Glass Breaking

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Purpose

The main **purpose** of this project is to develop a scientific software called Glass-BR following a rational document driven process.
In the end, Glass-BR should be able to predict whether a *specified* glass slab is likely to resist a *specified* blast.

Inputs

The software will need the following inputs:

1. **Glass Characteristics**
    - **Glass Type** - *AN* (Annealed Glass), *FT* (Fully Tempered Glass), *HS* (Heat Strengthened Glass)
    - **Glass Dimensions - a** (length of the glass slab), **b** (breadth of the glass slab), **t** (nominal thickness of the glass slab)

   Using these data we can calculate the **probability of glass breakage**.
2. **Tolerable Probability of Glass Breakage**
3. **Blast Characteristics**
    - **SD (Stand Off Distance)** - SD_x, SD_y, SD_z
    - **TNT (TNT Equivalent Factor)**
    - **w (Charge Weight)**

∗ NOTE: Be careful of the data constraints.

Outputs

The software should output the following quantities:

1. **Input values & Known values**
   - **Input values** - GT, a, b, t, P_{btol}, SD_x, SD_y, SD_z, TNT, w
     $*$ NOTE: If any of these input data violates the input constraints, it will throw an error.
   - **Known values** - m k (surface flaw parameters), E (modulus of elasticity), t_d (duration of the load), LDF (Load Duration Factor), LSF (Load Share Factor)

2. Calculated values & Final result

- **Calculated values**

  Probability of breakage P_b $P_b = 1 - e^{-B}$ where B is the risk of failure

  Actual thickness h $h = h(t)$

  Stress Distribution Factor J $J = J(\hat{q}, \frac{a}{b})$

  Dimensionless load $\hat{q}$ $\hat{q} = \frac{q(ab)^2}{Eh^4 GTF}$

  Aspect Ratio AR $AR = \frac{a}{b}$

  Load Resistance LR $LR = NFL \times GTF \times LSF$

  Non-Factored Load NFL $NFL = \frac{\hat{q}_{tol} Eh^4}{(ab)^2}$

  Tolerable load $\hat{q}_{tol}$ $\hat{q}_{tol}(J_{tol}, \frac{a}{b})$

  Tolerable Stress Distribution Factor J_{tol}

  $$J_{tol} = ln[ln(\frac{1}{1-P_{btol}})\frac{(\frac{a}{1000}\times\frac{b}{1000})^{m-1}}{k((E\times 1000)(\frac{h}{1000})^2)^m LDF}]$$

  Glass Type Factor GTF $AN \Rightarrow 1.0$ $FT \Rightarrow 4.0$ $HS \Rightarrow 2.0$

  Applied load (demand) q $q = q(w_{TNT}, SD)$

2. **Calculated values & Final result**

- **Final result**

  Compare:

  - **Tolerable probability of breakage** (input) & **Probability of breakage** (calculated / output)
    if $P_{btol} > P_b$, then *True*; else, *False*.
  - **Load Resistance** (calculated / output) & **Demand** (calculated / output)
    if $LR > q$, then *True*; else, *False*.

  Both *True*, output the message "For the given input parameters, the glass is considered safe";
  Otherwise, output the message "For the given input parameters, the glass is **NOT** considered safe".

The Overall System Design

Decompose into modules.

Level 1	**Level 2**	**Implemented by**
Hardware-Hiding Module		OS
Behaviour-Hiding Module	Input Format Module Input Parameters Module Input Constraints Module Output Format Module Derived Values Module Calculations Module Interpolation Data Module Control Module	Glass-BR
Software Decision Module	Interpolation Module	Glass-BR

Hardware-Hiding Module provides the interface between the hardware and the software.

Input Format Module converts the input data into the data structure used by the Input Parameters Module. (reads from a file)

Input Parameters Module stores the parameters needed for the program. (defines a class "Param")

Input Constraints Module defines the constraints on the input data.

Output Format Module outputs the results of the program. (writes to a file)

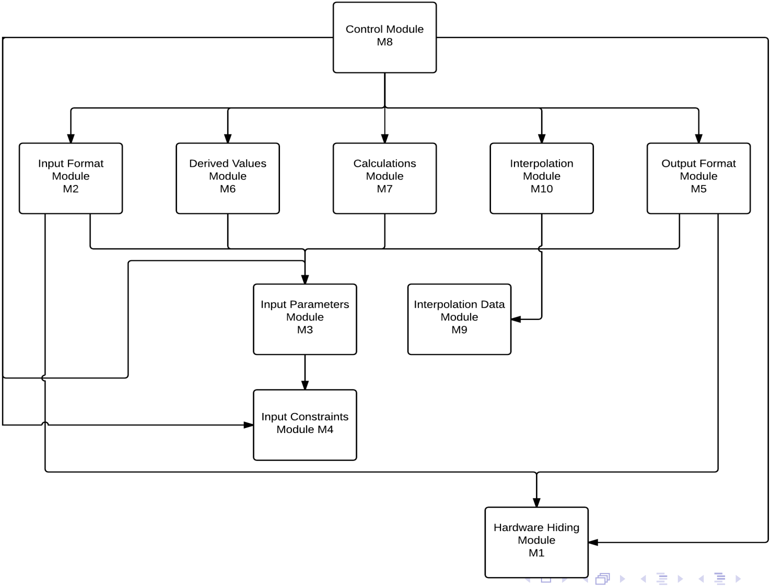
Derived Values Module defines the equations transforming the initial inputs into derived quantities. (e.g. GTF: $AN \Rightarrow 1.0$)

Calculations Module defines the equations for solving for P_b, q and LR.

Control Module provides the main program.

Interpolation Data Module converts the input interpolation data into the data structure used by Interpolation Module. (reads from a file)

Interpolation Module provides the equations that take the input parameters and interpolation data and return an interpolated value.


Control Module
M8
Input Format
Module
M2
Derived Values
Module
M6
Calculations
Module
M7
Interpolation
Module
M10
Output Format
Module
M5
Input Parameters
Module
M3
Interpolation Data
Module
M9
Input Constraints
Module M4
Hardware Hiding
Module
M1

How to Execute

Level 1	Level 2	Written in
Hardware-Hiding Module		-
Behaviour-Hiding Module	Input Format Module	Python
	Input Parameters Module	Python
	Input Constraints Module	Python
	Output Format Module	Python
	Derived Values Module	Python
	Calculations Module	Python
	Interpolation Data Module	Python (NumPy)
	Control Module	Python
Software Decision Module	Interpolation Module	Python (NumPy)

Some Test Cases

1 **Safe**:

- **Inputs**:

length a	1600	mm
breadth b	1500	mm
thickness t	10	mm
glass type	*HS*	-
weight of charge w	10	kg
TNT equivalent factor	1.0	-
SD_x	0	m
SD_y	1.5	m
SD_z	11.0	m
Tolerable probability P_{btol}	0.008	-

- **Outputs**:

E	7.17×10^7	SD	11.101802
a	1600	t_d	3
b	1500	TNT	1.0
AR	1.066667	w	10.0
$glasstype$	HS	w_{TNT}	10.0
GTF	2	q	3.258286
t	10.0	J	9.548952
h	9.02	$\hat{q}_{tol}$	4.152349×10^1
k	2.86×10^{-53}	P_b	1.301525×10^{-4}
LDF	0.269649	LR	6.843002
LSF	1	NFL	3.421501
m	7	$SafetyRequirement-1$	1.000000
P_{btol}	0.008	$SafetyRequirement-2$	1.000000
SD_{vect}	(0.0, 1.5, 11.0)		

"For the given input parameters, the glass is considered safe."

2 NOT safe

- **Inputs**

length a	1600	mm
breadth b	1500	mm
thickness t	5	mm
glass type	AN	-
weight of charge w	10	kg
TNT equivalent factor	1.0	-
SD_x	0	m
SD_y	1.5	m
SD_z	11.0	m
Tolerable probability P_{btol}	0.008	-

- **Outputs**

E	7.17×10^{7}	SD	11.101802
a	1600	t_d	3
b	1500	TNT	1.0
AR	1.066667	w	10.0
$glasstype$	AN	w_{TNT}	10.0
GTF	1	q	3.258286
t	5.0	J	2.704263×10^{1}
h	4.57	$\hat{q}_{tol}$	2.966019×10^{2}
k	2.86×10^{-53}	P_b	3.149685×10^{-1}
LDF	0.269649	LR	1.610406
LSF	1	NFL	1.610406
m	7	$SafetyRequirement - 1$	0.000000
P_{btol}	0.008	$SafetyRequirement - 2$	0.000000
SD_{vect}	(0.0, 1.5, 11.0)		

"For the given input parameters, the glass is NOT considered safe."

Thank You!