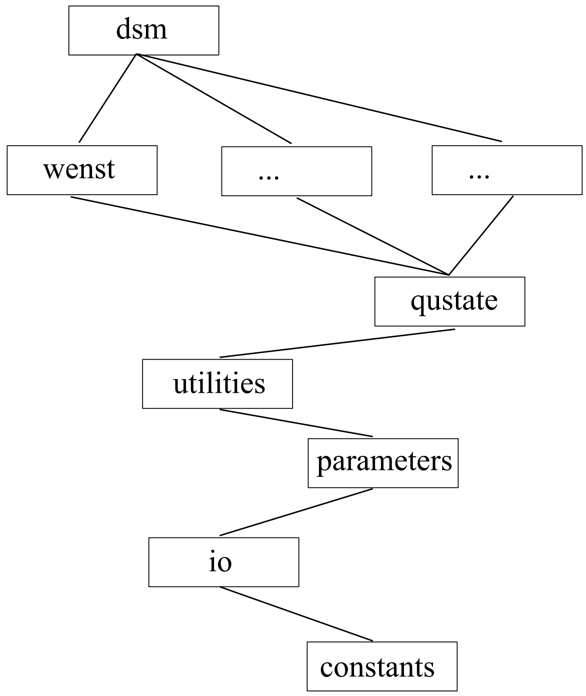

Figure 3.1: Schematic overview of the module structure of `DSM`. Upper modules can use data and subroutines from lower modules. Some of the modules as $\cdots$ are missing in this version.

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` into `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 distributed 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.

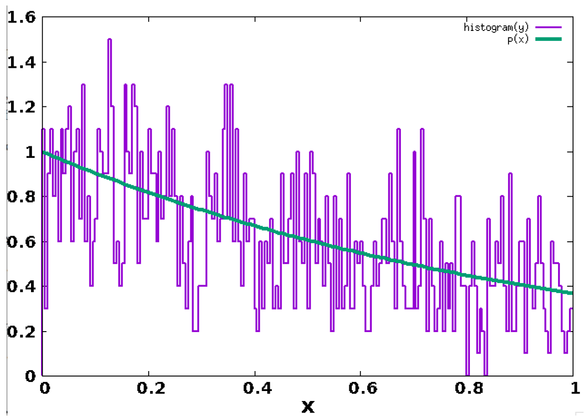

Figure 5.1: Plot of $p(x)$ and histogram of y.