

ceras

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# Chapter 1

## Namespace Index

### 1.1 Namespace List

Here is a list of all namespaces with brief descriptions:

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<a href="#">ceras::ceras_private</a>	62
<a href="#">ceras::dataset</a>	63
<a href="#">ceras::dataset::fashion_mnist</a>	63
<a href="#">ceras::dataset::mnist</a>	63



## Chapter 2

# Hierarchical Index

### 2.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

ceras::compiled_model< Model, Optimizer, Loss > . . . . .	74
ceras::complex< Real_Ex, Imag_Ex > . . . . .	79
enable_id	
ceras::adadelta< Loss, T > . . . . .	65
ceras::adagrad< Loss, T > . . . . .	67
ceras::adam< Loss, T > . . . . .	69
ceras::binary_operator< Lhs_Operator, Rhs_Operator, Forward_Action, Backward_Action > . . . . .	71
ceras::constant< Tsor > . . . . .	80
ceras::gradient_descent< Loss, T > . . . . .	82
ceras::place_holder< Tsor > . . . . .	95
ceras::rmsprop< Loss, T > . . . . .	100
ceras::sgd< Loss, T > . . . . .	106
ceras::tensor< T, Allocator > . . . . .	109
ceras::unary_operator< Operator, Forward_Action, Backward_Action > . . . . .	119
ceras::value< T > . . . . .	122
ceras::variable< Tsor > . . . . .	124
enable_shared	
ceras::adadelta< Loss, T > . . . . .	65
ceras::adagrad< Loss, T > . . . . .	67
ceras::adam< Loss, T > . . . . .	69
ceras::gradient_descent< Loss, T > . . . . .	82
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enable_shared_state	
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std::false_type	
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ceras::is_variable< T > . . . . .	88
ceras::model< Ex, Ph > . . . . .	89

ceras::place_holder_state< Tsor > . . . . .	98
ceras::regularizer< Float > . . . . .	98
ceras::regularizer< value_type > . . . . .	98
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ceras::tensor_deduction< L, R > . . . . .	119
ceras::tensor_deduction< Lhs_Operator, Rhc_Operator > . . . . .	119
std::true_type	
ceras::is_binary_operator< binary_operator< Lhs_Operator, Rhc_Operator, Forward_Action, Backward_Action > > . . . . .	84
ceras::is_complex< complex< Real_Ex, Imag_Ex > > . . . . .	84
ceras::is_constant< constant< Tsor > > . . . . .	85
ceras::is_place_holder< place_holder< Tsor > > . . . . .	86
ceras::is_tensor< tensor< T, A > > . . . . .	86
ceras::is_unary_operator< unary_operator< Operator, Forward_Action, Backward_Action > > . . . .	87
ceras::is_value< value< T > > . . . . .	88
ceras::is_variable< variable< Tsor > > . . . . .	88
ceras::variable_state< Tsor > . . . . .	129
ceras::view< T, N > . . . . .	130
ceras::view_1d< T > . . . . .	131
ceras::view_2d< T > . . . . .	132
ceras::view_3d< T > . . . . .	138
ceras::view_4d< T > . . . . .	140



## Chapter 3

# Class Index

### 3.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

<a href="#">ceras::adadelta&lt; Loss, T &gt;</a>	65
<a href="#">ceras::adagrad&lt; Loss, T &gt;</a>	67
<a href="#">ceras::adam&lt; Loss, T &gt;</a>	69
<a href="#">ceras::binary_operator&lt; Lhs_Operator, Rhs_Operator, Forward_Action, Backward_Action &gt;</a>	71
<a href="#">ceras::compiled_model&lt; Model, Optimizer, Loss &gt;</a>	74
<a href="#">ceras::complex&lt; Real_Ex, Imag_Ex &gt;</a>	79
<a href="#">ceras::constant&lt; Tzor &gt;</a>	
Creates a constant expression from a tensor-like object	80
<a href="#">ceras::gradient_descent&lt; Loss, T &gt;</a>	82
<a href="#">ceras::is_binary_operator&lt; T &gt;</a>	83
<a href="#">ceras::is_binary_operator&lt; binary_operator&lt; Lhs_Operator, Rhs_Operator, Forward_Action, Backward_Action &gt; &gt;</a>	84
<a href="#">ceras::is_complex&lt; T &gt;</a>	84
<a href="#">ceras::is_complex&lt; complex&lt; Real_Ex, Imag_Ex &gt; &gt;</a>	84
<a href="#">ceras::is_constant&lt; T &gt;</a>	85
<a href="#">ceras::is_constant&lt; constant&lt; Tzor &gt; &gt;</a>	85
<a href="#">ceras::is_place_holder&lt; T &gt;</a>	85
<a href="#">ceras::is_place_holder&lt; place_holder&lt; Tzor &gt; &gt;</a>	86
<a href="#">ceras::is_tensor&lt; T &gt;</a>	86
<a href="#">ceras::is_tensor&lt; tensor&lt; T, A &gt; &gt;</a>	86
<a href="#">ceras::is_unary_operator&lt; T &gt;</a>	87
<a href="#">ceras::is_unary_operator&lt; unary_operator&lt; Operator, Forward_Action, Backward_Action &gt; &gt;</a>	87
<a href="#">ceras::is_value&lt; T &gt;</a>	87
<a href="#">ceras::is_value&lt; value&lt; T &gt; &gt;</a>	88
<a href="#">ceras::is_variable&lt; T &gt;</a>	88
<a href="#">ceras::is_variable&lt; variable&lt; Tzor &gt; &gt;</a>	88
<a href="#">ceras::model&lt; Ex, Ph &gt;</a>	89
<a href="#">ceras::place_holder&lt; Tzor &gt;</a>	95
<a href="#">ceras::place_holder_state&lt; Tzor &gt;</a>	98
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<a href="#">ceras::rmsprop&lt; Loss, T &gt;</a>	100
<a href="#">ceras::ceras_private::session&lt; Tzor &gt;</a>	102
<a href="#">ceras::sgd&lt; Loss, T &gt;</a>	106
<a href="#">ceras::tensor&lt; T, Allocator &gt;</a>	109
<a href="#">ceras::tensor_deduction&lt; L, R &gt;</a>	119

<a href="#">ceras::unary_operator&lt; Operator, Forward_Action, Backward_Action &gt;</a>	<a href="#">119</a>
<a href="#">ceras::value&lt; T &gt;</a>	<a href="#">122</a>
<a href="#">ceras::variable&lt; Tsor &gt;</a>	<a href="#">124</a>
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# File Index

### 4.1 File List

Here is a list of all files with brief descriptions:

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## Chapter 5

# Namespace Documentation

### 5.1 ceras Namespace Reference

#### Namespaces

- [ceras\\_private](#)
- [dataset](#)

#### Classes

- struct [complex](#)
- struct [is\\_complex](#)
- struct [is\\_complex< complex< Real\\_Ex, Imag\\_Ex > >](#)
- struct [constant](#)  
*Creates a constant expression from a tensor-like object.*
- struct [is\\_constant](#)
- struct [is\\_constant< constant< Tsor > >](#)
- struct [compiled\\_model](#)
- struct [model](#)
- struct [unary\\_operator](#)
- struct [binary\\_operator](#)
- struct [is\\_unary\\_operator](#)
- struct [is\\_unary\\_operator< unary\\_operator< Operator, Forward\\_Action, Backward\\_Action > >](#)
- struct [is\\_binary\\_operator](#)
- struct [is\\_binary\\_operator< binary\\_operator< Lhs\\_Operator, Rhc\\_Operator, Forward\\_Action, Backward\\_Action > >](#)
- struct [sgd](#)
- struct [adagrad](#)
- struct [rmsprop](#)
- struct [adadelat](#)
- struct [adam](#)
- struct [gradient\\_descent](#)
- struct [place\\_holder\\_state](#)
- struct [place\\_holder](#)
- struct [is\\_place\\_holder](#)
- struct [is\\_place\\_holder< place\\_holder< Tsor > >](#)
- struct [tensor](#)
- struct [is\\_tensor](#)

- struct [is\\_tensor](#)< [tensor](#)< T, A > >
- struct [view\\_1d](#)
- struct [view\\_2d](#)
- struct [view\\_3d](#)
- struct [view\\_4d](#)
- struct [view](#)
- struct [value](#)
- struct [is\\_value](#)
- struct [is\\_value](#)< [value](#)< T > >
- struct [tensor\\_deduction](#)
- struct [variable\\_state](#)
- struct [regularizer](#)
- struct [variable](#)
- struct [is\\_variable](#)
- struct [is\\_variable](#)< [variable](#)< Tsor > >

## Typedefs

- template<typename Loss , typename T >  
using [ada\\_grad](#) = [adagrad](#)< Loss, T >
- template<typename Loss , typename T >  
using [rms\\_prop](#) = [rmsprop](#)< Loss, T >
- template<typename Loss , typename T >  
using [ada\\_delta](#) = [adadelta](#)< Loss, T >
- template<typename T >  
using [default\\_allocator](#) = std::allocator< T >
- template<typename T >  
using [array](#) = [view\\_1d](#)< T >
- template<typename T >  
using [matrix](#) = [view\\_2d](#)< T >
- template<typename T >  
using [cube](#) = [view\\_3d](#)< T >
- template<typename T >  
using [tesseract](#) = [view\\_4d](#)< T >

## Functions

- template<Expression Ex>  
constexpr auto [softmax](#) (Ex const &ex) noexcept  
*Softmax activation function, an unary operator.*
- template<Expression Ex>  
auto [selu](#) (Ex const &ex) noexcept  
*Scaled Exponential Linear Unit (SELU) activation function, an unary operator. If  $x > 0$ , returns  $1.0507 x$ ; Otherwise, returns  $1.67326 * 1.0507 * (exp(x) - 1)$*
- template<Expression Ex>  
auto [softplus](#) (Ex const &ex) noexcept  
*Softplus function, an unary operator. Returns  $\log(exp(x) + 1)$ .*
- template<Expression Ex>  
auto [softsign](#) (Ex const &ex) noexcept  
*Softsign function, an unary operator. Returns  $x / (abs(x) + 1)$ .*
- template<Expression Ex>  
auto [sigmoid](#) (Ex const &ex) noexcept  
*Sigmoid function, an unary operator. Returns  $1 / (exp(-x) + 1)$ .*

- template<Expression Ex>  
auto **relu** (Ex const &ex) noexcept  
*Relu function, an unary operator. Returns  $x$  if positive, 0 otherwise.*
- template<Expression Ex>  
auto **relu6** (Ex const &ex) noexcept  
*Rectified Linear 6 function, an unary operator. Returns  $\min(\max(features, 0), 6)$ .*
- template<typename T>  
requires std::floating\_point< T > auto **leaky\_relu** (T const factor=0.2) noexcept  
*Leaky Rectified Linear function, an unary operator. Returns  $x$  if positive,  $\alpha x$  otherwise.  $\alpha$  defaults to 0.2.*
- template<Expression Ex>  
auto **negative\_relu** (Ex const &ex) noexcept
- template<typename T = float>  
requires std::floating\_point< T > auto **elu** (T const alpha=1.0) noexcept  
*Exponential Linear function, an unary operator. Returns  $x$  if positive,  $\alpha \cdot (\exp(x) - 1)$  otherwise.  $\alpha$  defaults to 0.2.*
- template<Expression Ex>  
auto **exponential** (Ex const &ex) noexcept  
*Exponential function, an unary operator. Returns  $\exp(x)$ .*
- template<Expression Ex>  
auto **hard\_sigmoid** (Ex const &ex) noexcept  
*Hard Sigmoid function, an unary operator. Piecewise linear approximation of the sigmoid function.*
- template<Expression Ex>  
auto **gelu** (Ex const &ex) noexcept  
*Gaussian Error function, an unary operator. GAUSSIAN ERROR LINEAR UNITS (GELUS) <https://arxiv.org/pdf/1606.08415.pdf>  $f(x) = 0.5x (1 + \tanh[\sqrt{2/\pi}(x + 0.044715x^3)])$   $df = x (1 + \tanh[\sqrt{2/\pi}(x + 0.044715x^3)]) + \sqrt{2/\pi} x \operatorname{sech}^2[\sqrt{2/\pi}(x + 0.044715x^3)] (1 + 0.134145x^2)$  where  $\operatorname{sech}^2(x) = 1 - \tanh^2(x)$  derivative generated using service from <https://www.symbolab.com/solver/derivative-calculator>.*
- template<Expression Ex>  
auto **swish** (Ex const &ex) noexcept  
*Swish activation function.*
- template<Expression Ex>  
auto **silu** (Ex const &ex) noexcept  
*An alias name of activation swish.*
- template<Expression Ex>  
auto **crelu** (Ex const &ex) noexcept  
*Concatenated Rectified Linear Units, an activation function which preserves both positive and negative phase information while enforcing non-saturated non-linearity.*
- template<Expression Real\_Ex, Expression Imag\_Ex>  
Real\_Ex **real** (**complex**< Real\_Ex, Imag\_Ex > const &c) noexcept
- template<Expression Real\_Ex, Expression Imag\_Ex>  
Imag\_Ex **imag** (**complex**< Real\_Ex, Imag\_Ex > const &c) noexcept
- template<Complex C>  
auto **abs** (C const &c) noexcept  
*Returns the magnitude of the complex expression.*
- template<Complex C>  
auto **norm** (C const &c) noexcept  
*Returns the squared magnitude of the complex expression.*
- template<Complex C>  
auto **conj** (C const &c) noexcept  
*Returns the conjugate of the complex expression.*
- template<Expression Em, Expression Ep>  
auto **polar** (Em const &em, Ep const &ep) noexcept

*Returns with given magnitude and phase angle.*

- template<Complex C>

auto [arg](#) (C const &c) noexcept

*Calculates the phase angle (in radians) of the complex expression.*

- template<Complex C>

auto [operator+](#) (C const &c) noexcept

*Returns the complex expression.*

- template<Complex C>

auto [operator-](#) (C const &c) noexcept

*Negatives the complex expression.*

- template<Complex Cl, Complex Cr>

auto [operator+](#) (Cl const &cl, Cr const &cr) noexcept

*Sums up two complex expressions.*

- template<Complex Cl, Complex Cr>

auto [operator-](#) (Cl const &cl, Cr const &cr) noexcept

*Subtracts one complex expression from the other one.*

- template<Complex Cl, Complex Cr>

auto [operator\\*](#) (Cl const &cl, Cr const &cr) noexcept

*Multiplies two complex expressions. Optimization here:  $(a+ib)*(c+id) = (ac-bd) + i(ad+bc) = (ac-bd) + i((a+b)*(c+d)-ac-bd)$*

- template<Complex C, Expression E>

auto [operator+](#) (C const &c, E const &e) noexcept

*Sums up a complex expression and an expression.*

- template<Complex C, Expression E>

auto [operator+](#) (E const &e, C const &c) noexcept

*Sums up a complex expression and an expression.*

- template<Complex C, Expression E>

auto [operator-](#) (C const &c, E const &e) noexcept

*Subtracts an expression from a complex expression.*

- template<Complex C, Expression E>

auto [operator-](#) (E const &e, C const &c) noexcept

*Subtracts a complex expression from an expression.*

- template<Complex C, Expression E>

auto [operator\\*](#) (C const &c, E const &e) noexcept

*Multiplies a complex expression with an expression.*

- template<Complex C, Expression E>

auto [operator\\*](#) (E const &e, C const &c) noexcept

*Multiplies an expression with a complex expression.*

- auto [Input](#) ()

- auto [Conv2D](#) (unsigned long output\_channels, std::vector< unsigned long > const &kernel\_size, std::vector< unsigned long > const &input\_shape, std::string const &padding="valid", std::vector< unsigned long > const &strides={1, 1}, std::vector< unsigned long > const &dilations={1, 1}, bool use\_bias=true, float kernel\_regularizer\_l1=0.0f, float kernel\_regularizer\_l2=0.0f, float bias\_regularizer\_l1=0.0f, float bias\_regularizer\_l2=0.0f)

*2D convolution layer.*

- auto [Dense](#) (unsigned long output\_size, unsigned long input\_size, bool use\_bias=true, float kernel\_regularizer\_l1=0.0f, float kernel\_regularizer\_l2=0.0f, float bias\_regularizer\_l1=0.0f, float bias\_regularizer\_l2=0.0f)

*Densely-connected layer.*

- auto [BatchNormalization](#) (std::vector< unsigned long > const &shape, float threshold=0.95f, float kernel\_regularizer\_l1=0.0f, float kernel\_regularizer\_l2=0.0f, float bias\_regularizer\_l1=0.0f, float bias\_regularizer\_l2=0.0f)

*Applies a transformation that maintains the mean output close to 0 and the output standard deviation close to 1.*



- auto [BatchNormalization](#) (float threshold, std::vector< unsigned long > const &shape, float kernel\_regularizer\_l1=0.0f, float kernel\_regularizer\_l2=0.0f, float bias\_regularizer\_l1=0.0f, float bias\_regularizer\_l2=0.0f)
- auto [Concatenate](#) (unsigned long axis=-1) noexcept
- auto [Add](#) () noexcept
- auto [Subtract](#) () noexcept
- auto [Multiply](#) () noexcept
- template<Expression Ex>  
auto [ReLU](#) (Ex const &ex) noexcept
- auto [Softmax](#) () noexcept
- template<typename T = float>  
auto [LeakyReLU](#) (T const factor=0.2) noexcept
- template<typename T = float>  
auto [ELU](#) (T const factor=0.2) noexcept
- auto [Reshape](#) (std::vector< unsigned long > const &new\_shape, bool include\_batch\_flag=true) noexcept
- auto [Flatten](#) () noexcept
- auto [MaxPooling2D](#) (unsigned long stride) noexcept
- auto [UpSampling2D](#) (unsigned long stride) noexcept
- template<typename T >  
auto [Dropout](#) (T factor) noexcept
- auto [AveragePooling2D](#) (unsigned long stride) noexcept
- template<Expression Lhs\_Expression, Expression Rhs\_Expression>  
constexpr auto [mean\\_squared\\_logarithmic\\_error](#) (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- template<Expression Lhs\_Expression, Expression Rhs\_Expression>  
constexpr auto [squared\\_loss](#) (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- template<Expression Lhs\_Expression, Expression Rhs\_Expression>  
constexpr auto [mean\\_squared\\_error](#) (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- template<Expression Lhs\_Expression, Expression Rhs\_Expression>  
constexpr auto [mse](#) (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- template<Expression Lhs\_Expression, Expression Rhs\_Expression>  
constexpr auto [abs\\_loss](#) (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- template<Expression Lhs\_Expression, Expression Rhs\_Expression>  
constexpr auto [mean\\_absolute\\_error](#) (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- template<Expression Lhs\_Expression, Expression Rhs\_Expression>  
constexpr auto [mae](#) (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- template<Expression Lhs\_Expression, Expression Rhs\_Expression>  
constexpr auto [cross\\_entropy](#) (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- template<Expression Lhs\_Expression, Expression Rhs\_Expression>  
constexpr auto [binary\\_cross\\_entropy\\_loss](#) (Lhs\_Expression const &ground\_truth, Rhs\_Expression const &prediction) noexcept
- template<Expression Lhs\_Expression, Expression Rhs\_Expression>  
constexpr auto [cross\\_entropy\\_loss](#) (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- template<Expression Lhs\_Expression, Expression Rhs\_Expression>  
constexpr auto [hinge\\_loss](#) (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- template<Expression Lhs\_Expression, Expression Rhs\_Expression, std::floating\_point FP>  
auto [binary\\_accuracy](#) (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex, FP threshold=0.5) noexcept
- template<Expression Ex>  
void [make\\_trainable](#) (Ex &ex, bool t)
- template<Expression Ex, Place\_Holder Ph, Expression Ey>  
auto [replace\\_placeholder\\_with\\_expression](#) (Ex const &ex, Ph const &old\_place\_holder, Ey const &new\_expression)

- `template<typename Model , typename Optimizer , typename Loss >`  
`auto make\_compiled\_model (Model const &m, Loss const &l, Optimizer const &o)`
- `template<Expression Ex>`  
`std::string computation\_graph (Ex const &ex) noexcept`
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto plus (Lhs_Expression const &lhs_ex, Rhs_Expression const &rhs_ex) noexcept`
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto operator+ (Lhs_Expression const &lhs_ex, Rhs_Expression const &rhs_ex) noexcept`
- `template<Expression Ex>`  
`constexpr auto operator+ (Ex const &ex) noexcept`
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`auto operator\* (Lhs_Expression const &lhs_ex, Rhs_Expression const &rhs_ex) noexcept`
- `template<Expression Ex>`  
`constexpr auto negative (Ex const &ex) noexcept`
- `template<Expression Ex>`  
`constexpr auto operator- (Ex const &ex) noexcept`
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto elementwise\_product (Lhs_Expression const &lhs_ex, Rhs_Expression const &rhs_ex) noexcept`
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto elementwise\_multiply (Lhs_Expression const &lhs_ex, Rhs_Expression const &rhs_ex) noexcept`
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto hadamard\_product (Lhs_Expression const &lhs_ex, Rhs_Expression const &rhs_ex) noexcept`
- `template<Expression Ex>`  
`constexpr auto sum\_reduce (Ex const &ex) noexcept`
- `template<Expression Ex>`  
`constexpr auto reduce\_sum (Ex const &ex) noexcept`
- `template<Expression Ex>`  
`constexpr auto mean\_reduce (Ex const &ex) noexcept`  
*Computes the mean of elements across all dimensions of an expression.*
- `template<Expression Ex>`  
`constexpr auto reduce\_mean (Ex const &ex) noexcept`  
*An alias name of [mean\\_reduce](#).*
- `template<Expression Ex>`  
`constexpr auto mean (Ex const &ex) noexcept`  
*An alias name of [mean\\_reduce](#).*
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto minus (Lhs_Expression const &lhs_ex, Rhs_Expression const &rhs_ex) noexcept`
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto operator- (Lhs_Expression const &lhs_ex, Rhs_Expression const &rhs_ex) noexcept`
- `template<Expression Ex>`  
`constexpr auto square (Ex const &ex) noexcept`
- `template<Place_Holder Ph>`  
`bool operator== (Ph const &lhs, Ph const &rhs)`
- `template<Place_Holder Ph>`  
`bool operator!= (Ph const &lhs, Ph const &rhs)`
- `template<Place_Holder Ph>`  
`bool operator< (Ph const &lhs, Ph const &rhs)`
- `template<Place_Holder Ph>`  
`bool operator> (Ph const &lhs, Ph const &rhs)`
- `template<Place_Holder Ph>`  
`bool operator<= (Ph const &lhs, Ph const &rhs)`
- `template<Place_Holder Ph>`  
`bool operator>= (Ph const &lhs, Ph const &rhs)`

- `auto lstm` (`std::unsigned long units`) `noexcept`
- `template<Tensor Tsor>`  
`ceras_private::session< Tsor > & get_default_session ()`
- `template<typename T , typename A = default_allocator<T>>`  
`constexpr tensor< T, A > as_tensor (T val) noexcept`
- `template<Tensor Tsor, typename CharT , typename Traits >`  
`std::basic_ostream< CharT, Traits > & operator<< (std::basic_ostream< CharT, Traits > &os_, Tsor const &tsor)`
- `template<typename T >`  
`requires std::floating_point< T > void gemm_cpu (T const *A, bool a_transposed, T const *B, bool b_transposed, unsigned long m, unsigned long n, unsigned long k, T *C)`
- `void update_cuda_gemm_threshold ()`
- `template<typename T >`  
`requires std::floating_point< T > void gemm (T const *A, bool a_transposed, T const *B, bool b_transposed, unsigned long m, unsigned long n, unsigned long k, T *C)`
- `template<typename T >`  
`requires std::floating_point< T > void gemm (view_2d< T > const &x, view_2d< T > const &y, view_2d< T > &ans)`
- `template<Tensor Tsor>`  
`Tsor add (Tsor const &lhs, Tsor const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor operator+ (Tsor const &lhs, Tsor const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor operator+ (typename Tsor::value_type const &lhs, Tsor const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor operator+ (Tsor const &lhs, typename Tsor::value_type const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor minus (Tsor const &lhs, Tsor const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor operator- (Tsor const &lhs, Tsor const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor operator- (typename Tsor::value_type const &lhs, Tsor const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor operator- (Tsor const &lhs, typename Tsor::value_type const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor operator* (typename Tsor::value_type const &lhs, Tsor const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor operator* (Tsor const &lhs, typename Tsor::value_type const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor operator/ (Tsor const &lhs, typename Tsor::value_type const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor reshape (Tsor const &ts, std::vector< unsigned long > const &new_shape)`
- `template<Tensor Tsor>`  
`void multiply (Tsor const &lhs, Tsor const &rhs, Tsor &ans) noexcept`
- `template<Tensor Tsor>`  
`Tsor multiply (Tsor const &lhs, Tsor const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor operator* (Tsor const &lhs, Tsor const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor elementwise_product (Tsor const &lhs, Tsor const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor hadamard_product (Tsor const &lhs, Tsor const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor elementwise_divide (Tsor const &lhs, Tsor const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor repeat (Tsor const &tsor, unsigned long n)`

- `template<Tensor Tsor>`  
`Tsor reduce\_sum (Tsor const &tsor)`
- `template<Tensor Tsor>`  
`Tsor reduce\_mean (Tsor const &tsor)`
- `template<Tensor Tsor>`  
`Tsor clip (Tsor &tsor, typename Tsor::value_type lower=0, typename Tsor::value_type upper=1)`
- `template<Tensor Tsor>`  
`Tsor squeeze (Tsor const &tsor)`
- `template<typename T, typename A = default_allocator<T>>>`  
`tensor< T, A > randn (std::vector< unsigned long > const &shape, T mean=T{0}, T stddev=T{1})`
- `template<typename T, typename A = default_allocator<T>>>`  
`tensor< T, A > truncated\_normal (std::vector< unsigned long > const &shape, T mean=T{0}, T stddev=T{1}, T lower=T{0}, T upper=T{1})`
- `template<typename T, typename A = default_allocator<T>>>`  
`tensor< T, A > random (std::vector< unsigned long > const &shape, T min=T{0}, T max=T{1})`
- `template<Tensor Tsor>`  
`Tsor random\_like (Tsor const &tsor, typename Tsor::value_type min=0, typename Tsor::value_type max=1)`
- `template<Tensor Tsor>`  
`Tsor randn\_like (Tsor const &tsor, typename Tsor::value_type mean=0, typename Tsor::value_type stddev=1)`
- `template<typename T, typename A = default_allocator<T>>>`  
`tensor< T, A > glorot\_uniform (std::initializer_list< unsigned long > shape)`
- `template<Tensor Tsor>`  
`Tsor deep\_copy (Tsor const &tsor)`
- `template<Tensor Tsor>`  
`Tsor copy (Tsor const &tsor)`
- `template<Tensor Tsor>`  
`Tsor concatenate (Tsor const &lhs, Tsor const &rhs, unsigned long axis=0) noexcept`
- `template<Tensor Tsor>`  
`Tsor repmat (Tsor const &tsor, unsigned long row_rep, unsigned long col_rep)`
- `template<Tensor Tsor>`  
`constexpr bool empty (Tsor const &tsor) noexcept`
- `template<typename T, typename A = default_allocator<T>>>`  
`constexpr tensor< T, A > zeros (std::vector< unsigned long > const &shape)`
- `template<Tensor Tsor>`  
`constexpr Tsor zeros\_like (Tsor const &tsor)`
- `template<typename T, typename A = default_allocator<T>>>`  
`constexpr tensor< T, A > ones (std::vector< unsigned long > const &shape)`
- `template<Tensor Tsor>`  
`constexpr Tsor ones\_like (Tsor const &tsor)`
- `template<Tensor Tsor>`  
`auto max (Tsor const &tsor)`
- `template<Tensor Tsor>`  
`auto amax (Tsor const &tsor)`
- `template<Tensor Tsor>`  
`auto min (Tsor const &tsor)`
- `template<Tensor Tsor>`  
`auto amin (Tsor const &tsor)`
- `template<Tensor Tsor>`  
`auto sum (Tsor const &tsor)`
- `template<Tensor Tsor>`  
`auto mean (Tsor const &tsor)`
- `template<Tensor Tsor>`  
`auto norm (Tsor const &tsor)`
- `template<Tensor Tsor>`  
`Tsor abs (Tsor const &tsor)`

- template<Tensor Tsor>  
Tsor [softmax](#) (Tsor const &tsor)
- template<Tensor Tsor>  
bool [has\\_nan](#) (Tsor const &tsor)
- template<Tensor Tsor>  
bool [has\\_inf](#) (Tsor const &tsor)
- template<Tensor Tsor>  
bool [is\\_valid](#) (Tsor const &tsor)
- template<Tensor Tsor, typename Function >  
Tsor [reduce](#) (Tsor const &ts, unsigned long axis, typename Tsor::value\_type const &init, Function const &func, bool keepdims=false) noexcept
- template<Tensor Tsor>  
Tsor [sum](#) (Tsor const &ts, unsigned long axis, bool keepdims=false) noexcept
- template<Tensor Tsor>  
requires std::floating\_point< typename Tsor::value\_type > Tsor [mean](#) (Tsor const &ts, unsigned long axis, bool keepdims=false) noexcept
- template<Tensor Tsor>  
requires std::floating\_point< typename Tsor::value\_type > Tsor [variance](#) (Tsor const &ts, unsigned long axis, bool keepdims=false) noexcept
- template<Tensor Tsor>  
requires std::floating\_point< typename Tsor::value\_type > Tsor [standard\\_deviation](#) (Tsor const &ts, unsigned long axis, bool keepdims=false) noexcept
- template<Tensor Tsor>  
requires std::floating\_point< typename Tsor::value\_type > Tsor::value\_type [var](#) (Tsor const &ts) noexcept
- template<Tensor Tsor>  
requires std::floating\_point< typename Tsor::value\_type > Tsor::value\_type [std](#) (Tsor const &ts) noexcept
- template<Tensor Tsor>  
Tsor [max](#) (Tsor const &ts, unsigned long axis, bool keepdims=false) noexcept
- template<Tensor Tsor>  
Tsor [min](#) (Tsor const &ts, unsigned long axis, bool keepdims=false) noexcept
- template<typename T, typename A = default\_allocator<T>>  
requires std::floating\_point< T > [tensor](#)< T, A > [linspace](#) (T start, T stop, unsigned long num, bool endpoint=true) noexcept
- template<class \_Tp, class \_CharT, class \_Traits, class \_Alloc >  
std::basic\_istream< \_CharT, \_Traits > & [read\\_tensor](#) (std::basic\_istream< \_CharT, \_Traits > &\_\_is, [tensor](#)< \_Tp, \_Alloc > &\_\_x)
- template<class \_Tp, class \_CharT, class \_Traits, class \_Alloc >  
std::basic\_ostream< \_CharT, \_Traits > & [write\\_tensor](#) (std::basic\_ostream< \_CharT, \_Traits > &\_\_os, [tensor](#)< \_Tp, \_Alloc > const &\_\_x)
- template<typename T, typename A = default\_allocator<T>>  
[tensor](#)< T, A > [load\\_tensor](#) (std::string const &file\_name)
- template<Tensor Tsor>  
void [save\\_tensor](#) (std::string const &file\_name, Tsor const &tsor)
- template<Variable Var>  
bool [operator==](#) (Var const &lhs, Var const &rhs) noexcept

## Variables

- template<typename T >  
constexpr bool [is\\_complex\\_v](#) = [is\\_complex](#)<T>::value
- template<typename T >  
concept [Complex](#) = [is\\_complex\\_v](#)<T>  
*A type that represents a complex expression.*
- template<class T >  
constexpr bool [is\\_constant\\_v](#) = [is\\_constant](#)<T>::value

- `template<typename T >`  
`concept Constant = is_constant_v<T>`
- `auto MeanSquaredError`  
*Computes the mean of squares of errors between labels and predictions.*
- `auto MSE`  
*An alias name of function [MeanSquaredError](#).*
- `auto MeanAbsoluteError`  
*Computes the mean of absolute errors between labels and predictions.*
- `auto MAE`  
*An alias name of function [MeanAbsoluteError](#).*
- `auto Hinge`
- `auto CategoricalCrossentropy`
- `auto CategoricalCrossEntropy`
- `auto BinaryCrossentropy`
- `auto BinaryCrossEntropy`
- `static constexpr auto make_unary_operator`
- `static constexpr auto make_binary_operator`
- `template<class T >`  
`constexpr bool is_unary_operator_v = is_unary_operator<T>::value`
- `template<typename T >`  
`concept Unary_Operator = is_unary_operator_v<T>`  
*A type that represents an unary operator.*
- `template<class T >`  
`constexpr bool is_binary_operator_v = is_binary_operator<T>::value`
- `template<typename T >`  
`concept Binary_Operator = is_binary_operator_v<T>`  
*A type that represents a binary operator.*
- `template<typename T >`  
`concept Operator = Unary_Operator<T> || Binary_Operator<T>`  
*A type that represents an unary or a binary operator.*
- `template<typename T >`  
`concept Expression = Operator<T> || Variable<T> || Place_Holder<T> || Constant<T> || Value<T>`  
*A type that represents a unary operator, a binary operator, a variable, a [place\\_holder](#), a constant or a value.*
- `auto Adam`
- `auto SGD`
- `auto Adagrad`
- `auto RMSprop`
- `auto Adadelta`
- `template<class T >`  
`constexpr bool is_place_holder_v = is_place_holder<T>::value`
- `template<typename T >`  
`concept Place_Holder = is_place_holder_v<T>`
- `static unsigned long random_seed = std::chrono::system_clock::now().time_since_epoch().count()`
- `static std::mt19937 random_generator {random_seed}`
- `template<class T >`  
`constexpr bool is_tensor_v = is_tensor<T>::value`
- `template<typename T >`  
`concept Tensor = is_tensor_v<T>`
- `template<class T >`  
`constexpr bool is_value_v = is_value<T>::value`
- `template<typename T >`  
`concept Value = is_value_v<T>`
- `template<class T >`  
`constexpr bool is_variable_v = is_variable<T>::value`
- `template<typename T >`  
`concept Variable = is_variable_v<T>`

## 5.1.1 Typedef Documentation

### 5.1.1.1 ada\_delta

```
template<typename Loss , typename T >  
using ceras::ada_delta = typedef adadelta< Loss, T >
```

### 5.1.1.2 ada\_grad

```
template<typename Loss , typename T >  
using ceras::ada_grad = typedef adagrad<Loss, T>
```

### 5.1.1.3 array

```
template<typename T >  
using ceras::array = typedef view_1d<T>
```

### 5.1.1.4 cube

```
template<typename T >  
using ceras::cube = typedef view_3d<T>
```

### 5.1.1.5 default\_allocator

```
template<typename T >  
using ceras::default_allocator = typedef std::allocator<T>
```

### 5.1.1.6 matrix

```
template<typename T >  
using ceras::matrix = typedef view_2d<T>
```

### 5.1.1.7 rms\_prop

```
template<typename Loss , typename T >
using ceras::rms_prop = typedef rmsprop< Loss, T >
```

### 5.1.1.8 tesseract

```
template<typename T >
using ceras::tesseract = typedef view_4d<T>
```

## 5.1.2 Function Documentation

### 5.1.2.1 abs() [1/2]

```
template<Complex C>
auto ceras::abs (
    C const & c ) [noexcept]
```

Returns the magnitude of the complex expression.

#### Parameters

<b>c</b>	Complex expression.
----------	---------------------

```
auto r = variable{ ... };
auto i = variable{ ... };
auto c = complex{ r, i };
auto a = abs( c );
```

### 5.1.2.2 abs() [2/2]

```
template<Tensor Tsor>
Tsor ceras::abs (
    Tsor const & tsor )
```

### 5.1.2.3 abs\_loss()

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::abs_loss (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]
```



#### 5.1.2.4 Add()

```
auto ceras::Add ( ) [inline], [noexcept]
```

Layer that adds two layers

Example usage:

```
auto input = Input(); // (16, )
auto x1 = Dense( 8, 16 )( input );
auto x2 = Dense( 8, 16 )( input );
auto x3 = Add()( x1, x2 ); // equivalent to 'x1 + x2'
auto m = model{ input, x3 };
```

#### 5.1.2.5 add()

```
template<Tensor Tsor>
Tsor ceras::add (
    Tsor const & lhs,
    Tsor const & rhs ) [noexcept]
```

#### 5.1.2.6 amax()

```
template<Tensor Tsor>
auto ceras::amax (
    Tsor const & tsor )
```

#### 5.1.2.7 amin()

```
template<Tensor Tsor>
auto ceras::amin (
    Tsor const & tsor )
```

#### 5.1.2.8 arg()

```
template<Complex C>
auto ceras::arg (
    C const & c ) [noexcept]
```

Calculates the phase angle (in radians) of the complex expression.

Parameters

<i>c</i>	Complex expression. Implemented as <code>atan2( image(c), real(c) )</code> .
----------	------------------------------------------------------------------------------

```

auto r = variable{ ... };
auto i = variable{ ... };
auto c = complex{ r, i };
auto a = arg( c );

```

#### 5.1.2.9 as\_tensor()

```

template<typename T , typename A = default_allocator<T>>
constexpr tensor<T, A> ceras::as_tensor (
    T val ) [constexpr], [noexcept]

```

#### 5.1.2.10 AveragePooling2D()

```

auto ceras::AveragePooling2D (
    unsigned long stride ) [inline], [noexcept]

```

Average pooling operation for spatial data.

#### 5.1.2.11 BatchNormalization() [1/2]

```

auto ceras::BatchNormalization (
    float threshold,
    std::vector< unsigned long > const & shape,
    float kernel_regularizer_l1 = 0.0f,
    float kernel_regularizer_l2 = 0.0f,
    float bias_regularizer_l1 = 0.0f,
    float bias_regularizer_l2 = 0.0f ) [inline]

```

#### 5.1.2.12 BatchNormalization() [2/2]

```

auto ceras::BatchNormalization (
    std::vector< unsigned long > const & shape,
    float threshold = 0.95f,
    float kernel_regularizer_l1 = 0.0f,
    float kernel_regularizer_l2 = 0.0f,
    float bias_regularizer_l1 = 0.0f,
    float bias_regularizer_l2 = 0.0f ) [inline]

```

Applies a transformation that maintains the mean output close to 0 and the output standard deviation close to 1.

##### Parameters

<i>shape</i>	Dimensionality of the input shape.
<i>threshold</i>	Momentum for the moving average.
<i>kernel_regularizer_l1</i>	L1 regularizer for the kernel. Defaults to 0.0f.
<i>kernel_regularizer_l2</i>	L2 regularizer for the kernel. Defaults to 0.0f.
<i>bias_regularizer_l1</i>	L1 regularizer for the bias vector. Defaults to 0.0f.
<i>bias_regularizer_l2</i>	L2 regularizer for the bias vector. Defaults to 0.0f.

Example code:

```
auto a = variable{ random<float>( {12, 34, 56, 78} ) };
auto b = BatchNormalization( {34, 56, 78}, 0.8f )( a ); // note the leading dimension of 'a' is interpreted
               as batch size, and only the rest 3 dimensions are required here.
```

#### 5.1.2.13 binary\_accuracy()

```
template<Expression Lhs_Expression, Expression Rhs_Expression, std::floating_point FP>
auto ceras::binary_accuracy (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex,
    FP threshold = 0.5 ) [noexcept]
```

#### 5.1.2.14 binary\_cross\_entropy\_loss()

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::binary_cross_entropy_loss (
    Lhs_Expression const & ground_truth,
    Rhs_Expression const & prediction ) [constexpr], [noexcept]
```

#### 5.1.2.15 clip()

```
template<Tensor Tsor>
Tsor ceras::clip (
    Tsor & tsor,
    typename Tsor::value_type lower = 0,
    typename Tsor::value_type upper = 1 )
```

#### 5.1.2.16 computation\_graph()

```
template<Expression Ex>
std::string ceras::computation_graph (
    Ex const & ex ) [inline], [noexcept]
```

Generating the computation graph, in [graph description language](#).

##### Parameters

<i>ex</i>	An expression.
-----------	----------------

**Returns**

A string describing the computation graph, in graph description language.

**5.1.2.17 concatenate()**

```
template<Tensor Tsor>
Tsor ceras::concatenate (
    Tsor const & lhs,
    Tsor const & rhs,
    unsigned long axis = 0 ) [noexcept]
```

**5.1.2.18 Concatenate()**

```
auto ceras::Concatenate (
    unsigned long axis = -1 ) [inline], [noexcept]
```

Layer that concatenates two layers.

**Parameters**

<i>axis</i>	The concatenation axis. Default to the last channel.
-------------	------------------------------------------------------

**Example usage:**

```
auto l1 = variable{ tensor<float>{ {12, 11, 3} } };
auto l2 = variable{ tensor<float>{ {12, 11, 4} } };
auto l12 = Concatenate()( l1, l2 ); // should be of shape (12, 11, 7)
```

**5.1.2.19 conj()**

```
template<Complex C>
auto ceras::conj (
    C const & c ) [noexcept]
```

Returns the conjugate of the complex expression.

**Parameters**

<i>c</i>	Complex expression.
----------	---------------------

```
auto r = variable{ ... };
auto i = variable{ ... };
auto c = complex{ r, i };
auto a = conj( c );
```

### 5.1.2.20 Conv2D()

```
auto ceras::Conv2D (
    unsigned long output_channels,
    std::vector< unsigned long > const & kernel_size,
    std::vector< unsigned long > const & input_shape,
    std::string const & padding = "valid",
    std::vector< unsigned long > const & strides = {1,1},
    std::vector< unsigned long > const & dilations = {1, 1},
    bool use_bias = true,
    float kernel_regularizer_l1 = 0.0f,
    float kernel_regularizer_l2 = 0.0f,
    float bias_regularizer_l1 = 0.0f,
    float bias_regularizer_l2 = 0.0f ) [inline]
```

2D convolution layer.

#### Parameters

<i>output_channels</i>	Dimensionality of the output space.
<i>kernel_size</i>	The height and width of the convolutional window.
<i>input_shape</i>	Dimensionality of the input shape.
<i>padding</i>	valid or same. valid suggests no padding. same suggests zero padding. Defaults to valid.
<i>strides</i>	The strides along the height and width direction. Defaults to (1, 1).
<i>dilations</i>	The dialation along the height and width direction. Defaults to (1, 1).
<i>use_bias</i>	Wether or not use a bias vector. Defaults to true.
<i>kernel_regularizer_l1</i>	L1 regularizer for the kernel. Defaults to 0.0f.
<i>kernel_regularizer_l2</i>	L2 regularizer for the kernel. Defaults to 0.0f.
<i>bias_regularizer_l1</i>	L1 regularizer for the bias vector. Defaults to 0.0f.
<i>bias_regularizer_l2</i>	L2 regularizer for the bias vector. Defaults to 0.0f.

#### Example code:

```
auto x = Input{};
auto y = Conv2D( 32, {3, 3}, {28, 28, 1}, "same" )( x );
auto z = Flatten()( y );
auto u = Dense( 10, 28*28*32 )( z );
auto m = model{ x, u };
```

### 5.1.2.21 copy()

```
template<Tensor Tsor>
Tsor ceras::copy (
    Tsor const & tsor )
```

### 5.1.2.22 `crelu()`

```
template<Expression Ex>
auto ceras::crelu (
    Ex const & ex ) [noexcept]
```

Concatenated Rectified Linear Units, an activation function which preserves both positive and negative phase information while enforcing non-saturated non-linearity.

Reference: Shang, Wenling, Kihyuk Sohn, Diogo Almeida, and Honglak Lee. "Understanding and Improving Convolutional Neural Networks via Concatenated Rectified Linear Units." ArXiv:1603.05201 [Cs], July 19, 2016.

```
http://arxiv.org/abs/1603.05201.
auto v = variable{ random<float>{ 3, 3 } };
auto c = crelu( v );
```

### 5.1.2.23 `cross_entropy()`

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::cross_entropy (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]
```

### 5.1.2.24 `cross_entropy_loss()`

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::cross_entropy_loss (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]
```

### 5.1.2.25 `deep_copy()`

```
template<Tensor Tsor>
Tsor ceras::deep_copy (
    Tsor const & tsor )
```

### 5.1.2.26 `Dense()`

```
auto ceras::Dense (
    unsigned long output_size,
    unsigned long input_size,
    bool use_bias = true,
    float kernel_regularizer_l1 = 0.0f,
    float kernel_regularizer_l2 = 0.0f,
    float bias_regularizer_l1 = 0.0f,
    float bias_regularizer_l2 = 0.0f ) [inline]
```

Densely-connected layer.

## Parameters

<i>output_size</i>	Dimensionality of output shape. The output shape is (batch_size, output_size).
<i>input_size</i>	Dimensionality of input shape. The input shape is (batch_size, input_size).
<i>use_bias</i>	Using a bias vector or not. Defaults to <code>true</code> .
<i>kernel_regularizer_l1</i>	L1 regularizer for the kernel. Defaults to <code>0.0f</code> .
<i>kernel_regularizer_l2</i>	L2 regularizer for the kernel. Defaults to <code>0.0f</code> .
<i>bias_regularizer_l1</i>	L1 regularizer for the bias vector. Defaults to <code>0.0f</code> .
<i>bias_regularizer_l2</i>	L2 regularizer for the bias vector. Defaults to <code>0.0f</code> .

## Example code:

```

auto x = Input{};
auto y = Dense( 10, 28*28 )( x );
auto m = model{ x, y };

```

## 5.1.2.27 Dropout()

```

template<typename T >
auto ceras::Dropout (
    T factor ) [inline], [noexcept]

```

Applies Dropout to the input.

## 5.1.2.28 elementwise\_divide()

```

template<Tensor Tsor>
Tsor ceras::elementwise_divide (
    Tsor const & lhs,
    Tsor const & rhs ) [noexcept]

```

## 5.1.2.29 elementwise\_multiply()

```

template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::elementwise_multiply (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]

```

## 5.1.2.30 elementwise\_product() [1/2]

```

template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::elementwise_product (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]

```

### 5.1.2.31 elementwise\_product() [2/2]

```
template<Tensor Tsor>
Tsor ceras::elementwise_product (
    Tsor const & lhs,
    Tsor const & rhs ) [noexcept]
```

### 5.1.2.32 elu()

```
template<typename T = float>
requires std::floating_point<T> auto ceras::elu (
    T const alpha = 1.0 ) [noexcept]
```

Exponential Linear function, an unary operator. Returns  $x$  if positive,  $\alpha * (\exp(x) - 1)$  otherwise.  $\alpha$  defaults to 0.2.

#### Parameters

ex	An input operator.
----	--------------------

```
auto x = Input();
auto y = Dense( 10, 28*28 )( x );
auto output = elu(0.1f)( y );
```

### 5.1.2.33 ELU()

```
template<typename T = float>
auto ceras::ELU (
    T const factor = 0.2 ) [inline], [noexcept]
```

Exponential Linear Unit.

### 5.1.2.34 empty()

```
template<Tensor Tsor>
constexpr bool ceras::empty (
    Tsor const & tsor ) [constexpr], [noexcept]
```

### 5.1.2.35 exponential()

```
template<Expression Ex>
auto ceras::exponential (
    Ex const & ex ) [inline], [noexcept]
```

Exponential function, an unary operator. Returns  $\exp(x)$ .



## Parameters

ex	An input operator.
----	--------------------

```
auto x = Input();
auto y = Dense( 10, 28*28 )( x );
auto output = exponential( y );
```

## 5.1.2.36 Flatten()

```
auto ceras::Flatten ( ) [inline], [noexcept]
```

Flattens the input. Does not affect the batch size.

## 5.1.2.37 gelu()

```
template<Expression Ex>
auto ceras::gelu (
    Ex const & ex ) [inline], [noexcept]
```

Gaussian Error function, an unary operator. GAUSSIAN ERROR LINEAR UNITS (GELUS) <https://arxiv.org/pdf/1606.08415.pdf>  $f(x) = 0.5x (1 + \tanh[\sqrt{2/\pi}(x + 0.044715x^3)])$   $df = x (1 + \tanh[\sqrt{2/\pi}(x + 0.044715x^3)]) + \sqrt{2/\pi} x \operatorname{sech}^2[\sqrt{2/\pi}(x + 0.044715x^3)]$  where  $\operatorname{sech}^2(x) = 1 - \tanh^2(x)$  derivative generated using service from <https://www.symbolab.com/solver/derivative-calculator>.

## Parameters

ex	An input operator.
----	--------------------

```
auto x = Input();
auto y = Dense( 10, 28*28 )( x );
auto output = gelu( y );
```

## 5.1.2.38 gemm() [1/2]

```
template<typename T >
requires std::floating_point<T> void ceras::gemm (
    T const * A,
    bool a_transposed,
    T const * B,
    bool b_transposed,
    unsigned long m,
    unsigned long n,
    unsigned long k,
    T * C )
```

**5.1.2.39 gemm() [2/2]**

```
template<typename T >
requires std::floating_point<T> void ceras::gemm (
    view_2d< T > const & x,
    view_2d< T > const & y,
    view_2d< T > & ans )
```

**5.1.2.40 gemm\_cpu()**

```
template<typename T >
requires std::floating_point<T> void ceras::gemm_cpu (
    T const * A,
    bool a_transposed,
    T const * B,
    bool b_transposed,
    unsigned long m,
    unsigned long n,
    unsigned long k,
    T * C )
```

**5.1.2.41 get\_default\_session()**

```
template<Tensor Tsor>
ceras_private::session< Tsor > & ceras::get_default_session ( )
```

**5.1.2.42 glorot\_uniform()**

```
template<typename T , typename A = default_allocator<T>>
tensor<T,A> ceras::glorot_uniform (
    std::initializer_list< unsigned long > shape )
```

**5.1.2.43 hadamard\_product() [1/2]**

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::hadamard_product (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr, [noexcept]]
```

**5.1.2.44 hadamard\_product()** [2/2]

```
template<Tensor Tsor>
Tsor ceras::hadamard_product (
    Tsor const & lhs,
    Tsor const & rhs ) [noexcept]
```

**5.1.2.45 hard\_sigmoid()**

```
template<Expression Ex>
auto ceras::hard_sigmoid (
    Ex const & ex ) [inline], [noexcept]
```

Hard Sigmoid function, an unary operator. Piecewise linear approximation of the sigmoid function.

**Parameters**

<b>ex</b>	An input operator.
-----------	--------------------

```
auto x = Input();
auto y = Dense( 10, 28*28 )( x );
auto output = hard_sigmoid( y );
```

**5.1.2.46 has\_inf()**

```
template<Tensor Tsor>
bool ceras::has_inf (
    Tsor const & tsor )
```

**5.1.2.47 has\_nan()**

```
template<Tensor Tsor>
bool ceras::has_nan (
    Tsor const & tsor )
```

**5.1.2.48 hinge\_loss()**

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::hinge_loss (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]
```

#### 5.1.2.49 imag()

```
template<Expression Real_Ex, Expression Imag_Ex>
Imag_Ex ceras::imag (
    complex< Real_Ex, Imag_Ex > const & c ) [noexcept]
```

@brief Returns the imaginary part of the complex expression.

##### Parameters

<i>c</i>	A complex expression.
----------	-----------------------

#### 5.1.2.50 Input()

```
auto ceras::Input ( ) [inline]
```

#### 5.1.2.51 is\_valid()

```
template<Tensor Tsor>
bool ceras::is_valid (
    Tsor const & tsor )
```

#### 5.1.2.52 leaky\_relu()

```
template<typename T >
requires std::floating_point<T> auto ceras::leaky_relu (
    T const factor = 0.2 ) [noexcept]
```

Leaky Rectified Linear function, an unary operator. Returns  $x$  if positive,  $\alpha x$  otherwise.  $\alpha$  defaults to 0.2.

##### Parameters

<i>ex</i>	An input operator.
-----------	--------------------

```
auto x = Input();
auto y = Dense( 10, 28*28 )( x );
auto output = leaky_relu(0.1f)( y );
```

#### 5.1.2.53 LeakyReLU()

```
template<typename T = float>
```

```
auto ceras::LeakyReLU (
    T const factor = 0.2 ) [inline], [noexcept]
```

leaky relu activation function.

#### 5.1.2.54 linspace()

```
template<typename T , typename A = default_allocator<T>>
requires std::floating_point<T> tensor<T,A> ceras::linspace (
    T start,
    T stop,
    unsigned long num,
    bool endpoint = true ) [noexcept]
```

#### 5.1.2.55 load\_tensor()

```
template<typename T , typename A = default_allocator<T>>
tensor<T,A> ceras::load_tensor (
    std::string const & file_name )
```

#### 5.1.2.56 lstm()

```
auto ceras::lstm (
    std::unsigned long units ) [inline], [noexcept]
```

#### 5.1.2.57 mae()

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::mae (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]
```

#### 5.1.2.58 make\_compiled\_model()

```
template<typename Model , typename Optimizer , typename Loss >
auto ceras::make_compiled_model (
    Model const & m,
    Loss const & l,
    Optimizer const & o ) [inline]
```

**5.1.2.59 make\_trainable()**

```
template<Expression Ex>
void ceras::make_trainable (
    Ex & ex,
    bool t )
```

Setting an expression's trainable flag

**5.1.2.60 max() [1/2]**

```
template<Tensor Tsor>
Tsor ceras::max (
    Tsor const & ts,
    unsigned long axis,
    bool keepdims = false ) [noexcept]
```

**5.1.2.61 max() [2/2]**

```
template<Tensor Tsor>
auto ceras::max (
    Tsor const & tsor )
```

**5.1.2.62 MaxPooling2D()**

```
auto ceras::MaxPooling2D (
    unsigned long stride ) [inline], [noexcept]
```

Max pooling operation for 2D spatial data.

**5.1.2.63 mean() [1/3]**

```
template<Expression Ex>
constexpr auto ceras::mean (
    Ex const & ex ) [constexpr], [noexcept]
```

An alias name of mean\_reduce.

**5.1.2.64 mean() [2/3]**

```
template<Tensor Tsor>
requires std::floating_point<typename Tsor::value_type> Tsor ceras::mean (
    Tsor const & ts,
    unsigned long axis,
    bool keepdims = false ) [noexcept]
```

**5.1.2.65 mean()** [3/3]

```
template<Tensor Tsor>
auto ceras::mean (
    Tsor const & tsor )
```

**5.1.2.66 mean\_absolute\_error()**

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::mean_absolute_error (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]
```

**5.1.2.67 mean\_reduce()**

```
template<Expression Ex>
constexpr auto ceras::mean_reduce (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes the mean of elements across all dimensions of an expression.

**Parameters**

<i>ex</i>	Incoming expression.
-----------	----------------------

**Example code:**

```
auto va = place_holder<tensor<float>{}>;
auto vb = variable{ random<float>{ 3, 4 } };
auto diff = mean_reduce( va, vb );
```

**5.1.2.68 mean\_squared\_error()**

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::mean_squared_error (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]
```

**5.1.2.69 mean\_squared\_logarithmic\_error()**

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::mean_squared_logarithmic_error (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]
```

**5.1.2.70 min() [1/2]**

```
template<Tensor Tsor>
Tsor ceras::min (
    Tsor const & ts,
    unsigned long axis,
    bool keepdims = false ) [noexcept]
```

**5.1.2.71 min() [2/2]**

```
template<Tensor Tsor>
auto ceras::min (
    Tsor const & tsor )
```

**5.1.2.72 minus() [1/2]**

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::minus (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]
```

**5.1.2.73 minus() [2/2]**

```
template<Tensor Tsor>
Tsor ceras::minus (
    Tsor const & lhs,
    Tsor const & rhs ) [noexcept]
```

**5.1.2.74 mse()**

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::mse (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]
```



### 5.1.2.75 Multiply()

```
auto ceras::Multiply ( ) [inline], [noexcept]
```

Layer that elementwise multiplies two layers

Example usage:

```
auto input = Input(); // (16, )
auto x1 = Dense( 8, 16 )( input );
auto x2 = Dense( 8, 16 )( input );
auto x3 = Multiply()( x1, x2 ); // equivalent to 'elementwise_multiply(x1, x2)'
auto m = model{ input, x3 };
```

### 5.1.2.76 multiply() [1/2]

```
template<Tensor Tsor>
Tsor ceras::multiply (
    Tsor const & lhs,
    Tsor const & rhs ) [noexcept]
```

### 5.1.2.77 multiply() [2/2]

```
template<Tensor Tsor>
void ceras::multiply (
    Tsor const & lhs,
    Tsor const & rhs,
    Tsor & ans ) [noexcept]
```

### 5.1.2.78 negative()

```
template<Expression Ex>
constexpr auto ceras::negative (
    Ex const & ex ) [constexpr], [noexcept]
```

### 5.1.2.79 negative\_relu()

```
template<Expression Ex>
auto ceras::negative_relu (
    Ex const & ex ) [noexcept]
```

### 5.1.2.80 norm() [1/2]

```
template<Complex C>
auto ceras::norm (
    C const & c ) [noexcept]
```

Returns the squared magnitude of the complex expression.

## Parameters

<b>c</b>	Complex expression.
----------	---------------------

```

auto r = variable{ ... };
auto i = variable{ ... };
auto c = complex{ r, i };
auto a = norm( c );

```

**5.1.2.81 norm()** [2/2]

```

template<Tensor Tsor>
auto ceras::norm (
    Tsor const & tsor )

```

**5.1.2.82 ones()**

```

template<typename T , typename A = default_allocator<T>>
constexpr tensor<T,A> ceras::ones (
    std::vector< unsigned long > const & shape ) [constexpr]

```

**5.1.2.83 ones\_like()**

```

template<Tensor Tsor>
constexpr Tsor ceras::ones_like (
    Tsor const & tsor ) [constexpr]

```

**5.1.2.84 operator"!="()**

```

template<Place_Holder Ph>
bool ceras::operator!= (
    Ph const & lhs,
    Ph const & rhs )

```

**5.1.2.85 operator\*()** [1/7]

```

template<Complex C, Expression E>
auto ceras::operator* (
    C const & c,
    E const & e ) [noexcept]

```

Multiplies a complex expression with an expression.

**5.1.2.86 operator\*() [2/7]**

```
template<Complex Cl, Complex Cr>
auto ceras::operator* (
    Cl const & c1,
    Cr const & cr ) [noexcept]
```

Multiplies two complex expressions. Optimization here:  $(a+ib)*(c+id) = (ac-bd) + i(ad+bc) = (ac-bd) + i((a+b)*(c+d)-ac-bd)$

```
auto c1 = complex{ ..., ... };
auto c2 = complex{ ..., ... };
auto c12 = c1 * c2;
```

**5.1.2.87 operator\*() [3/7]**

```
template<Complex C, Expression E>
auto ceras::operator* (
    E const & e,
    C const & c ) [noexcept]
```

Multiplies an expression with a compression expression.

**5.1.2.88 operator\*() [4/7]**

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
auto ceras::operator* (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [noexcept]
```

**5.1.2.89 operator\*() [5/7]**

```
template<Tensor Tsor>
Tsor ceras::operator* (
    Tsor const & lhs,
    Tsor const & rhs ) [noexcept]
```

**5.1.2.90 operator\*() [6/7]**

```
template<Tensor Tsor>
Tsor ceras::operator* (
    Tsor const & lhs,
    typename Tsor::value_type const & rhs ) [noexcept]
```

**5.1.2.91 operator\*() [7/7]**

```
template<Tensor Tsor>
Tsor ceras::operator* (
    typename Tsor::value_type const & lhs,
    Tsor const & rhs ) [noexcept]
```

**5.1.2.92 operator+() [1/9]**

```
template<Complex C>
auto ceras::operator+ (
    C const & c ) [noexcept]
```

Returns the complex expression.

**5.1.2.93 operator+() [2/9]**

```
template<Complex C, Expression E>
auto ceras::operator+ (
    C const & c,
    E const & e ) [noexcept]
```

Sums up a complex expression and an expression.

**5.1.2.94 operator+() [3/9]**

```
template<Complex Cl, Complex Cr>
auto ceras::operator+ (
    Cl const & cl,
    Cr const & cr ) [noexcept]
```

Sums up two complex expressions.

**5.1.2.95 operator+() [4/9]**

```
template<Complex C, Expression E>
auto ceras::operator+ (
    E const & e,
    C const & c ) [noexcept]
```

Sums up a complex expression and an expression.

**5.1.2.96 operator+()** [5/9]

```
template<Expression Ex>
constexpr auto ceras::operator+ (
    Ex const & ex ) [constexpr], [noexcept]
```

**5.1.2.97 operator+()** [6/9]

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::operator+ (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]
```

**5.1.2.98 operator+()** [7/9]

```
template<Tensor Tsor>
Tsor ceras::operator+ (
    Tsor const & lhs,
    Tsor const & rhs ) [noexcept]
```

**5.1.2.99 operator+()** [8/9]

```
template<Tensor Tsor>
Tsor ceras::operator+ (
    Tsor const & lhs,
    typename Tsor::value_type const & rhs ) [noexcept]
```

**5.1.2.100 operator+()** [9/9]

```
template<Tensor Tsor>
Tsor ceras::operator+ (
    typename Tsor::value_type const & lhs,
    Tsor const & rhs ) [noexcept]
```

**5.1.2.101 operator-()** [1/9]

```
template<Complex C>
auto ceras::operator- (
    C const & c ) [noexcept]
```

Negatives the complex expression.

**5.1.2.102 operator-() [2/9]**

```
template<Complex C, Expression E>
auto ceras::operator- (
    C const & c,
    E const & e ) [noexcept]
```

Subtracts an expression from a compression expression.

**5.1.2.103 operator-() [3/9]**

```
template<Complex Cl, Complex Cr>
auto ceras::operator- (
    Cl const & cl,
    Cr const & cr ) [noexcept]
```

Subtracts one complex expression from the other one.

**5.1.2.104 operator-() [4/9]**

```
template<Complex C, Expression E>
auto ceras::operator- (
    E const & e,
    C const & c ) [noexcept]
```

Subtractsa complex expression from an expression.

**5.1.2.105 operator-() [5/9]**

```
template<Expression Ex>
constexpr auto ceras::operator- (
    Ex const & ex ) [constexpr], [noexcept]
```

**5.1.2.106 operator-() [6/9]**

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::operator- (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]
```

**5.1.2.107 operator-() [7/9]**

```
template<Tensor Tsor>
Tsor ceras::operator- (
    Tsor const & lhs,
    Tsor const & rhs ) [noexcept]
```

**5.1.2.108 operator-() [8/9]**

```
template<Tensor Tsor>
Tsor ceras::operator- (
    Tsor const & lhs,
    typename Tsor::value_type const & rhs ) [noexcept]
```

**5.1.2.109 operator-() [9/9]**

```
template<Tensor Tsor>
Tsor ceras::operator- (
    typename Tsor::value_type const & lhs,
    Tsor const & rhs ) [noexcept]
```

**5.1.2.110 operator/()**

```
template<Tensor Tsor>
Tsor ceras::operator/ (
    Tsor const & lhs,
    typename Tsor::value_type const & rhs ) [noexcept]
```

**5.1.2.111 operator<()**

```
template<Place_Holder Ph>
bool ceras::operator< (
    Ph const & lhs,
    Ph const & rhs )
```

**5.1.2.112 operator<<()**

```
template<Tensor Tsor, typename CharT , typename Traits >
std::basic_ostream<CharT, Traits>& ceras::operator<< (
    std::basic_ostream< CharT, Traits > & os_,
    Tsor const & tsor )
```

#### 5.1.2.113 operator<=()

```
template<Place_Holder Ph>
bool ceras::operator<= (
    Ph const & lhs,
    Ph const & rhs )
```

#### 5.1.2.114 operator==( ) [1/2]

```
template<Place_Holder Ph>
bool ceras::operator==(
    Ph const & lhs,
    Ph const & rhs )
```

#### 5.1.2.115 operator==( ) [2/2]

```
template<Variable Var>
bool ceras::operator==(
    Var const & lhs,
    Var const & rhs ) [noexcept]
```

#### 5.1.2.116 operator>()

```
template<Place_Holder Ph>
bool ceras::operator> (
    Ph const & lhs,
    Ph const & rhs )
```

#### 5.1.2.117 operator>=()

```
template<Place_Holder Ph>
bool ceras::operator>= (
    Ph const & lhs,
    Ph const & rhs )
```

#### 5.1.2.118 plus()

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::plus (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]
```



**5.1.2.119 polar()**

```
template<Expression Em, Expression Ep>
auto ceras::polar (
    Em const & em,
    Ep const & ep ) [noexcept]
```

Returns with given magnitude and phase angle.

**Parameters**

<i>em</i>	Magnitude.
<i>ep</i>	Phase.

```
auto r = variable{ ... };
auto i = variable{ ... };
auto a = polar( r, i );
```

**5.1.2.120 randn()**

```
template<typename T , typename A = default_allocator<T>>
tensor<T,A> ceras::randn (
    std::vector< unsigned long > const & shape,
    T mean = T{0},
    T stddev = T{1} )
```

**5.1.2.121 randn\_like()**

```
template<Tensor Tsor>
Tsor ceras::randn_like (
    Tsor const & tsor,
    typename Tsor::value_type mean = 0,
    typename Tsor::value_type stddev = 1 )
```

**5.1.2.122 random()**

```
template<typename T , typename A = default_allocator<T>>
tensor<T,A> ceras::random (
    std::vector< unsigned long > const & shape,
    T min = T{0},
    T max = T{1} )
```

**5.1.2.123 random\_like()**

```
template<Tensor Tsor>
Tsor ceras::random_like (
    Tsor const & tsor,
    typename Tsor::value_type min = 0,
    typename Tsor::value_type max = 1 )
```

**5.1.2.124 read\_tensor()**

```
template<class _Tp , class _CharT , class _Traits , class _Alloc >
std::basic_istream<_CharT, _Traits>& ceras::read_tensor (
    std::basic_istream< _CharT, _Traits > & __is,
    tensor< _Tp, _Alloc > & __x )
```

**5.1.2.125 real()**

```
template<Expression Real_Ex, Expression Imag_Ex>
Real_Ex ceras::real (
    complex< Real_Ex, Imag_Ex > const & c ) [noexcept]
```

@bref Returns the real part of the complex expression.

**Parameters**

<i>c</i>	A complex expression.
----------	-----------------------

**5.1.2.126 reduce()**

```
template<Tensor Tsor, typename Function >
Tsor ceras::reduce (
    Tsor const & ts,
    unsigned long axis,
    typename Tsor::value_type const & init,
    Function const & func,
    bool keepdims = false ) [noexcept]
```

**5.1.2.127 reduce\_mean() [1/2]**

```
template<Expression Ex>
constexpr auto ceras::reduce_mean (
    Ex const & ex ) [constexpr], [noexcept]
```

An alias name of `mean_reduce`.

**5.1.2.128 reduce\_mean()** [2/2]

```
template<Tensor Tsor>
Tsor ceras::reduce_mean (
    Tsor const & tsor )
```

**5.1.2.129 reduce\_sum()** [1/2]

```
template<Expression Ex>
constexpr auto ceras::reduce_sum (
    Ex const & ex ) [constexpr], [noexcept]
```

**5.1.2.130 reduce\_sum()** [2/2]

```
template<Tensor Tsor>
Tsor ceras::reduce_sum (
    Tsor const & tsor )
```

**5.1.2.131 relu()**

```
template<Expression Ex>
auto ceras::relu (
    Ex const & ex ) [noexcept]
```

Relu function, an unary operator. Returns *x* if positive, 0 otherwise.

**Parameters**

<i>ex</i>	An input operator.
-----------	--------------------

```
auto x = Input();
auto y = Dense( 10, 28*28 ) ( x );
auto output = relu( y );
```

**5.1.2.132 ReLU()**

```
template<Expression Ex>
auto ceras::ReLU (
    Ex const & ex ) [inline], [noexcept]
```

Rectified Linear Unit activation function.

### 5.1.2.133 relu6()

```
template<Expression Ex>
auto ceras::relu6 (
    Ex const & ex ) [noexcept]
```

Rectified Linear 6 function, an unary operator. Returns  $\min(\max(\text{features}, 0), 6)$ .

#### Parameters

<i>ex</i>	An input operator.
-----------	--------------------

```
auto x = Input();
auto y = Dense( 10, 28*28 )( x );
auto output = relu6( y );
```

### 5.1.2.134 repeat()

```
template<Tensor Tsor>
Tsor ceras::repeat (
    Tsor const & tsor,
    unsigned long n )
```

### 5.1.2.135 replace\_placeholder\_with\_expression()

```
template<Expression Ex, Place_Holder Ph, Expression Ey>
auto ceras::replace_placeholder_with_expression (
    Ex const & ex,
    Ph const & old_placeholder,
    Ey const & new_expression )
```

Replacing a [place\\_holder](#) with an expression.

#### Parameters

<i>ex</i>	Can be a unary operator, binary operator, variable, <a href="#">place_holder</a> , a constant or a value
<i>old_placeholder</i>	An place holder in <i>ex</i>
<i>new_expression</i>	An expression that will replace <i>old_placeholder</i> in <i>ex</i> .

#### Returns

A expression inheriting the topology of *ex*, but with *old\_placeholder* replaced by *new\_expression*

### 5.1.2.136 repmat()

```
template<Tensor Tsor>
Tsor ceras::repmat (
```

```
Tsor const & tsor,
unsigned long row_rep,
unsigned long col_rep )
```

#### 5.1.2.137 Reshape()

```
auto ceras::Reshape (
    std::vector< unsigned long > const & new_shape,
    bool include_batch_flag = true ) [inline], [noexcept]
```

Reshapes inputs into the given shape.

#### 5.1.2.138 reshape()

```
template<Tensor Tsor>
Tsor ceras::reshape (
    Tsor const & ts,
    std::vector< unsigned long > const & new_shape )
```

#### 5.1.2.139 save\_tensor()

```
template<Tensor Tsor>
void ceras::save_tensor (
    std::string const & file_name,
    Tsor const & tsor )
```

#### 5.1.2.140 selu()

```
template<Expression Ex>
auto ceras::selu (
    Ex const & ex ) [inline], [noexcept]
```

Scaled Exponential Linear Unit (SELU) activation function, an unary operator. If  $x > 0$ , returns  $1.0507 x$ ; Otherwise, returns  $1.67326 * 1.0507 * (\exp(x) - 1)$

##### Parameters

<i>ex</i>	An input operator
-----------	-------------------

```
auto x = Input();
auto y = Dense( 10, 28*28 ) ( x );
auto output = selu( y );
```

#### 5.1.2.141 sigmoid()

```
template<Expression Ex>
auto ceras::sigmoid (
    Ex const & ex ) [inline], [noexcept]
```

Sigmoid function, an unary operator. Returns  $1 / (\exp(-x) + 1)$ .

##### Parameters

<b>ex</b>	An input operator.
-----------	--------------------

```
auto x = Input();
auto y = Dense( 10, 28*28 )( x );
auto output = sigmoid( y );
```

#### 5.1.2.142 silu()

```
template<Expression Ex>
auto ceras::silu (
    Ex const & ex ) [noexcept]
```

An alias name of activation swish.

#### 5.1.2.143 Softmax()

```
auto ceras::Softmax ( ) [inline], [noexcept]
```

Softmax activation function.

#### 5.1.2.144 softmax() [1/2]

```
template<Expression Ex>
constexpr auto ceras::softmax (
    Ex const & ex ) [constexpr], [noexcept]
```

Softmax activation function, an unary operator.

##### Parameters

<b>ex</b>	An input operator
-----------	-------------------

```
auto x = Input();
auto y = Dense( 10, 28*28 )( x );
auto output = softmax( y );
```

**5.1.2.145 softmax()** [2/2]

```
template<Tensor Tsor>
Tsor ceras::softmax (
    Tsor const & tsor )
```

**5.1.2.146 softplus()**

```
template<Expression Ex>
auto ceras::softplus (
    Ex const & ex ) [inline], [noexcept]
```

Softplus function, an unary operator. Returns  $\log(\exp(x) + 1)$ .

**Parameters**

<i>ex</i>	An input operator
-----------	-------------------

```
auto x = Input();
auto y = Dense( 10, 28*28 )( x );
auto output = softplus( y );
```

**5.1.2.147 softsign()**

```
template<Expression Ex>
auto ceras::softsign (
    Ex const & ex ) [inline], [noexcept]
```

Softsign function, an unary operator. Returns  $x / (\text{abs}(x) + 1)$ .

**Parameters**

<i>ex</i>	An input operator.
-----------	--------------------

```
auto x = Input();
auto y = Dense( 10, 28*28 )( x );
auto output = softsign( y );
```

**5.1.2.148 square()**

```
template<Expression Ex>
constexpr auto ceras::square (
    Ex const & ex ) [constexpr], [noexcept]
```

Returns the square of the input

## Parameters

<i>ex</i>	The input operator.
-----------	---------------------

## Returns

An instance of a [unary\\_operator](#) that evaluate the squared value of the input operator.

## Example code:

```
auto e = variable<tensor<float>>( /*...*/ );
auto square = square(e);
```

## 5.1.2.149 squared\_loss()

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto ceras::squared_loss (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr, [noexcept]
```

## 5.1.2.150 squeeze()

```
template<Tensor Tsor>
Tsor ceras::squeeze (
    Tsor const & tsor )
```

## 5.1.2.151 standard\_deviation()

```
template<Tensor Tsor>
requires std::floating_point<typename Tsor::value_type> Tsor ceras::standard_deviation (
    Tsor const & ts,
    unsigned long axis,
    bool keepdims = false ) [noexcept]
```

## 5.1.2.152 std()

```
template<Tensor Tsor>
requires std::floating_point<typename Tsor::value_type> Tsor::value_type ceras::std (
    Tsor const & ts ) [noexcept]
```



**5.1.2.153 Subtract()**

```
auto ceras::Subtract ( ) [inline], [noexcept]
```

Layer that subtracts two layers

Example usage:

```
auto input = Input(); // (16, )
auto x1 = Dense( 8, 16 )( input );
auto x2 = Dense( 8, 16 )( input );
auto x3 = Subtract()( x1, x2 ); // equivalent to 'x1 - x2'
auto m = model{ input, x3 };
```

**5.1.2.154 sum() [1/2]**

```
template<Tensor Tsor>
Tsor ceras::sum (
    Tsor const & ts,
    unsigned long axis,
    bool keepdims = false ) [noexcept]
```

**5.1.2.155 sum() [2/2]**

```
template<Tensor Tsor>
auto ceras::sum (
    Tsor const & tsor )
```

**5.1.2.156 sum\_reduce()**

```
template<Expression Ex>
constexpr auto ceras::sum_reduce (
    Ex const & ex ) [constexpr], [noexcept]
```

**5.1.2.157 swish()**

```
template<Expression Ex>
auto ceras::swish (
    Ex const & ex ) [noexcept]
```

Swish activation function.

Reference: Ramachandran, Prajit, Barret Zoph, and Quoc V. Le. "Searching for Activation Functions." ArXiv:1710.05941 [Cs], October 16, 2017. <http://arxiv.org/abs/1710.05941>.

## Parameters

<i>ex</i>	Input expression.
-----------	-------------------

**5.1.2.158 truncated\_normal()**

```
template<typename T , typename A = default_allocator<T>>
tensor<T,A> ceras::truncated_normal (
    std::vector< unsigned long > const & shape,
    T mean = T{0},
    T stddev = T{1},
    T lower = T{0},
    T upper = T{1} )
```

**5.1.2.159 update\_cuda\_gemm\_threshold()**

```
void ceras::update_cuda_gemm_threshold ( ) [inline]
```

**5.1.2.160 UpSampling2D()**

```
auto ceras::UpSampling2D (
    unsigned long stride ) [inline], [noexcept]
```

Upsampling layer for 2D inputs.

**5.1.2.161 var()**

```
template<Tensor Tsor>
requires std::floating_point<typename Tsor::value_type> Tsor::value_type ceras::var (
    Tsor const & ts ) [noexcept]
```

**5.1.2.162 variance()**

```
template<Tensor Tsor>
requires std::floating_point<typename Tsor::value_type> Tsor ceras::variance (
    Tsor const & ts,
    unsigned long axis,
    bool keepdims = false ) [noexcept]
```

### 5.1.2.163 write\_tensor()

```
template<class _Tp , class _CharT , class _Traits , class _Alloc >
std::basic_ostream<_CharT, _Traits>& ceras::write_tensor (
    std::basic_ostream< _CharT, _Traits > & __os,
    tensor< _Tp, _Alloc > const & __x )
```

### 5.1.2.164 zeros()

```
template<typename T , typename A = default_allocator<T>>
constexpr tensor<T,A> ceras::zeros (
    std::vector< unsigned long > const & shape ) [constexpr]
```

### 5.1.2.165 zeros\_like()

```
template<Tensor Tsor>
constexpr Tsor ceras::zeros_like (
    Tsor const & tsor ) [constexpr]
```

## 5.1.3 Variable Documentation

### 5.1.3.1 Adadelta

```
auto ceras::Adadelta [inline]
```

#### Initial value:

```
= [] ( auto ... args )
{
    return [=]<Expression Ex>( Ex& loss )
    {
        return adadelta{loss, args...};
    };
}
```

### 5.1.3.2 Adagrad

```
auto ceras::Adagrad [inline]
```

#### Initial value:

```
= [] ( auto ... args )
{
    return [=]<Expression Ex>( Ex& loss )
    {
        return adagrad{loss, args...};
    };
}
```

### 5.1.3.3 Adam

```
auto ceras::Adam [inline]
```

#### Initial value:

```
= [] ( auto ... args )
{
    return [=] <Expression Ex> ( Ex& loss )
    {
        return adam{loss, args...};
    };
}
```

### 5.1.3.4 Binary\_Operator

```
template<typename T >
concept ceras::Binary_Operator = is_binary_operator_v<T>
```

A type that represents a binary operator.

```
@concept Binary_Operator<>
```

### 5.1.3.5 BinaryCrossentropy

```
auto ceras::BinaryCrossentropy [inline]
```

#### Initial value:

```
= [] ()
{
    return [] <Expression Ex > ( Ex const& output )
    {
        return [=] <Place_Holder Ph> ( Ph const& ground_truth )
        {
            return binary_cross_entropy_loss( ground_truth, output );
        };
    };
}
```

### 5.1.3.6 BinaryCrossEntropy

```
auto ceras::BinaryCrossEntropy [inline]
```

#### Initial value:

```
= [] ()
{
    return BinaryCrossentropy();
}
```

### 5.1.3.7 CategoricalCrossentropy

```
auto ceras::CategoricalCrossentropy [inline]
```

**Initial value:**

```
= [] ()
{
    return []<Expression Ex >( Ex const& output )
    {
        return [=]<Place_Holder Ph>( Ph const& ground_truth )
        {
            return cross_entropy_loss( ground_truth, output );
        };
    };
}
```

### 5.1.3.8 CategoricalCrossEntropy

```
auto ceras::CategoricalCrossEntropy [inline]
```

**Initial value:**

```
= [] ()
{
    return CategoricalCrossentropy();
}
```

### 5.1.3.9 Complex

```
template<typename T >
concept ceras::Complex = is_complex_v<T>
```

A type that represents a complex expression.

@concept Complex

### 5.1.3.10 Constant

```
template<typename T >
concept ceras::Constant = is_constant_v<T>
```

### 5.1.3.11 Expression

```
template<typename T >
concept ceras::Expression = Operator<T> || Variable<T> || Place_Holder<T> || Constant<T> ||
Value<T>
```

A type that represents a unary operator, a binary operator, a variable, a [place\\_holder](#), a constant or a value.

@concept Expression<>

### 5.1.3.12 Hinge

```
auto ceras::Hinge [inline]
```

**Initial value:**

```
= [] ()
{
    return []<Expression Ex >( Ex const& output )
    {
        return []<Place_Holder Ph>( Ph const& ground_truth )
        {
            return hinge_loss( ground_truth, output );
        };
    };
}
```

### 5.1.3.13 is\_binary\_operator\_v

```
template<class T >
constexpr bool ceras::is_binary_operator_v = is_binary_operator<T>::value [inline], [constexpr]
```

If T is an instance of a [binary\\_operator](#), the constant value equals to true. Otherwise this value is false.

### 5.1.3.14 is\_complex\_v

```
template<typename T >
constexpr bool ceras::is_complex_v = is_complex<T>::value [constexpr]
```

### 5.1.3.15 is\_constant\_v

```
template<class T >
constexpr bool ceras::is_constant_v = is_constant<T>::value [inline], [constexpr]
```

### 5.1.3.16 is\_place\_holder\_v

```
template<class T >
constexpr bool ceras::is_place_holder_v = is_place_holder<T>::value [inline], [constexpr]
```

### 5.1.3.17 is\_tensor\_v

```
template<class T >
constexpr bool ceras::is_tensor_v = is_tensor<T>::value [inline], [constexpr]
```

### 5.1.3.18 is\_unary\_operator\_v

```
template<class T >
constexpr bool ceras::is_unary_operator_v = is_unary_operator<T>::value [inline], [constexpr]
```

If T is an instance of a [unary\\_operator](#), the constant value equals to `true`. Otherwise this value is `false`.

### 5.1.3.19 is\_value\_v

```
template<class T >
constexpr bool ceras::is_value_v = is_value<T>::value [inline], [constexpr]
```

### 5.1.3.20 is\_variable\_v

```
template<class T >
constexpr bool ceras::is_variable_v = is_variable<T>::value [inline], [constexpr]
```

### 5.1.3.21 MAE

```
auto ceras::MAE [inline]
```

#### Initial value:

```
= []()
{
    return MeanAbsoluteError();
}
```

An alias name of function [MeanAbsoluteError](#).

### 5.1.3.22 make\_binary\_operator

```
constexpr auto ceras::make_binary_operator [static], [constexpr]
```

#### Initial value:

```
= [] ( auto const& binary_forward_action, auto const& binary_backward_action, std::string const&
    name="Anonymous Binary Operator" ) noexcept
{
    return [&binary_forward_action, &binary_backward_action, &name] ( auto const& lhs_op, auto const&
    rhs_op ) noexcept
    {
        auto ans = binary_operator{ lhs_op, rhs_op, binary_forward_action, binary_backward_action };
        ans.name_ = name;
        return ans;
    };
}
```

### 5.1.3.23 make\_unary\_operator

```
constexpr auto ceras::make_unary_operator [static], [constexpr]
```

#### Initial value:

```
= [] ( auto const& unary_forward_action, auto const& unary_backward_action, std::string const&
    name="Anonymous Unary Operator" ) noexcept
{
    return [&unary_forward_action, &unary_backward_action, &name] ( auto const& op ) noexcept
    {
        auto ans = unary_operator{ op, unary_forward_action, unary_backward_action };
        ans.name_ = name;
        return ans;
    };
}
```

### 5.1.3.24 MeanAbsoluteError

```
auto ceras::MeanAbsoluteError [inline]
```

#### Initial value:

```
= [] ()
{
    return [] <Expression Ex > ( Ex const& output )
    {
        return [=] <Place_Holder Ph> ( Ph const& ground_truth )
        {
            return mean_absolute_error( ground_truth, output );
        };
    };
}
```

Computes the mean of absolute errors between labels and predictions.

```
auto input = place_holder<tensor<float>>{};
auto v = variable<tensor<float>>{ ones<float>({12, 34}) };
auto output = input * v;
auto m = model{ input, output };
auto cm = m.compile( MeanAbsoluteError(), Adam(128/*batch size*/, 0.01f/*learning rate*/) );
```

see also [mean\\_absolute\\_error](#)

### 5.1.3.25 MeanSquaredError

```
auto ceras::MeanSquaredError [inline]
```

#### Initial value:

```
= [] ()
{
    return [] <Expression Ex > ( Ex const& output )
    {
        return [=] <Place_Holder Ph> ( Ph const& ground_truth )
        {
            return mean_squared_error( ground_truth, output );
        };
    };
}
```

Computes the mean of squares of errors between labels and predictions.

```
auto input = place_holder<tensor<float>>{};
auto v = variable<tensor<float>>{ ones<float>({12, 34}) };
auto output = input * v;
auto m = model{ input, output };
auto cm = m.compile( MeanSquaredError(), Adam(128/*batch size*/, 0.01f/*learning rate*/) );
```

see also [mean\\_squared\\_error](#)



### 5.1.3.26 MSE

```
auto ceras::MSE [inline]
```

**Initial value:**

```
= [] ()
{
    return MeanSquaredError();
}
```

An alias name of function [MeanSquaredError](#).

### 5.1.3.27 Operator

```
template<typename T >
concept ceras::Operator = Unary_Operator<T> || Binary_Operator<T>
```

A type that represents an unary or a binary operator.

```
@concept Operator<>
```

### 5.1.3.28 Place\_Holder

```
template<typename T >
concept ceras::Place_Holder = is_place_holder_v<T>
```

### 5.1.3.29 random\_generator

```
std::mt19937 ceras::random_generator {random_seed} [static]
```

### 5.1.3.30 random\_seed

```
unsigned long ceras::random_seed = std::chrono::system_clock::now().time_since_epoch().count()
[static]
```

### 5.1.3.31 RMSprop

```
auto ceras::RMSprop [inline]
```

**Initial value:**

```
= [] ( auto ... args )
{
    return [=]<Expression Ex>( Ex& loss )
    {
        return rmsprop{loss, args...};
    };
}
```

### 5.1.3.32 SGD

```
auto ceras::SGD [inline]
```

#### Initial value:

```
= []( auto ... args )
{
    return [=]<Expression Ex>( Ex& loss )
    {
        return sgd{loss, args...};
    };
}
```

### 5.1.3.33 Tensor

```
template<typename T >
concept ceras::Tensor = is_tensor_v<T>
```

### 5.1.3.34 Unary\_Operator

```
template<typename T >
concept ceras::Unary_Operator = is_unary_operator_v<T>
```

A type that represents an unary operator.

```
@concept Unary_Operator<>
```

### 5.1.3.35 Value

```
template<typename T >
concept ceras::Value = is_value_v<T>
```

### 5.1.3.36 Variable

```
template<typename T >
concept ceras::Variable = is_variable_v<T>
```

## 5.2 ceras::ceras\_private Namespace Reference

### Classes

- struct [session](#)

## 5.3 ceras::dataset Namespace Reference

### Namespaces

- [fashion\\_mnist](#)
- [mnist](#)

## 5.4 ceras::dataset::fashion\_mnist Namespace Reference

### Functions

- auto [load\\_data](#) (std::string const &path=std::string{"/dataset/fashion\_mnist"})

### 5.4.1 Function Documentation

#### 5.4.1.1 load\_data()

```
auto ceras::dataset::fashion_mnist::load_data (
    std::string const & path = std::string{"/dataset/fashion_mnist"} ) [inline]
```

Loads the fashion-MNIST dataset.

#### Parameters

<i>path</i>	Path where to cache the dataset locally. Default to "/dataset/fashion_mnist", should be updated if running the program somewhere else.
-------------	----------------------------------------------------------------------------------------------------------------------------------------

#### Returns

A tuple of 4 tensors: x\_train, y\_train, x\_test, y\_test. x\_train, x\_test: uint8 arrays of grayscale image data with shapes (num\_samples, 28, 28). y\_train, y\_test: uint8 tensor of digit labels (integers in range 0-9) with shapes (num\_samples, 10). Note: for digit 0, the corresponding array is `[[1, 0, 0, 0, 0, 0, 0, 0, 0, 0]]`.

Label Description 0 T-shirt/top 1 Trouser 2 Pullover 3 Dress 4 Coat 5 Sandal 6 Shirt 7 Sneaker 8 Bag 9 Ankle boot

#### Example usage:

```
auto const& [x_train, y_train, x_test, y_test] =
    ceras::dataset::mnist::load_data("/home/feng/dataset/fashion_mnist");
```

The copyright for Fashion-MNIST is held by Zalando SE. Fashion-MNIST is licensed under the MIT license.

## 5.5 ceras::dataset::mnist Namespace Reference

### Functions

- auto [load\\_data](#) (std::string const &path=std::string{"/dataset/mnist"})

## 5.5.1 Function Documentation

### 5.5.1.1 load\_data()

```
auto ceras::dataset::mnist::load_data (
    std::string const & path = std::string{"/dataset/mnist"} ) [inline]
```

Loads the MNIST dataset.

#### Parameters

<i>path</i>	Path where to cache the dataset locally. Default to <code>"/dataset/mnist"</code> , should be updated if running the program somewhere else.
-------------	----------------------------------------------------------------------------------------------------------------------------------------------

#### Returns

A tuple of 4 tensors: `x_train`, `y_train`, `x_test`, `y_test`. `x_train`, `x_test`: uint8 arrays of grayscale image data with shapes `(num_samples, 28, 28)`. `y_train`, `y_test`: uint8 tensor of digit labels (integers in range 0-9) with shapes `(num_samples, 10)`. Note: for digit 0, the corresponding array is `[[1, 0, 0, 0, 0, 0, 0, 0, 0, 0]]`.

#### Example usage:

```
auto const& [x_train, y_train, x_test, y_test] =
    ceras::dataset::mnist::load_data("/home/feng/dataset/mnist");
```

Yann LeCun and Corinna Cortes hold the copyright of MNIST dataset, which is available under the terms of the Creative Commons Attribution-Share Alike 3.0 license.

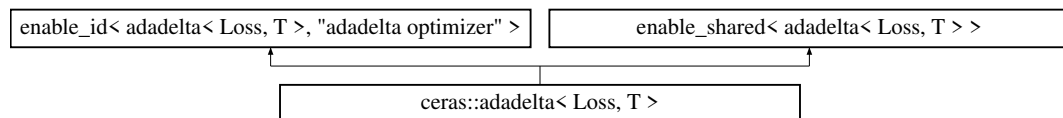
## Chapter 6

# Class Documentation

### 6.1 `ceras::adadelta< Loss, T >` Struct Template Reference

```
#include <optimizer.hpp>
```

Inheritance diagram for `ceras::adadelta< Loss, T >`:



#### Public Types

- typedef `tensor< T >` `tensor_type`

#### Public Member Functions

- `adadelta` (`Loss &loss`, `std::size_t batch_size`, `T rho=0.9`) `noexcept`
- void `forward` ()

#### Public Attributes

- `Loss &` `loss_`
- `T` `rho_`
- `T` `learning_rate_`
- unsigned long `iterations_`

#### 6.1.1 Member Typedef Documentation

### 6.1.1.1 tensor\_type

```
template<typename Loss , typename T >
typedef tensor< T > ceras::adadelta< Loss, T >::tensor_type
```

## 6.1.2 Constructor & Destructor Documentation

### 6.1.2.1 adadelta()

```
template<typename Loss , typename T >
ceras::adadelta< Loss, T >::adadelta (
    Loss & loss,
    std::size_t batch_size,
    T rho = 0.9 ) [inline], [noexcept]
```

## 6.1.3 Member Function Documentation

### 6.1.3.1 forward()

```
template<typename Loss , typename T >
void ceras::adadelta< Loss, T >::forward ( ) [inline]
```

## 6.1.4 Member Data Documentation

### 6.1.4.1 iterations\_

```
template<typename Loss , typename T >
unsigned long ceras::adadelta< Loss, T >::iterations_
```

### 6.1.4.2 learning\_rate\_

```
template<typename Loss , typename T >
T ceras::adadelta< Loss, T >::learning_rate_
```

### 6.1.4.3 loss\_

```
template<typename Loss , typename T >
Loss& ceras::adadelat< Loss, T >::loss_
```

### 6.1.4.4 rho\_

```
template<typename Loss , typename T >
T ceras::adadelat< Loss, T >::rho_
```

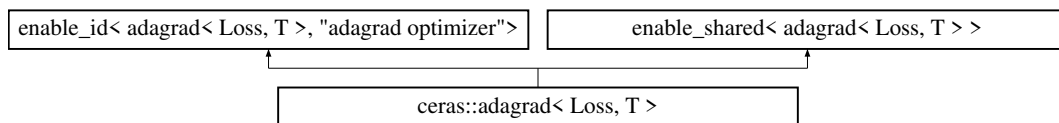
The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/optimizer.hpp

## 6.2 ceras::adagrad< Loss, T > Struct Template Reference

```
#include <optimizer.hpp>
```

Inheritance diagram for ceras::adagrad< Loss, T >:



### Public Types

- typedef [tensor](#)< T > [tensor\\_type](#)

### Public Member Functions

- [adagrad](#) (Loss &loss, std::size\_t batch\_size, T learning\_rate=1.0e-1, T decay=0.0) noexcept
- void [forward](#) ()

### Public Attributes

- Loss & [loss\\_](#)
- T [learning\\_rate\\_](#)
- T [decay\\_](#)
- unsigned long [iterations\\_](#)

### 6.2.1 Member Typedef Documentation

### 6.2.1.1 tensor\_type

```
template<typename Loss , typename T >
typedef tensor< T > ceras::adagrad< Loss, T >::tensor\_type
```

## 6.2.2 Constructor & Destructor Documentation

### 6.2.2.1 adagrad()

```
template<typename Loss , typename T >
ceras::adagrad< Loss, T >::adagrad (
    Loss & loss,
    std::size_t batch_size,
    T learning_rate = 1.0e-1,
    T decay = 0.0 ) [inline], [noexcept]
```

## 6.2.3 Member Function Documentation

### 6.2.3.1 forward()

```
template<typename Loss , typename T >
void ceras::adagrad< Loss, T >::forward ( ) [inline]
```

## 6.2.4 Member Data Documentation

### 6.2.4.1 decay\_

```
template<typename Loss , typename T >
T ceras::adagrad< Loss, T >::decay_
```

### 6.2.4.2 iterations\_

```
template<typename Loss , typename T >
unsigned long ceras::adagrad< Loss, T >::iterations_
```



#### 6.2.4.3 learning\_rate\_

```
template<typename Loss , typename T >
T ceras::adagrad< Loss, T >::learning_rate_
```

#### 6.2.4.4 loss\_

```
template<typename Loss , typename T >
Loss& ceras::adagrad< Loss, T >::loss_
```

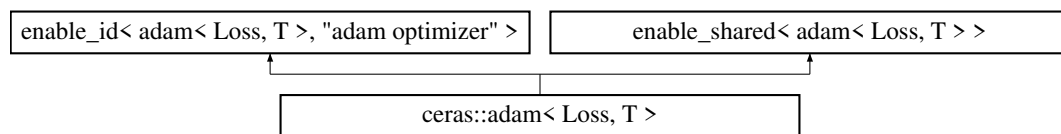
The documentation for this struct was generated from the following file:

- [/data/structured\\_folders/workspace/github.repo/ceras/include/optimizer.hpp](/data/structured_folders/workspace/github.repo/ceras/include/optimizer.hpp)

## 6.3 ceras::adam< Loss, T > Struct Template Reference

```
#include <optimizer.hpp>
```

Inheritance diagram for ceras::adam< Loss, T >:



### Public Types

- typedef [tensor](#)< T > [tensor\\_type](#)

### Public Member Functions

- [adam](#) (Loss &loss, std::size\_t batch\_size, T learning\_rate=1.0e-1, T beta\_1=0.9, T beta\_2=0.999, bool amsgrad=false) noexcept
- void [forward](#) ()

### Public Attributes

- Loss & [loss\\_](#)
- T [learning\\_rate\\_](#)
- T [beta\\_1\\_](#)
- T [beta\\_2\\_](#)
- bool [amsgrad\\_](#)
- unsigned long [iterations\\_](#)

## 6.3.1 Member Typedef Documentation

### 6.3.1.1 tensor\_type

```
template<typename Loss , typename T >
typedef tensor< T > ceras::adam< Loss, T >::tensor\_type
```

## 6.3.2 Constructor & Destructor Documentation

### 6.3.2.1 adam()

```
template<typename Loss , typename T >
ceras::adam< Loss, T >::adam (
    Loss & loss,
    std::size_t batch_size,
    T learning_rate = 1.0e-1,
    T beta_1 = 0.9,
    T beta_2 = 0.999,
    bool amsgrad = false ) [inline], [noexcept]
```

## 6.3.3 Member Function Documentation

### 6.3.3.1 forward()

```
template<typename Loss , typename T >
void ceras::adam< Loss, T >::forward ( ) [inline]
```

## 6.3.4 Member Data Documentation

### 6.3.4.1 amsgrad\_

```
template<typename Loss , typename T >
bool ceras::adam< Loss, T >::amsgrad\_
```

#### 6.3.4.2 beta\_1\_

```
template<typename Loss , typename T >
T ceras::adam< Loss, T >::beta_1_
```

#### 6.3.4.3 beta\_2\_

```
template<typename Loss , typename T >
T ceras::adam< Loss, T >::beta_2_
```

#### 6.3.4.4 iterations\_

```
template<typename Loss , typename T >
unsigned long ceras::adam< Loss, T >::iterations_
```

#### 6.3.4.5 learning\_rate\_

```
template<typename Loss , typename T >
T ceras::adam< Loss, T >::learning_rate_
```

#### 6.3.4.6 loss\_

```
template<typename Loss , typename T >
Loss& ceras::adam< Loss, T >::loss_
```

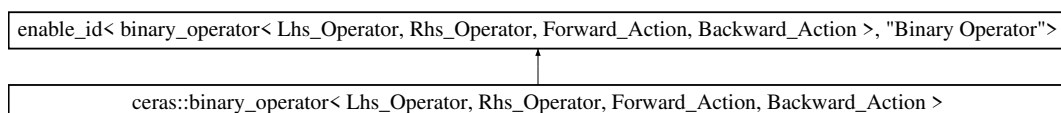
The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[optimizer.hpp](#)

## 6.4 ceras::binary\_operator< Lhs\_Operator, Rhs\_Operator, Forward\_Action, Backward\_Action > Struct Template Reference

```
#include <operation.hpp>
```

Inheritance diagram for ceras::binary\_operator< Lhs\_Operator, Rhs\_Operator, Forward\_Action, Backward\_Action >:



## Public Types

- typedef [tensor\\_deduction](#)< Lhs\_Operator, Rhs\_Operator >::[tensor\\_type](#) [tensor\\_type](#)

## Public Member Functions

- [binary\\_operator](#) (Lhs\_Operator const &lhs\_op, Rhs\_Operator const &rhs\_op, Forward\_Action const &forward\_action, Backward\_Action const &backward\_action) noexcept
- auto [forward](#) ()
- void [backward](#) ([tensor\\_type](#) const &grad)

## Public Attributes

- Lhs\_Operator [lhs\\_op\\_](#)
- Rhs\_Operator [rhs\\_op\\_](#)
- Forward\_Action [forward\\_action\\_](#)
- Backward\_Action [backward\\_action\\_](#)
- [tensor\\_type](#) [lhs\\_input\\_data\\_](#)
- [tensor\\_type](#) [rhs\\_input\\_data\\_](#)
- [tensor\\_type](#) [output\\_data\\_](#)

## 6.4.1 Member Typedef Documentation

### 6.4.1.1 [tensor\\_type](#)

```
template<typename Lhs_Operator , typename Rhs_Operator , typename Forward_Action , typename
Backward_Action >
typedef tensor\_deduction<Lhs_Operator, Rhs_Operator>::tensor\_type ceras::binary\_operator<
Lhs_Operator, Rhs_Operator, Forward_Action, Backward_Action >::tensor\_type
```

## 6.4.2 Constructor & Destructor Documentation

### 6.4.2.1 [binary\\_operator](#)()

```
template<typename Lhs_Operator , typename Rhs_Operator , typename Forward_Action , typename
Backward_Action >
ceras::binary\_operator< Lhs_Operator, Rhs_Operator, Forward_Action, Backward_Action >::binary\_operator
(
    Lhs_Operator const & lhs_op,
    Rhs_Operator const & rhs_op,
    Forward_Action const & forward_action,
    Backward_Action const & backward_action ) [inline], [noexcept]
```

### 6.4.3 Member Function Documentation

#### 6.4.3.1 backward()

```
template<typename Lhs_Operator , typename Rhs_Operator , typename Forward_Action , typename
Backward_Action >
void ceras::binary_operator< Lhs_Operator, Rhs_Operator, Forward_Action, Backward_Action >↵
::backward (
    tensor_type const & grad ) [inline]
```

#### 6.4.3.2 forward()

```
template<typename Lhs_Operator , typename Rhs_Operator , typename Forward_Action , typename
Backward_Action >
auto ceras::binary_operator< Lhs_Operator, Rhs_Operator, Forward_Action, Backward_Action >↵
::forward ( ) [inline]
```

### 6.4.4 Member Data Documentation

#### 6.4.4.1 backward\_action\_

```
template<typename Lhs_Operator , typename Rhs_Operator , typename Forward_Action , typename
Backward_Action >
Backward_Action ceras::binary_operator< Lhs_Operator, Rhs_Operator, Forward_Action, Backward↵
_Action >::backward_action_
```

#### 6.4.4.2 forward\_action\_

```
template<typename Lhs_Operator , typename Rhs_Operator , typename Forward_Action , typename
Backward_Action >
Forward_Action ceras::binary_operator< Lhs_Operator, Rhs_Operator, Forward_Action, Backward↵
_Action >::forward_action_
```

#### 6.4.4.3 lhs\_input\_data\_

```
template<typename Lhs_Operator , typename Rhs_Operator , typename Forward_Action , typename
Backward_Action >
tensor_type ceras::binary_operator< Lhs_Operator, Rhs_Operator, Forward_Action, Backward↵
_Action >::lhs_input_data_
```

#### 6.4.4.4 lhs\_op\_

```
template<typename Lhs_Operator , typename Rhs_Operator , typename Forward_Action , typename
Backward_Action >
Lhs_Operator ceras::binary_operator< Lhs_Operator, Rhs_Operator, Forward_Action, Backward_↵
Action >::lhs_op_
```

#### 6.4.4.5 output\_data\_

```
template<typename Lhs_Operator , typename Rhs_Operator , typename Forward_Action , typename
Backward_Action >
tensor_type ceras::binary_operator< Lhs_Operator, Rhs_Operator, Forward_Action, Backward_↵
Action >::output_data_
```

#### 6.4.4.6 rhs\_input\_data\_

```
template<typename Lhs_Operator , typename Rhs_Operator , typename Forward_Action , typename
Backward_Action >
tensor_type ceras::binary_operator< Lhs_Operator, Rhs_Operator, Forward_Action, Backward_↵
Action >::rhs_input_data_
```

#### 6.4.4.7 rhs\_op\_

```
template<typename Lhs_Operator , typename Rhs_Operator , typename Forward_Action , typename
Backward_Action >
Rhs_Operator ceras::binary_operator< Lhs_Operator, Rhs_Operator, Forward_Action, Backward_↵
Action >::rhs_op_
```

The documentation for this struct was generated from the following file:

- [/data/structured\\_folders/workspace/github.repo/ceras/include/operation.hpp](#)

## 6.5 ceras::compiled\_model< Model, Optimizer, Loss > Struct Template Reference

```
#include <model.hpp>
```

### Public Types

- typedef Model::input\_layer\_type [io\\_layer\\_type](#)

## Public Member Functions

- `compiled_model` (Model const &m, `io_layer_type` const &input\_place\_holder, `io_layer_type` const &ground\_truth\_place\_holder, Loss const &loss, Optimizer const &optimizer)
- `template<Tensor Tsr>`  
auto `evaluate` (Tsr const &inputs, Tsr const &outputs, unsigned long batch\_size=32)
- `template<Tensor Tsr>`  
auto `fit` (Tsr const &inputs, Tsr const &outputs, unsigned long batch\_size, unsigned long epoch=1, int verbose=0, double validation\_split=0.0)
- `template<Tensor Tsr>`  
auto `train_on_batch` (Tsr const &input, Tsr const &output)
- `template<Tensor Tsr>`  
auto `predict` (Tsr const &input\_tensor)
- `template<Expression Exp>`  
auto `operator()` (Exp const &ex) const noexcept
- void `trainable` (bool t)

## Public Attributes

- `decltype(std::declval< Optimizer >()(std::declval< Loss & >()))` typedef `optimizer_type`
- Model `model_`
- `io_layer_type` `input_place_holder_`
- `io_layer_type` `ground_truth_place_holder_`
- Loss `loss_`
- Optimizer `optimizer_`
- `optimizer_type` `compiled_optimizer_`

## 6.5.1 Member Typedef Documentation

### 6.5.1.1 io\_layer\_type

```
template<typename Model , typename Optimizer , typename Loss >
typedef Model::input_layer_type ceras::compiled_model< Model, Optimizer, Loss >::io_layer_type
```

## 6.5.2 Constructor & Destructor Documentation

### 6.5.2.1 compiled\_model()

```
template<typename Model , typename Optimizer , typename Loss >
ceras::compiled_model< Model, Optimizer, Loss >::compiled_model (
    Model const & m,
    io_layer_type const & input_place_holder,
    io_layer_type const & ground_truth_place_holder,
    Loss const & loss,
    Optimizer const & optimizer ) [inline]
```

## 6.5.3 Member Function Documentation

### 6.5.3.1 evaluate()

```
template<typename Model , typename Optimizer , typename Loss >
template<Tensor Tsor>
auto ceras::compiled_model< Model, Optimizer, Loss >::evaluate (
    Tsor const & inputs,
    Tsor const & outputs,
    unsigned long batch_size = 32 ) [inline]
```

Calculate the loss for the model in test model.

#### Parameters

<i>inputs</i>	Input data. A tensor of shape (samples, input_shape).
<i>outputs</i>	Output data. A tensor of shape (samples, output_shape).
<i>batch_size</i>	Number of samples per batch of computation. Default to 32.

#### Returns

Test loss. A scalar.

### 6.5.3.2 fit()

```
template<typename Model , typename Optimizer , typename Loss >
template<Tensor Tsor>
auto ceras::compiled_model< Model, Optimizer, Loss >::fit (
    Tsor const & inputs,
    Tsor const & outputs,
    unsigned long batch_size,
    unsigned long epoch = 1,
    int verbose = 0,
    double validation_split = 0.0 ) [inline]
```

Train the model on the selected dataset for a fixed numbers of epoches.

#### Parameters

<i>inputs</i>	Input data. A tensor of shape (samples, input_shape).
<i>outputs</i>	Input data. A tensor of shape (samples, output_shape).
<i>batch_size</i>	Number of samples per gradient update. Should agree with the batch size in the optimizer.
<i>epoch</i>	Number of epoches to train the dataset.
<i>verbose</i>	Verbosity mode. 0 for silent. 1 for one line per epoch.
<i>validation_split</i>	Fraction of the training data that will be used for validation. A floating number in range [0, 1].



**Returns**

A tuple of two vectors. The first vector gives the historical errors on the training data. The second vector gives the historical errors on the validation data.

**Example:**

```
model m{ ... };
auto cm = m.compile( ... );
tensor<float> inputs, outputs;
//...
unsigned long batch_size = 32;
unsigned long epoch = 10;
int verbose = 1;
double validation_split = 0.2;
auto errors = cm.fit( inputs, outputs, batch_size, epoch, verbose, validation_split );
```

**6.5.3.3 operator()**

```
template<typename Model , typename Optimizer , typename Loss >
template<Expression Exp>
auto ceras::compiled_model< Model, Optimizer, Loss >::operator() (
    Exp const & ex ) const [inline], [noexcept]
```

**6.5.3.4 predict()**

```
template<typename Model , typename Optimizer , typename Loss >
template<Tensor Tsor>
auto ceras::compiled_model< Model, Optimizer, Loss >::predict (
    Tsor const & input_tensor ) [inline]
```

**6.5.3.5 train\_on\_batch()**

```
template<typename Model , typename Optimizer , typename Loss >
template<Tensor Tsor>
auto ceras::compiled_model< Model, Optimizer, Loss >::train_on_batch (
    Tsor const & input,
    Tsor const & output ) [inline]
```

Running a single updated on a single batch of data.

**Parameters**

<i>input</i>	The input data to train the model. A tensor of shape (batch_size, input_shape).
<i>output</i>	The output data to train the model. A tensor of shape (batch_size, output_shape).

**Returns**

Training loss. A scalar.

Example code:

```
auto m = model{ ... };
auto cm = m.compile( ... );
for ( auto idx : range( 1024 ) )
{
    auto x = ...; // get batch input
    auto y = ...; // get batch output
    cm.train_on_batch( x, y );
}
```

### 6.5.3.6 trainable()

```
template<typename Model , typename Optimizer , typename Loss >
void ceras::compiled_model< Model, Optimizer, Loss >::trainable (
    bool t ) [inline]
```

## 6.5.4 Member Data Documentation

### 6.5.4.1 compiled\_optimizer\_

```
template<typename Model , typename Optimizer , typename Loss >
optimizer_type ceras::compiled_model< Model, Optimizer, Loss >::compiled_optimizer_
```

### 6.5.4.2 ground\_truth\_place\_holder\_

```
template<typename Model , typename Optimizer , typename Loss >
io_layer_type ceras::compiled_model< Model, Optimizer, Loss >::ground_truth_place_holder_
```

### 6.5.4.3 input\_place\_holder\_

```
template<typename Model , typename Optimizer , typename Loss >
io_layer_type ceras::compiled_model< Model, Optimizer, Loss >::input_place_holder_
```

### 6.5.4.4 loss\_

```
template<typename Model , typename Optimizer , typename Loss >
Loss ceras::compiled_model< Model, Optimizer, Loss >::loss_
```

#### 6.5.4.5 model\_

```
template<typename Model , typename Optimizer , typename Loss >  
Model ceras::compiled_model< Model, Optimizer, Loss >::model_
```

#### 6.5.4.6 optimizer\_

```
template<typename Model , typename Optimizer , typename Loss >  
Optimizer ceras::compiled_model< Model, Optimizer, Loss >::optimizer_
```

#### 6.5.4.7 optimizer\_type

```
template<typename Model , typename Optimizer , typename Loss >  
decltype(std::declval<Optimizer>() (std::declval<Loss&>())) typedef ceras::compiled_model<  
Model, Optimizer, Loss >::optimizer_type
```

The documentation for this struct was generated from the following file:

- [/data/structured\\_folders/workspace/github.repo/ceras/include/model.hpp](/data/structured_folders/workspace/github.repo/ceras/include/model.hpp)

## 6.6 ceras::complex< Real\_Ex, Imag\_Ex > Struct Template Reference

```
#include <complex_operator.hpp>
```

### Public Attributes

- Real\_Ex [real\\_](#)
- Imag\_Ex [imag\\_](#)

### 6.6.1 Member Data Documentation

#### 6.6.1.1 imag\_

```
template<Expression Real_Ex, Expression Imag_Ex>  
Imag_Ex ceras::complex< Real_Ex, Imag_Ex >::imag_
```

### 6.6.1.2 real\_

```
template<Expression Real_Ex, Expression Imag_Ex>
Real_Ex ceras::complex< Real_Ex, Imag_Ex >::real_
```

The documentation for this struct was generated from the following file:

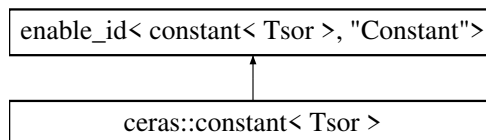
- [/data/structured\\_folders/workspace/github.repo/ceras/include/complex\\_operator.hpp](/data/structured_folders/workspace/github.repo/ceras/include/complex_operator.hpp)

## 6.7 ceras::constant< Tzor > Struct Template Reference

Creates a constant expression from a tensor-like object.

```
#include <constant.hpp>
```

Inheritance diagram for ceras::constant< Tzor >:



### Public Member Functions

- [constant](#) (Tzor const &data)
- void [backward](#) (auto) const
- Tzor [forward](#) () const
- auto [shape](#) () const

### Public Attributes

- Tzor [data\\_](#)

### 6.7.1 Detailed Description

```
template<Tensor Tzor>
struct ceras::constant< Tzor >
```

Creates a constant expression from a tensor-like object.

```
auto c = constant{ zeros<float>( {3, 3, 3} ) };
```

### 6.7.2 Constructor & Destructor Documentation

### 6.7.2.1 constant()

```
template<Tensor Tzor>
ceras::constant< Tzor >::constant (
    Tzor const & data ) [inline]
```

## 6.7.3 Member Function Documentation

### 6.7.3.1 backward()

```
template<Tensor Tzor>
void ceras::constant< Tzor >::backward (
    auto ) const [inline]
```

### 6.7.3.2 forward()

```
template<Tensor Tzor>
Tzor ceras::constant< Tzor >::forward ( ) const [inline]
```

### 6.7.3.3 shape()

```
template<Tensor Tzor>
auto ceras::constant< Tzor >::shape ( ) const [inline]
```

## 6.7.4 Member Data Documentation

### 6.7.4.1 data\_

```
template<Tensor Tzor>
Tzor ceras::constant< Tzor >::data_
```

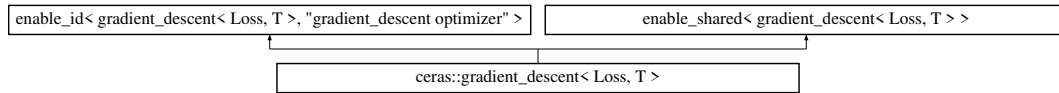
The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[constant.hpp](#)

## 6.8 ceras::gradient\_descent< Loss, T > Struct Template Reference

```
#include <optimizer.hpp>
```

Inheritance diagram for ceras::gradient\_descent< Loss, T >:



### Public Types

- typedef [tensor](#)< T > [tensor\\_type](#)

### Public Member Functions

- [gradient\\_descent](#) (Loss &loss, std::size\_t batch\_size, T learning\_rate=1.0e-3, T momentum=0.0) noexcept
- void [forward](#) ()

### Public Attributes

- Loss & [loss\\_](#)
- T [learning\\_rate\\_](#)
- T [momentum\\_](#)

## 6.8.1 Member Typedef Documentation

### 6.8.1.1 tensor\_type

```
template<typename Loss , typename T >
typedef tensor< T > ceras::gradient\_descent< Loss, T >::tensor\_type
```

## 6.8.2 Constructor & Destructor Documentation

### 6.8.2.1 gradient\_descent()

```
template<typename Loss , typename T >
ceras::gradient\_descent< Loss, T >::gradient\_descent (
    Loss & loss,
    std::size_t batch_size,
    T learning_rate = 1.0e-3,
    T momentum = 0.0 ) [inline], [noexcept]
```

## 6.8.3 Member Function Documentation

### 6.8.3.1 forward()

```
template<typename Loss , typename T >
void ceras::gradient_descent< Loss, T >::forward ( ) [inline]
```

## 6.8.4 Member Data Documentation

### 6.8.4.1 learning\_rate\_

```
template<typename Loss , typename T >
T ceras::gradient_descent< Loss, T >::learning_rate_
```

### 6.8.4.2 loss\_

```
template<typename Loss , typename T >
Loss& ceras::gradient_descent< Loss, T >::loss_
```

### 6.8.4.3 momentum\_

```
template<typename Loss , typename T >
T ceras::gradient_descent< Loss, T >::momentum_
```

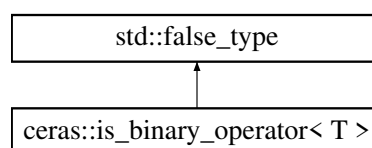
The documentation for this struct was generated from the following file:

- [/data/structured\\_folders/workspace/github.repo/ceras/include/optimizer.hpp](/data/structured_folders/workspace/github.repo/ceras/include/optimizer.hpp)

## 6.9 ceras::is\_binary\_operator< T > Struct Template Reference

```
#include <operation.hpp>
```

Inheritance diagram for ceras::is\_binary\_operator< T >:



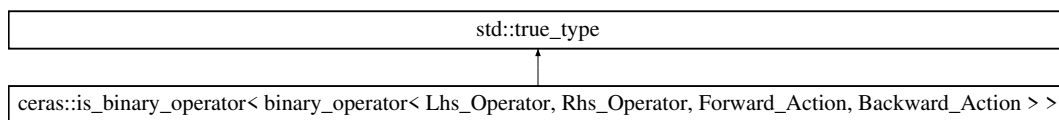
The documentation for this struct was generated from the following file:

- [/data/structured\\_folders/workspace/github.repo/ceras/include/operation.hpp](/data/structured_folders/workspace/github.repo/ceras/include/operation.hpp)

## 6.10 `ceras::is_binary_operator< binary_operator< Lhs_Operator, Rhc_Operator, Forward_Action, Backward_Action > >` Struct Template Reference

```
#include <operation.hpp>
```

Inheritance diagram for `ceras::is_binary_operator< binary_operator< Lhs_Operator, Rhc_Operator, Forward_Action, Backward_Action > >`:



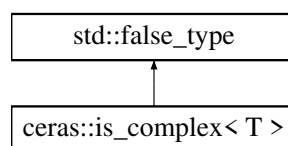
The documentation for this struct was generated from the following file:

- [/data/structured\\_folders/workspace/github.repo/ceras/include/operation.hpp](/data/structured_folders/workspace/github.repo/ceras/include/operation.hpp)

## 6.11 `ceras::is_complex< T >` Struct Template Reference

```
#include <complex_operator.hpp>
```

Inheritance diagram for `ceras::is_complex< T >`:



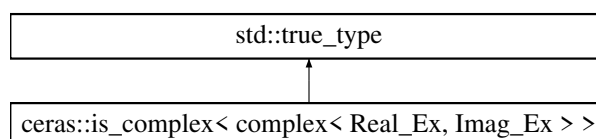
The documentation for this struct was generated from the following file:

- [/data/structured\\_folders/workspace/github.repo/ceras/include/complex\\_operator.hpp](/data/structured_folders/workspace/github.repo/ceras/include/complex_operator.hpp)

## 6.12 `ceras::is_complex< complex< Real_Ex, Imag_Ex > >` Struct Template Reference

```
#include <complex_operator.hpp>
```

Inheritance diagram for `ceras::is_complex< complex< Real_Ex, Imag_Ex > >`:



The documentation for this struct was generated from the following file:

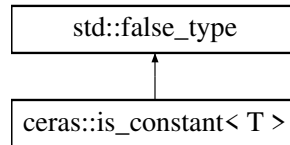
- [/data/structured\\_folders/workspace/github.repo/ceras/include/complex\\_operator.hpp](/data/structured_folders/workspace/github.repo/ceras/include/complex_operator.hpp)



## 6.13 ceras::is\_constant< T > Struct Template Reference

```
#include <constant.hpp>
```

Inheritance diagram for ceras::is\_constant< T >:



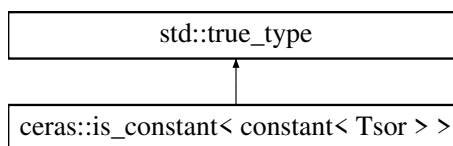
The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[constant.hpp](#)

## 6.14 ceras::is\_constant< constant< Tsor > > Struct Template Reference

```
#include <constant.hpp>
```

Inheritance diagram for ceras::is\_constant< constant< Tsor > >:



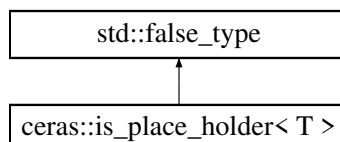
The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[constant.hpp](#)

## 6.15 ceras::is\_place\_holder< T > Struct Template Reference

```
#include <place_holder.hpp>
```

Inheritance diagram for ceras::is\_place\_holder< T >:



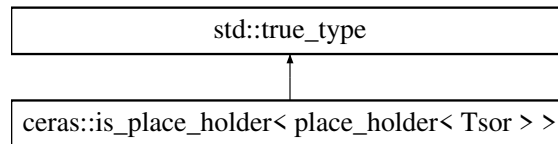
The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[place\\_holder.hpp](#)

## 6.16 `ceras::is_place_holder< place_holder< Tsor > >` Struct Template Reference

```
#include <place_holder.hpp>
```

Inheritance diagram for `ceras::is_place_holder< place_holder< Tsor > >`:



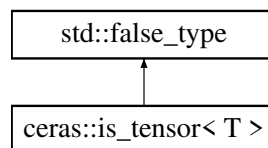
The documentation for this struct was generated from the following file:

- [/data/structured\\_folders/workspace/github.repo/ceras/include/place\\_holder.hpp](/data/structured_folders/workspace/github.repo/ceras/include/place_holder.hpp)

## 6.17 `ceras::is_tensor< T >` Struct Template Reference

```
#include <tensor.hpp>
```

Inheritance diagram for `ceras::is_tensor< T >`:



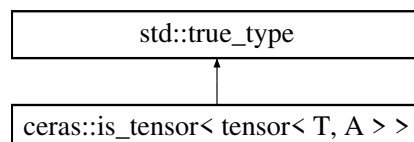
The documentation for this struct was generated from the following file:

- [/data/structured\\_folders/workspace/github.repo/ceras/include/tensor.hpp](/data/structured_folders/workspace/github.repo/ceras/include/tensor.hpp)

## 6.18 `ceras::is_tensor< tensor< T, A > >` Struct Template Reference

```
#include <tensor.hpp>
```

Inheritance diagram for `ceras::is_tensor< tensor< T, A > >`:



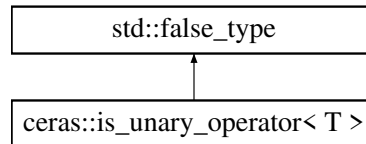
The documentation for this struct was generated from the following file:

- [/data/structured\\_folders/workspace/github.repo/ceras/include/tensor.hpp](/data/structured_folders/workspace/github.repo/ceras/include/tensor.hpp)

## 6.19 ceras::is\_unary\_operator< T > Struct Template Reference

```
#include <operation.hpp>
```

Inheritance diagram for ceras::is\_unary\_operator< T >:



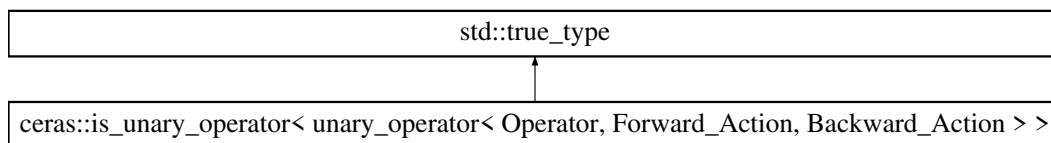
The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[operation.hpp](#)

## 6.20 ceras::is\_unary\_operator< unary\_operator< Operator, Forward\_Action, Backward\_Action > > Struct Template Reference

```
#include <operation.hpp>
```

Inheritance diagram for ceras::is\_unary\_operator< unary\_operator< Operator, Forward\_Action, Backward\_Action > >:



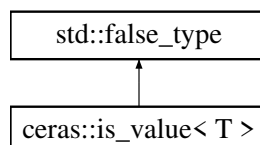
The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[operation.hpp](#)

## 6.21 ceras::is\_value< T > Struct Template Reference

```
#include <value.hpp>
```

Inheritance diagram for ceras::is\_value< T >:



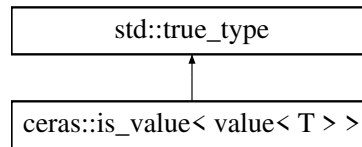
The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[value.hpp](#)

## 6.22 ceras::is\_value< value< T > > Struct Template Reference

```
#include <value.hpp>
```

Inheritance diagram for ceras::is\_value< value< T > >:



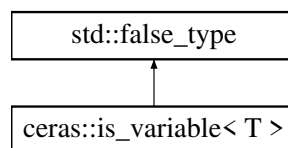
The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[value.hpp](#)

## 6.23 ceras::is\_variable< T > Struct Template Reference

```
#include <variable.hpp>
```

Inheritance diagram for ceras::is\_variable< T >:



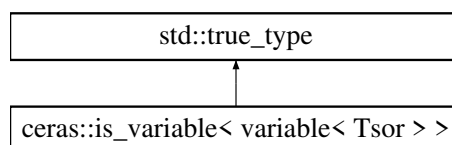
The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[variable.hpp](#)

## 6.24 ceras::is\_variable< variable< Tsor > > Struct Template Reference

```
#include <variable.hpp>
```

Inheritance diagram for ceras::is\_variable< variable< Tsor > >:



The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[variable.hpp](#)

## 6.25 ceras::model< Ex, Ph > Struct Template Reference

```
#include <model.hpp>
```

### Public Types

- typedef Ph [input\\_layer\\_type](#)
- typedef Ex [output\\_layer\\_type](#)

### Public Member Functions

- [input\\_layer\\_type](#) [input](#) () const noexcept
- [output\\_layer\\_type](#) [output](#) () const noexcept
- [model](#) ([input\\_layer\\_type](#) const &[place\\_holder](#), [output\\_layer\\_type](#) const &expression)
- template<Tensor Tsr>
  - auto [predict](#) (Tsr const &input\_tensor)
- template<Expression Exp>
  - auto [operator](#)() (Exp const &ex) const noexcept
- template<typename Loss , typename Optimizer >
  - auto [compile](#) (Loss const &l, Optimizer const &o)
- void [trainable](#) (bool t)
- void [save\\_weights](#) (std::string const &file)
- void [load\\_weights](#) (std::string const &file)
- void [summary](#) (std::string const &file\_name=std::string{}) const noexcept
- constexpr [model](#) (Input\_List const &input\_layer, Output\_List const &output\_layer)
- constexpr auto [input](#) () const
  - Returns the input layer(s) of the model in a 'list', which is are [place\\_holders](#).*
- constexpr auto [output](#) () const
  - Returns the output layer(s) of the model in a 'list', which is are expressions.*
- template<Tensor Tsr>
  - constexpr auto [predict](#) (Tsr const &input\_tensor) const
- template<List Tsr\_List>
  - auto [predict](#) (Tsr\_List const &input\_tensor) const

### Public Attributes

- [output\\_layer\\_type](#) [expression\\_](#)
  - output layer of the model.*
- [input\\_layer\\_type](#) [place\\_holder\\_](#)
- Input\_List [input\\_layer\\_](#)
- Output\_List [output\\_layer\\_](#)

#### 6.25.1 Detailed Description

```
template<Expression Ex, Place_Holder Ph>
struct ceras::model< Ex, Ph >
```

Groups an input layer (a place holder) and an output layer (an expression template) into an object.

## Template Parameters

<i>Ex</i>	The expression template for the output layer.
<i>Ph</i>	The place holder expression for the input layer

## 6.25.2 Member Typedef Documentation

### 6.25.2.1 input\_layer\_type

```
template<Expression Ex, Place_Holder Ph>
typedef Ph ceras::model< Ex, Ph >::input_layer_type
```

### 6.25.2.2 output\_layer\_type

```
template<Expression Ex, Place_Holder Ph>
typedef Ex ceras::model< Ex, Ph >::output_layer_type
```

## 6.25.3 Constructor & Destructor Documentation

### 6.25.3.1 model() [1/2]

```
template<Expression Ex, Place_Holder Ph>
ceras::model< Ex, Ph >::model (
    input_layer_type const & place_holder,
    output_layer_type const & expression ) [inline]
```

## Parameters

<a href="#"><i>place_holder</i></a>	The input layer of the model, a place holder.
<i>expression</i>	The output layer of the model, a expression template.

Example code to generate a model:

```
auto input = Input();
auto l1 = relu( Dense( 1024, 28*28 )( input ) );
auto output = sigmoid( Dense( 10, 1024 )( l1 ) );
auto m = model{ input, output };
```

### 6.25.3.2 model() [2/2]

```
template<Expression Ex, Place_Holder Ph>
constexpr ceras::model< Ex, Ph >::model (
    Input_List const & input_layer,
    Output_List const & output_layer ) [inline], [constexpr]
```

## 6.25.4 Member Function Documentation

### 6.25.4.1 compile()

```
template<Expression Ex, Place_Holder Ph>
template<typename Loss , typename Optimizer >
auto ceras::model< Ex, Ph >::compile (
    Loss const & l,
    Optimizer const & o ) [inline]
```

Compile the model for training

#### Parameters

<i>l</i>	The loss to minimize.
<i>o</i>	The optimizer to do the optimization.

#### Returns

An instance of [compiled\\_model](#).

#### Example useage:

```
model m{ ... };
unsigned long batch_size = 16;
float learning_rate = 0.001f;
auto cm = m.compile( MeanSquaredError(), SGD( batch_size, learning_rate ) );
```

### 6.25.4.2 input() [1/2]

```
template<Expression Ex, Place_Holder Ph>
constexpr auto ceras::model< Ex, Ph >::input ( ) const [inline], [constexpr]
```

Returns the input layer(s) of the model in a 'list', which is are [place\\_holders](#).

### 6.25.4.3 input() [2/2]

```
template<Expression Ex, Place_Holder Ph>
input_layer_type ceras::model< Ex, Ph >::input ( ) const [inline], [noexcept]
```

Returns the input layer of the model, which is a [place\\_holder](#).

#### 6.25.4.4 load\_weights()

```
template<Expression Ex, Place_Holder Ph>
void ceras::model< Ex, Ph >::load_weights (
    std::string const & file ) [inline]
```

Loads all variables from a file

#### 6.25.4.5 operator>()

```
template<Expression Ex, Place_Holder Ph>
template<Expression Exp>
auto ceras::model< Ex, Ph >::operator() (
    Exp const & ex ) const [inline], [noexcept]
```

Generating a new expression by using the current model.

##### Parameters

ex	An expression that represents the input to the model.
----	-------------------------------------------------------

##### Returns

An expression that replacing the input node with a new epxression.

##### Example code

```
auto x = Input(); // input, (28*28,)
auto y = Dense( 128, 28*28 )( x );
auto m1 = model( x, y ); // this model is [(28*28,) -> (128,)]
auto u = Input(); // new input, (32,)
auto v = Dense( 28*28, 32 )( u );
auto m2 = model( u, v );
auto input = Input(); // (32, )
auto ouptut = m1( m2( input ) ); // this new expression is [(32,) -> (28*28,) -> (128,)], note x is not in
    this expression any more
auto m = model( input, output ); // create a new model
```

#### 6.25.4.6 output() [1/2]

```
template<Expression Ex, Place_Holder Ph>
constexpr auto ceras::model< Ex, Ph >::output ( ) const [inline], [constexpr]
```

Returns the output layer(s) of the model in a 'list', which is are expressions.

#### 6.25.4.7 output() [2/2]

```
template<Expression Ex, Place_Holder Ph>
output_layer_type ceras::model< Ex, Ph >::output ( ) const [inline], [noexcept]
```

Returns the output layer of the model.



## 6.25.4.8 predict() [1/3]

```
template<Expression Ex, Place_Holder Ph>
template<Tensor Tsor>
auto ceras::model< Ex, Ph >::predict (
    Tsor const & input_tensor ) [inline]
```

Making prediction by binding the nput data to the place\_holder\_ and evaluating expression\_.

## Parameters

<i>input_tensor</i>	The input samples.
---------------------	--------------------

## Returns

The result this model predicts.

## Example to predict

```
auto input = Input();
auto l1 = relu( Dense( 1024, 28*28 )( input ) );
auto output = sigmoid( Dense( 10, 1024 )( l1 ) );
// ... train the model after defining a loss and an optimizer
auto m = model{ input, output };
auto test_data = random( {128, 28*28} ); // batch size is 128
auto result = model.predict( test_data ); // should produce an tensor of (128, 10)
```

## 6.25.4.9 predict() [2/3]

```
template<Expression Ex, Place_Holder Ph>
template<Tensor Tsor>
constexpr auto ceras::model< Ex, Ph >::predict (
    Tsor const & input_tensor ) const [inline], [constexpr]
```

Making prediction by binding the nput data to the place\_holder\_ and evaluating expression\_.

## Parameters

<i>input_tensor</i>	The input samples.
---------------------	--------------------

## Returns

The result this model predicts.

## Example to predict

```
auto input = Input();
auto l1 = relu( Dense( 1024, 28*28 )( input ) );
auto output = sigmoid( Dense( 10, 1024 )( l1 ) );
// ... train the model after defining a loss and an optimizer
auto m = model{ input, output };
auto test_data = random( {128, 28*28} ); // batch size is 128
auto result = model.predict( test_data ); // should produce an tensor of (128, 10)
```

**6.25.4.10 predict()** [3/3]

```
template<Expression Ex, Place_Holder Ph>
template<List Tsor_List>
auto ceras::model< Ex, Ph >::predict (
    Tsor_List const & input_tensor ) const [inline]
```

**6.25.4.11 save\_weights()**

```
template<Expression Ex, Place_Holder Ph>
void ceras::model< Ex, Ph >::save_weights (
    std::string const & file ) [inline]
```

Writes all variables to a file

**6.25.4.12 summary()**

```
template<Expression Ex, Place_Holder Ph>
void ceras::model< Ex, Ph >::summary (
    std::string const & file_name = std::string{} ) const [inline], [noexcept]
```

Print the model summary to console or to a file.

**Parameters**

<i>file_name</i>	The file to save the summary. If empty, the summary will be printed to console. Empty by default.
------------------	---------------------------------------------------------------------------------------------------

**6.25.4.13 trainable()**

```
template<Expression Ex, Place_Holder Ph>
void ceras::model< Ex, Ph >::trainable (
    bool t ) [inline]
```

**6.25.5 Member Data Documentation****6.25.5.1 expression\_**

```
template<Expression Ex, Place_Holder Ph>
output_layer_type ceras::model< Ex, Ph >::expression_
```

output layer of the model.

### 6.25.5.2 input\_layer\_

```
template<Expression Ex, Place_Holder Ph>
Input_List ceras::model< Ex, Ph >::input_layer_
```

### 6.25.5.3 output\_layer\_

```
template<Expression Ex, Place_Holder Ph>
Output_List ceras::model< Ex, Ph >::output_layer_
```

### 6.25.5.4 place\_holder\_

```
template<Expression Ex, Place_Holder Ph>
input_layer_type ceras::model< Ex, Ph >::place_holder_
```

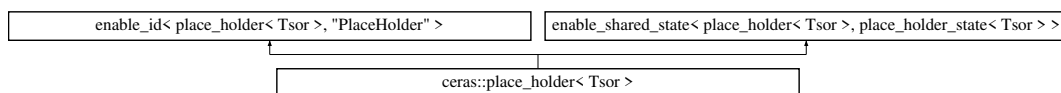
The documentation for this struct was generated from the following files:

- /data/structured\_folders/workspace/github.repo/ceras/include/model.hpp
- /data/structured\_folders/workspace/github.repo/ceras/include/xmodel.hpp

## 6.26 ceras::place\_holder< Tsor > Struct Template Reference

```
#include <place_holder.hpp>
```

Inheritance diagram for ceras::place\_holder< Tsor >:



### Public Types

- typedef Tsor [tensor\\_type](#)

### Public Member Functions

- [place\\_holder](#) ([place\\_holder](#) const &other)=default
- [place\\_holder](#) ([place\\_holder](#) &&other)=default
- [place\\_holder](#) & [operator=](#) ([place\\_holder](#) const &other)=default
- [place\\_holder](#) & [operator=](#) ([place\\_holder](#) &&other)=default
- [place\\_holder](#) ()
- [place\\_holder](#) (std::vector< unsigned long > const &shape\_hint)
- void [bind](#) (Tsor data)
- Tsor const [forward](#) () const
- void [reset](#) ()
- void [backward](#) (auto) const noexcept

## 6.26.1 Member Typedef Documentation

### 6.26.1.1 tensor\_type

```
template<Tensor Tsor>
typedef Tsor ceras::place\_holder< Tsor >::tensor\_type
```

## 6.26.2 Constructor & Destructor Documentation

### 6.26.2.1 place\_holder() [1/4]

```
template<Tensor Tsor>
ceras::place\_holder< Tsor >::place\_holder (
    place\_holder< Tsor > const & other ) [default]
```

### 6.26.2.2 place\_holder() [2/4]

```
template<Tensor Tsor>
ceras::place\_holder< Tsor >::place\_holder (
    place\_holder< Tsor > && other ) [default]
```

### 6.26.2.3 place\_holder() [3/4]

```
template<Tensor Tsor>
ceras::place\_holder< Tsor >::place\_holder ( ) [inline]
```

### 6.26.2.4 place\_holder() [4/4]

```
template<Tensor Tsor>
ceras::place\_holder< Tsor >::place\_holder (
    std::vector< unsigned long > const & shape_hint ) [inline]
```

## 6.26.3 Member Function Documentation

### 6.26.3.1 backward()

```
template<Tensor Tsor>
void ceras::place_holder< Tsor >::backward (
    auto ) const [inline], [noexcept]
```

### 6.26.3.2 bind()

```
template<Tensor Tsor>
void ceras::place_holder< Tsor >::bind (
    Tsor data ) [inline]
```

### 6.26.3.3 forward()

```
template<Tensor Tsor>
Tsor const ceras::place_holder< Tsor >::forward ( ) const [inline]
```

### 6.26.3.4 operator=() [1/2]

```
template<Tensor Tsor>
place_holder& ceras::place_holder< Tsor >::operator= (
    place_holder< Tsor > && other ) [default]
```

### 6.26.3.5 operator=() [2/2]

```
template<Tensor Tsor>
place_holder& ceras::place_holder< Tsor >::operator= (
    place_holder< Tsor > const & other ) [default]
```

### 6.26.3.6 reset()

```
template<Tensor Tsor>
void ceras::place_holder< Tsor >::reset ( ) [inline]
```

The documentation for this struct was generated from the following file:

- [/data/structured\\_folders/workspace/github.repo/ceras/include/place\\_holder.hpp](#)

## 6.27 ceras::place\_holder\_state< Tsor > Struct Template Reference

```
#include <place_holder.hpp>
```

### Public Attributes

- Tsor [data\\_](#)
- std::vector< unsigned long > [shape\\_hint\\_](#)

### 6.27.1 Member Data Documentation

#### 6.27.1.1 data\_

```
template<Tensor Tsor>  
Tsor ceras::place\_holder\_state< Tsor >::data\_
```

#### 6.27.1.2 shape\_hint\_

```
template<Tensor Tsor>  
std::vector< unsigned long> ceras::place\_holder\_state< Tsor >::shape\_hint\_
```

The documentation for this struct was generated from the following file:

- [/data/structured\\_folders/workspace/github.repo/ceras/include/place\\_holder.hpp](#)

## 6.28 ceras::regularizer< Float > Struct Template Reference

```
#include <variable.hpp>
```

### Public Types

- typedef Float [value\\_type](#)

### Public Member Functions

- constexpr [regularizer](#) ([value\\_type](#) l1, [value\\_type](#) l2, bool synchronized) noexcept

## Public Attributes

- [value\\_type l1\\_](#)
- [value\\_type l2\\_](#)
- [bool synchronized\\_](#)

## 6.28.1 Member Typedef Documentation

### 6.28.1.1 value\_type

```
template<typename Float >  
typedef Float ceras::regularizer< Float >::value\_type
```

## 6.28.2 Constructor & Destructor Documentation

### 6.28.2.1 regularizer()

```
template<typename Float >  
constexpr ceras::regularizer< Float >::regularizer (  
    value\_type l1,  
    value\_type l2,  
    bool synchronized ) [inline], [constexpr], [noexcept]
```

## 6.28.3 Member Data Documentation

### 6.28.3.1 l1\_

```
template<typename Float >  
value\_type ceras::regularizer< Float >::l1\_
```

### 6.28.3.2 l2\_

```
template<typename Float >  
value\_type ceras::regularizer< Float >::l2\_
```

### 6.28.3.3 synchronized\_

```
template<typename Float >
bool ceras::regularizer< Float >::synchronized_
```

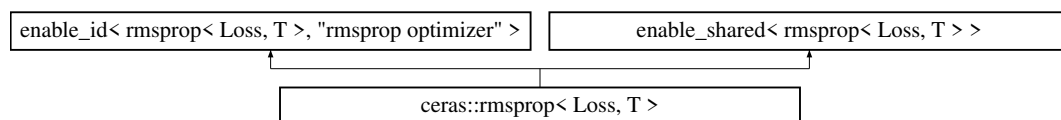
The documentation for this struct was generated from the following file:

- [/data/structured\\_folders/workspace/github.repo/ceras/include/variable.hpp](/data/structured_folders/workspace/github.repo/ceras/include/variable.hpp)

## 6.29 ceras::rmsprop< Loss, T > Struct Template Reference

```
#include <optimizer.hpp>
```

Inheritance diagram for ceras::rmsprop< Loss, T >:



### Public Types

- typedef [tensor](#)< T > [tensor\\_type](#)

### Public Member Functions

- [rmsprop](#) (Loss &loss, std::size\_t batch\_size, T learning\_rate=1.0e-1, T rho=0.9, T decay=0.0) noexcept
- void [forward](#) ()

### Public Attributes

- Loss & [loss\\_](#)
- T [learning\\_rate\\_](#)
- T [rho\\_](#)
- T [decay\\_](#)
- unsigned long [iterations\\_](#)

## 6.29.1 Member Typedef Documentation

### 6.29.1.1 tensor\_type

```
template<typename Loss , typename T >
typedef tensor< T > ceras::rmsprop< Loss, T >::tensor\_type
```



## 6.29.2 Constructor & Destructor Documentation

### 6.29.2.1 rmsprop()

```
template<typename Loss , typename T >
ceras::rmsprop< Loss, T >::rmsprop (
    Loss & loss,
    std::size_t batch_size,
    T learning_rate = 1.0e-1,
    T rho = 0.9,
    T decay = 0.0 ) [inline], [noexcept]
```

## 6.29.3 Member Function Documentation

### 6.29.3.1 forward()

```
template<typename Loss , typename T >
void ceras::rmsprop< Loss, T >::forward ( ) [inline]
```

## 6.29.4 Member Data Documentation

### 6.29.4.1 decay\_

```
template<typename Loss , typename T >
T ceras::rmsprop< Loss, T >::decay_
```

### 6.29.4.2 iterations\_

```
template<typename Loss , typename T >
unsigned long ceras::rmsprop< Loss, T >::iterations_
```

### 6.29.4.3 learning\_rate\_

```
template<typename Loss , typename T >
T ceras::rmsprop< Loss, T >::learning_rate_
```

#### 6.29.4.4 loss\_

```
template<typename Loss , typename T >
Loss& ceras::rmsprop< Loss, T >::loss_
```

#### 6.29.4.5 rho\_

```
template<typename Loss , typename T >
T ceras::rmsprop< Loss, T >::rho_
```

The documentation for this struct was generated from the following file:

- [/data/structured\\_folders/workspace/github.repo/ceras/include/optimizer.hpp](/data/structured_folders/workspace/github.repo/ceras/include/optimizer.hpp)

## 6.30 ceras::ceras\_private::session< Tsor > Struct Template Reference

```
#include <session.hpp>
```

### Public Types

- typedef [place\\_holder< Tsor > place\\_holder\\_type](#)
- typedef [variable< Tsor > variable\\_type](#)
- typedef [variable\\_state< Tsor > variable\\_state\\_type](#)

### Public Member Functions

- [session](#) ()
- [session](#) ([session](#) const &)=delete
- [session](#) ([session](#) &&)=default
- [session](#) & [operator=](#) ([session](#) const &)=delete
- [session](#) & [operator=](#) ([session](#) &&)=default
- void [rebind](#) ([place\\_holder\\_type](#) &p\_holder, Tsor const &value)
- void [bind](#) ([place\\_holder\\_type](#) &p\_holder, Tsor const &value)
- void [remember](#) ([variable\\_type](#) const &v)
- template<typename Operation >  
auto [run](#) (Operation &op) const
- template<typename Operation >  
void [tap](#) (Operation &op) const
- void [deserialize](#) (std::string const &file\_path)
- void [serialize](#) (std::string const &file\_path) const
- void [save](#) (std::string const &file\_path) const
- void [restore](#) (std::string const &file\_path)
- [~session](#) ()

## Public Attributes

- std::vector< [place\\_holder\\_type](#) > [place\\_holders\\_](#)
- std::map< int, [variable\\_type](#) > [variables\\_](#)

## 6.30.1 Member Typedef Documentation

### 6.30.1.1 place\_holder\_type

```
template<Tensor Tsor>
typedef place\_holder<Tsor> ceras::ceras\_private::session< Tsor >::place\_holder\_type
```

### 6.30.1.2 variable\_state\_type

```
template<Tensor Tsor>
typedef variable\_state<Tsor> ceras::ceras\_private::session< Tsor >::variable\_state\_type
```

### 6.30.1.3 variable\_type

```
template<Tensor Tsor>
typedef variable<Tsor> ceras::ceras\_private::session< Tsor >::variable\_type
```

## 6.30.2 Constructor & Destructor Documentation

### 6.30.2.1 session() [1/3]

```
template<Tensor Tsor>
ceras::ceras\_private::session< Tsor >::session ( ) [inline]
```

### 6.30.2.2 session() [2/3]

```
template<Tensor Tsor>
ceras::ceras\_private::session< Tsor >::session (
    session< Tsor > const & ) [delete]
```

### 6.30.2.3 session() [3/3]

```
template<Tensor Tsor>
ceras::ceras_private::session< Tsor >::session (
    session< Tsor > && ) [default]
```

### 6.30.2.4 ~session()

```
template<Tensor Tsor>
ceras::ceras_private::session< Tsor >::~~session ( ) [inline]
```

## 6.30.3 Member Function Documentation

### 6.30.3.1 bind()

```
template<Tensor Tsor>
void ceras::ceras_private::session< Tsor >::bind (
    place_holder_type & p_holder,
    Tsor const & value ) [inline]
```

### 6.30.3.2 deserialize()

```
template<Tensor Tsor>
void ceras::ceras_private::session< Tsor >::deserialize (
    std::string const & file_path ) [inline]
```

### 6.30.3.3 operator=() [1/2]

```
template<Tensor Tsor>
session& ceras::ceras_private::session< Tsor >::operator= (
    session< Tsor > && ) [default]
```

### 6.30.3.4 operator=() [2/2]

```
template<Tensor Tsor>
session& ceras::ceras_private::session< Tsor >::operator= (
    session< Tsor > const & ) [delete]
```

### 6.30.3.5 rebind()

```
template<Tensor Tsor>
void ceras::ceras_private::session< Tsor >::rebind (
    place_holder_type & p_holder,
    Tsor const & value ) [inline]
```

### 6.30.3.6 remember()

```
template<Tensor Tsor>
void ceras::ceras_private::session< Tsor >::remember (
    variable_type const & v ) [inline]
```

### 6.30.3.7 restore()

```
template<Tensor Tsor>
void ceras::ceras_private::session< Tsor >::restore (
    std::string const & file_path ) [inline]
```

### 6.30.3.8 run()

```
template<Tensor Tsor>
template<typename Operation >
auto ceras::ceras_private::session< Tsor >::run (
    Operation & op ) const [inline]
```

### 6.30.3.9 save()

```
template<Tensor Tsor>
void ceras::ceras_private::session< Tsor >::save (
    std::string const & file_path ) const [inline]
```

### 6.30.3.10 serialize()

```
template<Tensor Tsor>
void ceras::ceras_private::session< Tsor >::serialize (
    std::string const & file_path ) const [inline]
```

### 6.30.3.11 tap()

```
template<Tensor Tsor>
template<typename Operation >
void ceras::ceras_private::session< Tsor >::tap (
    Operation & op ) const [inline]
```

## 6.30.4 Member Data Documentation

### 6.30.4.1 place\_holders\_

```
template<Tensor Tsor>
std::vector<place_holder_type> ceras::ceras_private::session< Tsor >::place_holders_
```

### 6.30.4.2 variables\_

```
template<Tensor Tsor>
std::map<int, variable_type> ceras::ceras_private::session< Tsor >::variables_
```

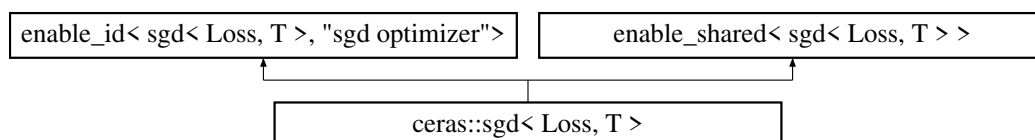
The documentation for this struct was generated from the following file:

- [/data/structured\\_folders/workspace/github.repo/ceras/include/session.hpp](/data/structured_folders/workspace/github.repo/ceras/include/session.hpp)

## 6.31 ceras::sgd< Loss, T > Struct Template Reference

```
#include <optimizer.hpp>
```

Inheritance diagram for ceras::sgd< Loss, T >:



## Public Types

- typedef `tensor< T >` `tensor_type`

## Public Member Functions

- [sgd](#) (Loss &loss, std::size\_t batch\_size, T learning\_rate=1.0e-1, T momentum=0.0, T decay=0.0, bool nesterov=false) noexcept
- void [forward](#) ()

## Public Attributes

- Loss & [loss\\_](#)
- T [learning\\_rate\\_](#)
- T [momentum\\_](#)
- T [decay\\_](#)
- bool [nesterov\\_](#)
- unsigned long [iterations\\_](#)

## 6.31.1 Member Typedef Documentation

### 6.31.1.1 tensor\_type

```
template<typename Loss , typename T >
typedef tensor< T > ceras::sgd< Loss, T >::tensor\_type
```

## 6.31.2 Constructor & Destructor Documentation

### 6.31.2.1 sgd()

```
template<typename Loss , typename T >
ceras::sgd< Loss, T >::sgd (
    Loss & loss,
    std::size_t batch_size,
    T learning_rate = 1.0e-1,
    T momentum = 0.0,
    T decay = 0.0,
    bool nesterov = false ) [inline], [noexcept]
```

## 6.31.3 Member Function Documentation

### 6.31.3.1 forward()

```
template<typename Loss , typename T >
void ceras::sgd< Loss, T >::forward ( ) [inline]
```

## 6.31.4 Member Data Documentation

### 6.31.4.1 decay\_

```
template<typename Loss , typename T >  
T ceras::sgd< Loss, T >::decay_
```

### 6.31.4.2 iterations\_

```
template<typename Loss , typename T >  
unsigned long ceras::sgd< Loss, T >::iterations_
```

### 6.31.4.3 learning\_rate\_

```
template<typename Loss , typename T >  
T ceras::sgd< Loss, T >::learning_rate_
```

### 6.31.4.4 loss\_

```
template<typename Loss , typename T >  
Loss& ceras::sgd< Loss, T >::loss_
```

### 6.31.4.5 momentum\_

```
template<typename Loss , typename T >  
T ceras::sgd< Loss, T >::momentum_
```

### 6.31.4.6 nesterov\_

```
template<typename Loss , typename T >  
bool ceras::sgd< Loss, T >::nesterov_
```

The documentation for this struct was generated from the following file:

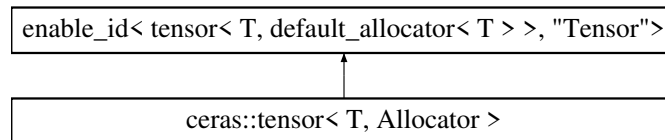
- [/data/structured\\_folders/workspace/github.repo/ceras/include/optimizer.hpp](#)



## 6.32 ceras::tensor< T, Allocator > Struct Template Reference

```
#include <tensor.hpp>
```

Inheritance diagram for ceras::tensor< T, Allocator >:



### Public Types

- typedef T [value\\_type](#)
- typedef Allocator [allocator](#)
- typedef std::vector< T, Allocator > [vector\\_type](#)
- typedef std::shared\_ptr< [vector\\_type](#) > [shared\\_vector](#)
- typedef [tensor](#) [self\\_type](#)

### Public Member Functions

- constexpr auto [begin](#) () noexcept
- constexpr auto [begin](#) () const noexcept
- constexpr auto [cbegin](#) () const noexcept
- constexpr auto [end](#) () noexcept
- constexpr auto [end](#) () const noexcept
- constexpr auto [cend](#) () const noexcept
- constexpr [self\\_type](#) & [reset](#) (T val=T{0})
- constexpr unsigned long [ndim](#) () const noexcept
- constexpr [self\\_type](#) & [deep\\_copy](#) ([self\\_type](#) const &other)
- constexpr [self\\_type](#) const [deep\\_copy](#) () const
- constexpr [self\\_type](#) const [copy](#) () const
- constexpr [value\\_type](#) & [operator\[\]](#) (unsigned long idx)
- constexpr [value\\_type](#) const & [operator\[\]](#) (unsigned long idx) const
- [tensor](#) ()
- constexpr [tensor](#) (std::vector< unsigned long > const &[shape](#), std::initializer\_list< T > init, const Allocator &alloc=Allocator())
- constexpr [tensor](#) (std::vector< unsigned long > const &[shape](#))
- constexpr [tensor](#) (std::vector< unsigned long > const &[shape](#), T init)
- constexpr [tensor](#) ([tensor](#) const &other, unsigned long memory\_offset)
- constexpr [tensor](#) ([self\\_type](#) const &other) noexcept
- constexpr [tensor](#) ([self\\_type](#) &&other) noexcept
- constexpr [self\\_type](#) & [operator=](#) ([self\\_type](#) const &other) noexcept
- constexpr [self\\_type](#) & [operator=](#) ([self\\_type](#) &&other) noexcept
- constexpr std::vector< unsigned long > const & [shape](#) () const noexcept
- constexpr unsigned long [size](#) () const noexcept
- constexpr [self\\_type](#) & [resize](#) (std::vector< unsigned long > const &new\_shape)
- constexpr [self\\_type](#) & [reshape](#) (std::vector< unsigned long > const &new\_shape)
- constexpr [self\\_type](#) & [shrink\\_to](#) (std::vector< unsigned long > const &new\_shape)
- constexpr [self\\_type](#) & [creep\\_to](#) (unsigned long new\_memory\_offset)
- constexpr bool [empty](#) () const noexcept

- constexpr [value\\_type](#) \* [data](#) () noexcept
- constexpr const [value\\_type](#) \* [data](#) () const noexcept
- template<typename Function >  
constexpr [self\\_type](#) & [map](#) (Function const &f)
- constexpr [self\\_type](#) & [operator+=](#) ([self\\_type](#) const &other)
- constexpr [self\\_type](#) & [operator+=](#) ([value\\_type](#) x)
- constexpr [self\\_type](#) & [operator-=](#) ([self\\_type](#) const &other)
- constexpr [self\\_type](#) & [operator-=](#) ([value\\_type](#) x)
- constexpr [self\\_type](#) & [operator\\*=](#) ([self\\_type](#) const &other)
- constexpr [self\\_type](#) & [operator\\*=](#) ([value\\_type](#) x)
- constexpr [self\\_type](#) & [operator/=](#) ([self\\_type](#) const &other)
- constexpr [self\\_type](#) & [operator/=](#) ([value\\_type](#) x)
- constexpr [self\\_type](#) const [operator-](#) () const
- constexpr [value\\_type as\\_scalar](#) () const noexcept
- template<typename U >  
constexpr auto [as\\_type](#) () const noexcept
- [tensor slice](#) (unsigned long m, unsigned long n) const noexcept

## Public Attributes

- std::vector< unsigned long > [shape\\_](#)
- unsigned long [memory\\_offset\\_](#)
- [shared\\_vector](#) [vector\\_](#)

## 6.32.1 Member Typedef Documentation

### 6.32.1.1 allocator

```
template<typename T , typename Allocator = default_allocator<T>>
typedef Allocator ceras::tensor< T, Allocator >::allocator
```

### 6.32.1.2 self\_type

```
template<typename T , typename Allocator = default_allocator<T>>
typedef tensor ceras::tensor< T, Allocator >::self\_type
```

### 6.32.1.3 shared\_vector

```
template<typename T , typename Allocator = default_allocator<T>>
typedef std::shared_ptr<vector\_type> ceras::tensor< T, Allocator >::shared\_vector
```

#### 6.32.1.4 value\_type

```
template<typename T , typename Allocator = default_allocator<T>>
typedef T ceras::tensor< T, Allocator >::value_type
```

#### 6.32.1.5 vector\_type

```
template<typename T , typename Allocator = default_allocator<T>>
typedef std::vector<T, Allocator> ceras::tensor< T, Allocator >::vector_type
```

### 6.32.2 Constructor & Destructor Documentation

#### 6.32.2.1 tensor() [1/7]

```
template<typename T , typename Allocator = default_allocator<T>>
ceras::tensor< T, Allocator >::tensor ( ) [inline]
```

#### 6.32.2.2 tensor() [2/7]

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr ceras::tensor< T, Allocator >::tensor (
    std::vector< unsigned long > const & shape,
    std::initializer_list< T > init,
    const Allocator & alloc = Allocator() ) [inline], [constexpr]
```

#### 6.32.2.3 tensor() [3/7]

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr ceras::tensor< T, Allocator >::tensor (
    std::vector< unsigned long > const & shape ) [inline], [constexpr]
```

#### 6.32.2.4 tensor() [4/7]

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr ceras::tensor< T, Allocator >::tensor (
    std::vector< unsigned long > const & shape,
    T init ) [inline], [constexpr]
```

**6.32.2.5 tensor() [5/7]**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr ceras::tensor< T, Allocator >::tensor (
    tensor< T, Allocator > const & other,
    unsigned long memory_offset ) [inline], [constexpr]
```

**6.32.2.6 tensor() [6/7]**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr ceras::tensor< T, Allocator >::tensor (
    self_type const & other ) [inline], [constexpr], [noexcept]
```

**6.32.2.7 tensor() [7/7]**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr ceras::tensor< T, Allocator >::tensor (
    self_type && other ) [inline], [constexpr], [noexcept]
```

**6.32.3 Member Function Documentation****6.32.3.1 as\_scalar()**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr value_type ceras::tensor< T, Allocator >::as_scalar ( ) const [inline], [constexpr],
[noexcept]
```

**6.32.3.2 as\_type()**

```
template<typename T , typename Allocator = default_allocator<T>>
template<typename U >
constexpr auto ceras::tensor< T, Allocator >::as_type ( ) const [inline], [constexpr], [noexcept]
```

**6.32.3.3 begin() [1/2]**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr auto ceras::tensor< T, Allocator >::begin ( ) const [inline], [constexpr], [noexcept]
```

**6.32.3.4 begin()** [2/2]

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr auto ceras::tensor< T, Allocator >::begin ( ) [inline], [constexpr], [noexcept]
```

**6.32.3.5 cbegin()**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr auto ceras::tensor< T, Allocator >::cbegin ( ) const [inline], [constexpr], [noexcept]
```

**6.32.3.6 cend()**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr auto ceras::tensor< T, Allocator >::cend ( ) const [inline], [constexpr], [noexcept]
```

**6.32.3.7 copy()**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type const ceras::tensor< T, Allocator >::copy ( ) const [inline], [constexpr]
```

**6.32.3.8 creep\_to()**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type& ceras::tensor< T, Allocator >::creep_to (
    unsigned long new_memory_offset ) [inline], [constexpr]
```

**6.32.3.9 data()** [1/2]

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr const value_type* ceras::tensor< T, Allocator >::data ( ) const [inline], [constexpr],
[noexcept]
```

**6.32.3.10 data()** [2/2]

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr value_type* ceras::tensor< T, Allocator >::data ( ) [inline], [constexpr], [noexcept]
```

**6.32.3.11 deep\_copy() [1/2]**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type const ceras::tensor< T, Allocator >::deep_copy ( ) const [inline], [constexpr]
```

**6.32.3.12 deep\_copy() [2/2]**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type& ceras::tensor< T, Allocator >::deep_copy (
    self_type const & other ) [inline], [constexpr]
```

**6.32.3.13 empty()**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr bool ceras::tensor< T, Allocator >::empty ( ) const [inline], [constexpr], [noexcept]
```

**6.32.3.14 end() [1/2]**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr auto ceras::tensor< T, Allocator >::end ( ) const [inline], [constexpr], [noexcept]
```

**6.32.3.15 end() [2/2]**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr auto ceras::tensor< T, Allocator >::end ( ) [inline], [constexpr], [noexcept]
```

**6.32.3.16 map()**

```
template<typename T , typename Allocator = default_allocator<T>>
template<typename Function >
constexpr self_type& ceras::tensor< T, Allocator >::map (
    Function const & f ) [inline], [constexpr]
```

**6.32.3.17** ndim()

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr unsigned long ceras::tensor< T, Allocator >::ndim ( ) const [inline], [constexpr],
[noexcept]
```

**6.32.3.18** operator\*=( ) [1/2]

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type& ceras::tensor< T, Allocator >::operator*= (
    self_type const & other ) [inline], [constexpr]
```

**6.32.3.19** operator\*=( ) [2/2]

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type& ceras::tensor< T, Allocator >::operator*= (
    value_type x ) [inline], [constexpr]
```

**6.32.3.20** operator+=( ) [1/2]

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type& ceras::tensor< T, Allocator >::operator+= (
    self_type const & other ) [inline], [constexpr]
```

**6.32.3.21** operator+=( ) [2/2]

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type& ceras::tensor< T, Allocator >::operator+= (
    value_type x ) [inline], [constexpr]
```

**6.32.3.22** operator-()

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type const ceras::tensor< T, Allocator >::operator- ( ) const [inline], [constexpr]
```

**6.32.3.23 operator-=( ) [1/2]**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type& ceras::tensor< T, Allocator >::operator-= (
    self_type const & other ) [inline], [constexpr]
```

**6.32.3.24 operator-=( ) [2/2]**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type& ceras::tensor< T, Allocator >::operator-= (
    value_type x ) [inline], [constexpr]
```

**6.32.3.25 operator/=( ) [1/2]**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type& ceras::tensor< T, Allocator >::operator/= (
    self_type const & other ) [inline], [constexpr]
```

**6.32.3.26 operator/=( ) [2/2]**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type& ceras::tensor< T, Allocator >::operator/= (
    value_type x ) [inline], [constexpr]
```

**6.32.3.27 operator=( ) [1/2]**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type& ceras::tensor< T, Allocator >::operator= (
    self_type && other ) [inline], [constexpr], [noexcept]
```

**6.32.3.28 operator=( ) [2/2]**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type& ceras::tensor< T, Allocator >::operator= (
    self_type const & other ) [inline], [constexpr], [noexcept]
```



**6.32.3.29 operator[]() [1/2]**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr value_type& ceras::tensor< T, Allocator >::operator[] (
    unsigned long idx ) [inline], [constexpr]
```

**6.32.3.30 operator[]() [2/2]**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr value_type const& ceras::tensor< T, Allocator >::operator[] (
    unsigned long idx ) const [inline], [constexpr]
```

**6.32.3.31 reset()**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type& ceras::tensor< T, Allocator >::reset (
    T val = T{0} ) [inline], [constexpr]
```

Resetting all elements in the tensor to a fixed value (default to 0), without change the shape.

Example code:

```
tensor<float> ts;
//...
ts.reset();
```

**6.32.3.32 reshape()**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type& ceras::tensor< T, Allocator >::reshape (
    std::vector< unsigned long > const & new_shape ) [inline], [constexpr]
```

**6.32.3.33 resize()**

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type& ceras::tensor< T, Allocator >::resize (
    std::vector< unsigned long > const & new_shape ) [inline], [constexpr]
```

### 6.32.3.34 shape()

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr std::vector< unsigned long > const& ceras::tensor< T, Allocator >::shape ( ) const
[inline], [constexpr], [noexcept]
```

### 6.32.3.35 shrink\_to()

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr self_type& ceras::tensor< T, Allocator >::shrink_to (
    std::vector< unsigned long > const & new_shape ) [inline], [constexpr]
```

### 6.32.3.36 size()

```
template<typename T , typename Allocator = default_allocator<T>>
constexpr unsigned long ceras::tensor< T, Allocator >::size ( ) const [inline], [constexpr],
[noexcept]
```

### 6.32.3.37 slice()

```
template<typename T , typename Allocator = default_allocator<T>>
tensor ceras::tensor< T, Allocator >::slice (
    unsigned long m,
    unsigned long n ) const [inline], [noexcept]
```

## 6.32.4 Member Data Documentation

### 6.32.4.1 memory\_offset\_

```
template<typename T , typename Allocator = default_allocator<T>>
unsigned long ceras::tensor< T, Allocator >::memory_offset_
```

### 6.32.4.2 shape\_

```
template<typename T , typename Allocator = default_allocator<T>>
std::vector<unsigned long> ceras::tensor< T, Allocator >::shape_
```

## 6.32.4.3 vector\_

```
template<typename T , typename Allocator = default_allocator<T>>
shared_vector ceras::tensor< T, Allocator >::vector_
```

The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[tensor.hpp](#)

## 6.33 ceras::tensor\_deduction&lt; L, R &gt; Struct Template Reference

```
#include <value.hpp>
```

## Public Types

- using [op\\_type](#) = std::conditional< [is\\_value\\_v](#)< L >, R, L >::type
- using [tensor\\_type](#) = std::remove\_cv\_t< decltype(std::declval< [op\\_type](#) >()).forward())>

## 6.33.1 Member Typedef Documentation

## 6.33.1.1 op\_type

```
template<typename L , typename R >
using ceras::tensor_deduction< L, R >::op_type = std::conditional<is_value_v<L>, R, L>::type
```

## 6.33.1.2 tensor\_type

```
template<typename L , typename R >
using ceras::tensor_deduction< L, R >::tensor_type = std::remove_cv_t<decltype(std::declval<op_type>()).forwa
```

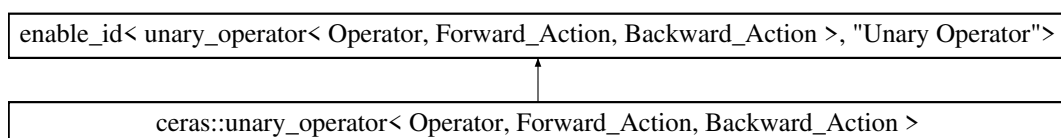
The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[value.hpp](#)

## 6.34 ceras::unary\_operator&lt; Operator, Forward\_Action, Backward\_Action &gt; Struct Template Reference

```
#include <operation.hpp>
```

Inheritance diagram for ceras::unary\_operator< Operator, Forward\_Action, Backward\_Action >:



## Public Member Functions

- [unary\\_operator](#) ([Operator](#) const &op, Forward\_Action const &forward\_action, Backward\_Action const &backward\_action) noexcept
- auto [forward](#) ()
- void [backward](#) ([tensor\\_type](#) const &grad)

## Public Attributes

- [Operator](#) [op\\_](#)
- Forward\_Action [forward\\_action\\_](#)
- Backward\_Action [backward\\_action\\_](#)
- decltype(std::declval< Forward\_Action >()(std::declval< decltype([op\\_](#))>().[forward](#)())) typedef [tensor\\_type](#)
- [tensor\\_type](#) [input\\_data\\_](#)
- [tensor\\_type](#) [output\\_data\\_](#)

## 6.34.1 Constructor & Destructor Documentation

### 6.34.1.1 unary\_operator()

```
template<typename Operator , typename Forward_Action , typename Backward_Action >
ceras::unary_operator< Operator, Forward_Action, Backward_Action >::unary_operator (
    Operator const & op,
    Forward_Action const & forward_action,
    Backward_Action const & backward_action ) [inline], [noexcept]
```

## 6.34.2 Member Function Documentation

### 6.34.2.1 backward()

```
template<typename Operator , typename Forward_Action , typename Backward_Action >
void ceras::unary_operator< Operator, Forward_Action, Backward_Action >::backward (
    tensor_type const & grad ) [inline]
```

### 6.34.2.2 forward()

```
template<typename Operator , typename Forward_Action , typename Backward_Action >
auto ceras::unary_operator< Operator, Forward_Action, Backward_Action >::forward ( ) [inline]
```

### 6.34.3 Member Data Documentation

#### 6.34.3.1 backward\_action\_

```
template<typename Operator , typename Forward_Action , typename Backward_Action >
Backward_Action ceras::unary_operator< Operator, Forward_Action, Backward_Action >::backward_↵
_action_
```

#### 6.34.3.2 forward\_action\_

```
template<typename Operator , typename Forward_Action , typename Backward_Action >
Forward_Action ceras::unary_operator< Operator, Forward_Action, Backward_Action >::forward_↵
action_
```

#### 6.34.3.3 input\_data\_

```
template<typename Operator , typename Forward_Action , typename Backward_Action >
tensor_type ceras::unary_operator< Operator, Forward_Action, Backward_Action >::input_data_
```

#### 6.34.3.4 op\_

```
template<typename Operator , typename Forward_Action , typename Backward_Action >
Operator ceras::unary_operator< Operator, Forward_Action, Backward_Action >::op_
```

#### 6.34.3.5 output\_data\_

```
template<typename Operator , typename Forward_Action , typename Backward_Action >
tensor_type ceras::unary_operator< Operator, Forward_Action, Backward_Action >::output_data_
```

#### 6.34.3.6 tensor\_type

```
template<typename Operator , typename Forward_Action , typename Backward_Action >
decltype( std::declval<Forward_Action>() ( std::declval<decltype(op_)>().forward() ) ) typedef
ceras::unary_operator< Operator, Forward_Action, Backward_Action >::tensor_type
```

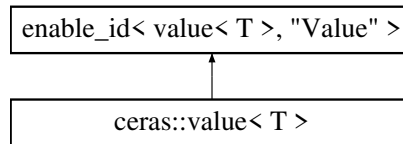
The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[operation.hpp](#)

## 6.35 ceras::value< T > Struct Template Reference

```
#include <value.hpp>
```

Inheritance diagram for ceras::value< T >:



### Public Types

- typedef T [value\\_type](#)

### Public Member Functions

- [value](#) ()=delete
- [value](#) ([value\\_type](#) v) noexcept
- [value](#) ([value](#) const &) noexcept=default
- [value](#) ([value](#) &&) noexcept=default
- [value](#) & [operator=](#) ([value](#) const &) noexcept=default
- [value](#) & [operator=](#) ([value](#) &&) noexcept=default
- void [backward](#) (auto) noexcept
- template<Tensor Tsor>  
Tsor const [forward](#) (Tsor const &refer) const

### Public Attributes

- [value\\_type](#) data\_

### 6.35.1 Member Typedef Documentation

#### 6.35.1.1 value\_type

```
template<typename T >
typedef T ceras::value< T >::value_type
```

### 6.35.2 Constructor & Destructor Documentation

**6.35.2.1 value()** [1/4]

```
template<typename T >
ceras::value< T >::value ( ) [delete]
```

**6.35.2.2 value()** [2/4]

```
template<typename T >
ceras::value< T >::value (
    value_type v ) [inline], [noexcept]
```

**6.35.2.3 value()** [3/4]

```
template<typename T >
ceras::value< T >::value (
    value< T > const & ) [default], [noexcept]
```

**6.35.2.4 value()** [4/4]

```
template<typename T >
ceras::value< T >::value (
    value< T > && ) [default], [noexcept]
```

**6.35.3 Member Function Documentation****6.35.3.1 backward()**

```
template<typename T >
void ceras::value< T >::backward (
    auto ) [inline], [noexcept]
```

**6.35.3.2 forward()**

```
template<typename T >
template<Tensor Tsor>
Tsor const ceras::value< T >::forward (
    Tsor const & refer ) const [inline]
```

### 6.35.3.3 operator=() [1/2]

```
template<typename T >
value& ceras::value< T >::operator= (
    value< T > && ) [default], [noexcept]
```

### 6.35.3.4 operator=() [2/2]

```
template<typename T >
value& ceras::value< T >::operator= (
    value< T > const & ) [default], [noexcept]
```

## 6.35.4 Member Data Documentation

### 6.35.4.1 data\_

```
template<typename T >
value_type ceras::value< T >::data_
```

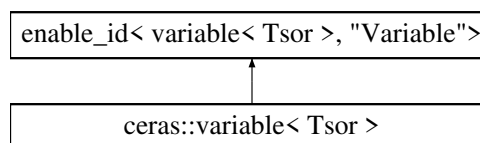
The documentation for this struct was generated from the following file:

- [/data/structured\\_folders/workspace/github.repo/ceras/include/value.hpp](/data/structured_folders/workspace/github.repo/ceras/include/value.hpp)

## 6.36 ceras::variable< Tsor > Struct Template Reference

```
#include <variable.hpp>
```

Inheritance diagram for ceras::variable< Tsor >:



## Public Types

- typedef Tsor [tensor\\_type](#)
- typedef tensor\_type::value\_type [value\\_type](#)



## Public Member Functions

- `variable` (`tensor_type` const &`data`, `value_type` l1=`value_type`{0}, `value_type` l2=`value_type`{0}, bool `trainable`=true)
- `variable` ()=delete
- `variable` (`variable` const &`other`)=default
- `variable` (`variable` &&)=default
- `variable` & `operator=` (`variable` &&)=default
- `variable` & `operator=` (`variable` const &`other`)=default
- `tensor_type` const `forward` () noexcept
- void `backward` (auto const &`grad`) noexcept
- std::vector< std::size\_t > `shape` () const noexcept
- std::vector< `tensor_type` > & `contexts` ()
- std::vector< `tensor_type` > `contexts` () const
- `tensor_type` & `data` ()
- `tensor_type` `data` () const
- `tensor_type` & `gradient` ()
- `tensor_type` `gradient` () const
- void `reset` ()
- bool `trainable` () const noexcept
- void `trainable` (bool t)

## Public Attributes

- std::shared\_ptr< `variable_state`< `tensor_type` > > `state_`
- `regularizer`< `value_type` > `regularizer_`
- bool `trainable_`

## 6.36.1 Member Typedef Documentation

### 6.36.1.1 tensor\_type

```
template<Tensor Ttor>
typedef Ttor ceras::variable< Ttor >::tensor_type
```

### 6.36.1.2 value\_type

```
template<Tensor Ttor>
typedef tensor_type::value_type ceras::variable< Ttor >::value_type
```

## 6.36.2 Constructor & Destructor Documentation

**6.36.2.1 variable() [1/4]**

```
template<Tensor Tsor>
ceras::variable< Tsor >::variable (
    tensor_type const & data,
    value_type l1 = value_type{0},
    value_type l2 = value_type{0},
    bool trainable = true ) [inline]
```

**6.36.2.2 variable() [2/4]**

```
template<Tensor Tsor>
ceras::variable< Tsor >::variable ( ) [delete]
```

**6.36.2.3 variable() [3/4]**

```
template<Tensor Tsor>
ceras::variable< Tsor >::variable (
    variable< Tsor > const & other ) [default]
```

**6.36.2.4 variable() [4/4]**

```
template<Tensor Tsor>
ceras::variable< Tsor >::variable (
    variable< Tsor > && ) [default]
```

**6.36.3 Member Function Documentation****6.36.3.1 backward()**

```
template<Tensor Tsor>
void ceras::variable< Tsor >::backward (
    auto const & grad ) [inline], [noexcept]
```

**6.36.3.2 contexts() [1/2]**

```
template<Tensor Tsor>
std::vector<tensor_type>& ceras::variable< Tsor >::contexts ( ) [inline]
```

### 6.36.3.3 contexts() [2/2]

```
template<Tensor Tzor>
std::vector<tensor_type> ceras::variable< Tzor >::contexts ( ) const [inline]
```

### 6.36.3.4 data() [1/2]

```
template<Tensor Tzor>
tensor_type& ceras::variable< Tzor >::data ( ) [inline]
```

### 6.36.3.5 data() [2/2]

```
template<Tensor Tzor>
tensor_type ceras::variable< Tzor >::data ( ) const [inline]
```

### 6.36.3.6 forward()

```
template<Tensor Tzor>
tensor_type const ceras::variable< Tzor >::forward ( ) [inline], [noexcept]
```

### 6.36.3.7 gradient() [1/2]

```
template<Tensor Tzor>
tensor_type& ceras::variable< Tzor >::gradient ( ) [inline]
```

### 6.36.3.8 gradient() [2/2]

```
template<Tensor Tzor>
tensor_type ceras::variable< Tzor >::gradient ( ) const [inline]
```

### 6.36.3.9 operator=() [1/2]

```
template<Tensor Tzor>
variable& ceras::variable< Tzor >::operator= (
    variable< Tzor > && ) [default]
```

#### 6.36.3.10 operator=() [2/2]

```
template<Tensor Tsor>
variable& ceras::variable< Tsor >::operator= (
    variable< Tsor > const & other ) [default]
```

#### 6.36.3.11 reset()

```
template<Tensor Tsor>
void ceras::variable< Tsor >::reset ( ) [inline]
```

#### 6.36.3.12 shape()

```
template<Tensor Tsor>
std::vector<std::size_t> ceras::variable< Tsor >::shape ( ) const [inline], [noexcept]
```

#### 6.36.3.13 trainable() [1/2]

```
template<Tensor Tsor>
bool ceras::variable< Tsor >::trainable ( ) const [inline], [noexcept]
```

#### 6.36.3.14 trainable() [2/2]

```
template<Tensor Tsor>
void ceras::variable< Tsor >::trainable (
    bool t ) [inline]
```

### 6.36.4 Member Data Documentation

#### 6.36.4.1 regularizer\_

```
template<Tensor Tsor>
regularizer<value_type> ceras::variable< Tsor >::regularizer_
```

#### 6.36.4.2 state\_

```
template<Tensor Tzor>
std::shared_ptr<variable_state<tensor_type> > ceras::variable< Tzor >::state_
```

#### 6.36.4.3 trainable\_

```
template<Tensor Tzor>
bool ceras::variable< Tzor >::trainable_
```

The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[variable.hpp](#)

## 6.37 ceras::variable\_state< Tzor > Struct Template Reference

```
#include <variable.hpp>
```

### Public Attributes

- Tzor [data\\_](#)
- Tzor [gradient\\_](#)
- std::vector< Tzor > [contexts\\_](#)

### 6.37.1 Member Data Documentation

#### 6.37.1.1 contexts\_

```
template<Tensor Tzor>
std::vector<Tzor> ceras::variable_state< Tzor >::contexts_
```

#### 6.37.1.2 data\_

```
template<Tensor Tzor>
Tzor ceras::variable_state< Tzor >::data_
```

### 6.37.1.3 gradient\_

```
template<Tensor Tsor>
Tsor ceras::variable_state< Tsor >::gradient_
```

The documentation for this struct was generated from the following file:

- [/data/structured\\_folders/workspace/github.repo/ceras/include/variable.hpp](/data/structured_folders/workspace/github.repo/ceras/include/variable.hpp)

## 6.38 ceras::view< T, N > Struct Template Reference

```
#include <tensor.hpp>
```

### Public Member Functions

- `template<typename T, typename ... Sizes>`  
`constexpr view (T *data, Sizes ... sizes) noexcept`
- `constexpr view< T, N-1 > operator[] (unsigned long index) noexcept`

### Public Attributes

- `T * data_`
- `std::array< unsigned long, N > shape_`

## 6.38.1 Constructor & Destructor Documentation

### 6.38.1.1 view()

```
template<typename T, unsigned long N>
template<typename T, typename ... Sizes>
constexpr ceras::view< T, N >::view (
    T * data,
    Sizes ... sizes ) [inline], [constexpr], [noexcept]
```

## 6.38.2 Member Function Documentation

### 6.38.2.1 operator[]()

```
template<typename T, unsigned long N>
constexpr view<T, N-1> ceras::view< T, N >::operator[] (
    unsigned long index ) [inline], [constexpr], [noexcept]
```

### 6.38.3 Member Data Documentation

#### 6.38.3.1 data\_

```
template<typename T , unsigned long N>
T* ceras::view< T, N >::data_
```

#### 6.38.3.2 shape\_

```
template<typename T , unsigned long N>
std::array<unsigned long, N> ceras::view< T, N >::shape_
```

The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[tensor.hpp](#)

## 6.39 ceras::view\_1d< T > Struct Template Reference

```
#include <tensor.hpp>
```

### Public Member Functions

- constexpr T & [operator\[\]](#) (unsigned long idx) noexcept
- constexpr T const & [operator\[\]](#) (unsigned long idx) const noexcept

### Public Attributes

- T \* [data](#)
- unsigned long [dims](#)

### 6.39.1 Member Function Documentation

#### 6.39.1.1 operator[]() [1/2]

```
template<typename T >
constexpr T const& ceras::view_1d< T >::operator[] (
    unsigned long idx ) const [inline], [constexpr], [noexcept]
```

### 6.39.1.2 operator[]() [2/2]

```
template<typename T >
constexpr T& ceras::view_1d< T >::operator[] (
    unsigned long idx ) [inline], [constexpr], [noexcept]
```

## 6.39.2 Member Data Documentation

### 6.39.2.1 data

```
template<typename T >
T* ceras::view_1d< T >::data
```

### 6.39.2.2 dims

```
template<typename T >
unsigned long ceras::view_1d< T >::dims
```

The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[tensor.hpp](#)

## 6.40 ceras::view\_2d< T > Struct Template Reference

```
#include <tensor.hpp>
```

### Public Types

- typedef T [value\\_type](#)
- typedef [value\\_type](#) \* [row\\_type](#)
- typedef const [value\\_type](#) \* [const\\_row\\_type](#)
- typedef stride\_iterator< [value\\_type](#) \* > [col\\_type](#)
- typedef stride\_iterator< const [value\\_type](#) \* > [const\\_col\\_type](#)



## Public Member Functions

- template<typename A >  
constexpr [view\\_2d](#) ([tensor](#)< T, A > &tsor, unsigned long [row](#), unsigned long [col](#), bool transposed=false) noexcept
- constexpr [view\\_2d](#) (T \*[data](#), unsigned long [row](#), unsigned long [col](#), bool transposed=false) noexcept
- constexpr [view\\_2d](#) (const T \*[data](#), unsigned long [row](#), unsigned long [col](#), bool transposed=false) noexcept
- constexpr T \* [operator\[\]](#) (unsigned long index)
- constexpr const T \* [operator\[\]](#) (unsigned long index) const
- constexpr auto [shape](#) () const noexcept
- constexpr unsigned long [size](#) () const noexcept
- constexpr T \* [data](#) () noexcept
- constexpr const T \* [data](#) () const noexcept
- constexpr T \* [begin](#) () noexcept
- constexpr const T \* [end](#) () const noexcept
- constexpr unsigned long [row](#) () const noexcept
- constexpr unsigned long [col](#) () const noexcept
- constexpr [row\\_type](#) [row\\_begin](#) (unsigned long index=0) noexcept
- constexpr [row\\_type](#) [row\\_end](#) (unsigned long index=0) noexcept
- constexpr [const\\_row\\_type](#) [row\\_begin](#) (unsigned long index=0) const noexcept
- constexpr [const\\_row\\_type](#) [row\\_end](#) (unsigned long index=0) const noexcept
- constexpr [col\\_type](#) [col\\_begin](#) (unsigned long index=0) noexcept
- constexpr [col\\_type](#) [col\\_end](#) (unsigned long index=0) noexcept
- constexpr [const\\_col\\_type](#) [col\\_begin](#) (unsigned long index=0) const noexcept
- constexpr [const\\_col\\_type](#) [col\\_end](#) (unsigned long index=0) const noexcept

## Public Attributes

- T \* [data\\_](#)
- unsigned long [row\\_](#)
- unsigned long [col\\_](#)
- bool [transposed\\_](#)

## 6.40.1 Member Typedef Documentation

### 6.40.1.1 col\_type

```
template<typename T >
typedef stride_iterator<value_type*> ceras::view\_2d< T >::col_type
```

### 6.40.1.2 const\_col\_type

```
template<typename T >
typedef stride_iterator<const value_type*> ceras::view\_2d< T >::const_col_type
```

### 6.40.1.3 const\_row\_type

```
template<typename T >
typedef const value_type* ceras::view_2d< T >::const_row_type
```

### 6.40.1.4 row\_type

```
template<typename T >
typedef value_type* ceras::view_2d< T >::row_type
```

### 6.40.1.5 value\_type

```
template<typename T >
typedef T ceras::view_2d< T >::value_type
```

## 6.40.2 Constructor & Destructor Documentation

### 6.40.2.1 view\_2d() [1/3]

```
template<typename T >
template<typename A >
constexpr ceras::view_2d< T >::view_2d (
    tensor< T, A > & tsor,
    unsigned long row,
    unsigned long col,
    bool transposed = false ) [inline], [constexpr], [noexcept]
```

### 6.40.2.2 view\_2d() [2/3]

```
template<typename T >
constexpr ceras::view_2d< T >::view_2d (
    T * data,
    unsigned long row,
    unsigned long col,
    bool transposed = false ) [inline], [constexpr], [noexcept]
```

**6.40.2.3 view\_2d()** [3/3]

```
template<typename T >
constexpr ceras::view_2d< T >::view_2d (
    const T * data,
    unsigned long row,
    unsigned long col,
    bool transposed = false ) [inline], [constexpr], [noexcept]
```

**6.40.3 Member Function Documentation****6.40.3.1 begin()**

```
template<typename T >
constexpr T* ceras::view_2d< T >::begin ( ) [inline], [constexpr], [noexcept]
```

**6.40.3.2 col()**

```
template<typename T >
constexpr unsigned long ceras::view_2d< T >::col ( ) const [inline], [constexpr], [noexcept]
```

**6.40.3.3 col\_begin()** [1/2]

```
template<typename T >
constexpr const_col_type ceras::view_2d< T >::col_begin (
    unsigned long index = 0 ) const [inline], [constexpr], [noexcept]
```

**6.40.3.4 col\_begin()** [2/2]

```
template<typename T >
constexpr col_type ceras::view_2d< T >::col_begin (
    unsigned long index = 0 ) [inline], [constexpr], [noexcept]
```

**6.40.3.5 col\_end()** [1/2]

```
template<typename T >
constexpr const_col_type ceras::view_2d< T >::col_end (
    unsigned long index = 0 ) const [inline], [constexpr], [noexcept]
```

#### 6.40.3.6 col\_end() [2/2]

```
template<typename T >
constexpr col_type ceras::view_2d< T >::col_end (
    unsigned long index = 0 ) [inline], [constexpr], [noexcept]
```

#### 6.40.3.7 data() [1/2]

```
template<typename T >
constexpr const T* ceras::view_2d< T >::data ( ) const [inline], [constexpr], [noexcept]
```

#### 6.40.3.8 data() [2/2]

```
template<typename T >
constexpr T* ceras::view_2d< T >::data ( ) [inline], [constexpr], [noexcept]
```

#### 6.40.3.9 end()

```
template<typename T >
constexpr const T* ceras::view_2d< T >::end ( ) const [inline], [constexpr], [noexcept]
```

#### 6.40.3.10 operator[]() [1/2]

```
template<typename T >
constexpr T* ceras::view_2d< T >::operator[] (
    unsigned long index ) [inline], [constexpr]
```

#### 6.40.3.11 operator[]() [2/2]

```
template<typename T >
constexpr const T* ceras::view_2d< T >::operator[] (
    unsigned long index ) const [inline], [constexpr]
```

**6.40.3.12 row()**

```
template<typename T >
constexpr unsigned long ceras::view_2d< T >::row ( ) const [inline], [constexpr], [noexcept]
```

**6.40.3.13 row\_begin() [1/2]**

```
template<typename T >
constexpr const_row_type ceras::view_2d< T >::row_begin (
    unsigned long index = 0 ) const [inline], [constexpr], [noexcept]
```

**6.40.3.14 row\_begin() [2/2]**

```
template<typename T >
constexpr row_type ceras::view_2d< T >::row_begin (
    unsigned long index = 0 ) [inline], [constexpr], [noexcept]
```

**6.40.3.15 row\_end() [1/2]**

```
template<typename T >
constexpr const_row_type ceras::view_2d< T >::row_end (
    unsigned long index = 0 ) const [inline], [constexpr], [noexcept]
```

**6.40.3.16 row\_end() [2/2]**

```
template<typename T >
constexpr row_type ceras::view_2d< T >::row_end (
    unsigned long index = 0 ) [inline], [constexpr], [noexcept]
```

**6.40.3.17 shape()**

```
template<typename T >
constexpr auto ceras::view_2d< T >::shape ( ) const [inline], [constexpr], [noexcept]
```

#### 6.40.3.18 size()

```
template<typename T >
constexpr unsigned long ceras::view_2d< T >::size ( ) const [inline], [constexpr], [noexcept]
```

### 6.40.4 Member Data Documentation

#### 6.40.4.1 col\_

```
template<typename T >
unsigned long ceras::view_2d< T >::col_
```

#### 6.40.4.2 data\_

```
template<typename T >
T* ceras::view_2d< T >::data_
```

#### 6.40.4.3 row\_

```
template<typename T >
unsigned long ceras::view_2d< T >::row_
```

#### 6.40.4.4 transposed\_

```
template<typename T >
bool ceras::view_2d< T >::transposed_
```

The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[tensor.hpp](#)

## 6.41 ceras::view\_3d< T > Struct Template Reference

```
#include <tensor.hpp>
```

## Public Member Functions

- constexpr [view\\_3d](#) (T \*data, unsigned long row, unsigned long col, unsigned long channel) noexcept
- constexpr auto [operator\[\]](#) (unsigned long index) noexcept
- constexpr auto [operator\[\]](#) (unsigned long index) const noexcept

## Public Attributes

- T \* [data\\_](#)
- unsigned long [row\\_](#)
- unsigned long [col\\_](#)
- unsigned long [channel\\_](#)

## 6.41.1 Constructor & Destructor Documentation

### 6.41.1.1 view\_3d()

```
template<typename T >
constexpr ceras::view_3d< T >::view_3d (
    T * data,
    unsigned long row,
    unsigned long col,
    unsigned long channel ) [inline], [constexpr], [noexcept]
```

## 6.41.2 Member Function Documentation

### 6.41.2.1 operator[]() [1/2]

```
template<typename T >
constexpr auto ceras::view_3d< T >::operator[] (
    unsigned long index ) const [inline], [constexpr], [noexcept]
```

### 6.41.2.2 operator[]() [2/2]

```
template<typename T >
constexpr auto ceras::view_3d< T >::operator[] (
    unsigned long index ) [inline], [constexpr], [noexcept]
```

## 6.41.3 Member Data Documentation

#### 6.41.3.1 channel\_

```
template<typename T >
unsigned long ceras::view_3d< T >::channel_
```

#### 6.41.3.2 col\_

```
template<typename T >
unsigned long ceras::view_3d< T >::col_
```

#### 6.41.3.3 data\_

```
template<typename T >
T* ceras::view_3d< T >::data_
```

#### 6.41.3.4 row\_

```
template<typename T >
unsigned long ceras::view_3d< T >::row_
```

The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[tensor.hpp](#)

## 6.42 ceras::view\_4d< T > Struct Template Reference

```
#include <tensor.hpp>
```

### Public Member Functions

- constexpr [view\\_4d](#) (T \*data, unsigned long batch\_size, unsigned long row, unsigned long col, unsigned long channel) noexcept
- constexpr auto [operator\[\]](#) (unsigned long index) noexcept
- constexpr auto [operator\[\]](#) (unsigned long index) const noexcept



## Public Attributes

- T \* [data\\_](#)  
*The pointer to the start position of the 1-D array.*
- unsigned long [batch\\_size\\_](#)  
*The batch size of the 4-D tensor, also the first dimension of the tensor.*
- unsigned long [row\\_](#)  
*The row of the 4-D tensor, also the second dimension of the tensor.*
- unsigned long [col\\_](#)  
*The column of the 4-D tensor, also the third dimension of the tensor.*
- unsigned long [channel\\_](#)  
*The channel of the 4-D tensor, also the last dimension of the tensor.*

### 6.42.1 Detailed Description

```
template<typename T>
struct ceras::view_4d< T >
```

A class viewing a 1-D array as a 4-D tensor. This class is useful when treating an array as a typical 4-D tensor in a neural network, with a shape of [batch\_size, row, column, channel].

### 6.42.2 Constructor & Destructor Documentation

#### 6.42.2.1 view\_4d()

```
template<typename T >
constexpr ceras::view_4d< T >::view_4d (
    T * data,
    unsigned long batch_size,
    unsigned long row,
    unsigned long col,
    unsigned long channel ) [inline], [constexpr], [noexcept]
```

Constructor of [view\\_4d](#)

#### Parameters

<i>data</i>	The raw pointer to the start position of the 1-D array.
<i>batch_size</i>	The first dimension of the 4-D tensor, also for the batch size in the CNN layers.
<i>row</i>	The second dimension of the 4-D tensor, also for the row in the CNN layers.
<i>col</i>	The third dimension of the 4-D tensor, also for the column in the CNN layers.
<i>channel</i>	The last dimension of the 4-D tensor, also for the channel in the CNN layers.

## 6.42.3 Member Function Documentation

### 6.42.3.1 operator[]() [1/2]

```
template<typename T >
constexpr auto ceras::view_4d< T >::operator[] (
    unsigned long index ) const [inline], [constexpr], [noexcept]
```

Giving a [view\\_3d](#) interface for operator [].

#### Parameters

<i>index</i>	The first dimension of the 4-D tensor.
--------------	----------------------------------------

#### Example usage:

```
std::vector<float> array;
array.resize( 16*8*8*3 );
// operations on 'array'
auto t = view_4d{ array.data(), 16, 8, 8, 3 };
float v0123 = t[0][1][2][3];
```

### 6.42.3.2 operator[]() [2/2]

```
template<typename T >
constexpr auto ceras::view_4d< T >::operator[] (
    unsigned long index ) [inline], [constexpr], [noexcept]
```

Giving a [view\\_3d](#) interface for operator [].

#### Parameters

<i>index</i>	The first dimension of the 4-D tensor.
--------------	----------------------------------------

#### Example usage:

```
std::vector<float> array;
array.resize( 16*8*8*3 );
auto t = view_4d{ array.data(), 16, 8, 8, 3 };
t[0][1][2][3] = 1.0;
```

## 6.42.4 Member Data Documentation

### 6.42.4.1 batch\_size\_

```
template<typename T >
unsigned long ceras::view_4d< T >::batch_size_
```

The batch size of the 4-D tensor, also the first dimension of the tensor.

#### 6.42.4.2 channel\_

```
template<typename T >  
unsigned long ceras::view_4d< T >::channel_
```

The channel of the 4-D tensor, also the last dimension of the tensor.

#### 6.42.4.3 col\_

```
template<typename T >  
unsigned long ceras::view_4d< T >::col_
```

The column of the 4-D tensor, also the third dimension of the tensor.

#### 6.42.4.4 data\_

```
template<typename T >  
T* ceras::view_4d< T >::data_
```

The pointer to the start position of the 1-D array.

#### 6.42.4.5 row\_

```
template<typename T >  
unsigned long ceras::view_4d< T >::row_
```

The row of the 4-D tensor, also the second dimension of the tensor.

The documentation for this struct was generated from the following file:

- /data/structured\_folders/workspace/github.repo/ceras/include/[tensor.hpp](#)



## Chapter 7

# File Documentation

### 7.1 `/data/structured_↵` `folders/workspace/github.repo/ceras/include/activation.hpp` File Reference

```
#include "../operation.hpp"
#include "../tensor.hpp"
#include "../utils/range.hpp"
#include "../utils/better_assert.hpp"
#include "../utils/for_each.hpp"
#include "../utils/context_cast.hpp"
```

#### Namespaces

- [ceras](#)

#### Functions

- `template<Expression Ex>`  
`constexpr auto ceras::softmax` (`Ex const &ex`) `noexcept`  
*Softmax activation function, an unary operator.*
- `template<Expression Ex>`  
`auto ceras::selu` (`Ex const &ex`) `noexcept`  
*Scaled Exponential Linear Unit (SELU) activation function, an unary operator. If  $x > 0$ , returns  $1.0507 x$ ; Otherwise, returns  $1.67326 * 1.0507 * (\exp(x) - 1)$*
- `template<Expression Ex>`  
`auto ceras::softplus` (`Ex const &ex`) `noexcept`  
*Softplus function, an unary operator. Returns  $\log(\exp(x) + 1)$ .*
- `template<Expression Ex>`  
`auto ceras::softsign` (`Ex const &ex`) `noexcept`  
*Softsign function, an unary operator. Returns  $x / (\text{abs}(x) + 1)$ .*
- `template<Expression Ex>`  
`auto ceras::sigmoid` (`Ex const &ex`) `noexcept`  
*Sigmoid function, an unary operator. Returns  $1 / (\exp(-x) + 1)$ .*

- template<Expression Ex>  
auto `ceras::relu` (Ex const &ex) noexcept  
*Relu function, an unary operator. Returns  $x$  if positive, 0 otherwise.*
- template<Expression Ex>  
auto `ceras::relu6` (Ex const &ex) noexcept  
*Rectified Linear 6 function, an unary operator. Returns  $\min(\max(\text{features}, 0), 6)$ .*
- template<typename T>  
requires std::floating\_point< T > auto `ceras::leaky_relu` (T const factor=0.2) noexcept  
*Leaky Rectified Linear function, an unary operator. Returns  $x$  if positive,  $\alpha x$  otherwise.  $\alpha$  defaults to 0.2.*
- template<Expression Ex>  
auto `ceras::negative_relu` (Ex const &ex) noexcept
- template<typename T = float>  
requires std::floating\_point< T > auto `ceras::elu` (T const alpha=1.0) noexcept  
*Exponential Linear function, an unary operator. Returns  $x$  if positive,  $\alpha \cdot (\exp(x) - 1)$  otherwise.  $\alpha$  defaults to 0.2.*
- template<Expression Ex>  
auto `ceras::exponential` (Ex const &ex) noexcept  
*Exponential function, an unary operator. Returns  $\exp(x)$ .*
- template<Expression Ex>  
auto `ceras::hard_sigmoid` (Ex const &ex) noexcept  
*Hard Sigmoid function, an unary operator. Piecewise linear approximation of the sigmoid function.*
- template<Expression Ex>  
auto `ceras::gelu` (Ex const &ex) noexcept  
*Gaussian Error function, an unary operator. GAUSSIAN ERROR LINEAR UNITS (GELUS) <https://arxiv.org/pdf/1606.08415.pdf>  $f(x) = 0.5x (1 + \tanh[\sqrt{2/\pi}(x + 0.044715x^3)])$   $df = x (1 + \tanh[\sqrt{2/\pi}(x + 0.044715x^3)]) + \sqrt{2/\pi} x \operatorname{sech}^2[\sqrt{2/\pi}(x + 0.044715x^3)] (1 + 0.44715x^2) (1 + 0.134145x^2)$  where  $\operatorname{sech}^2(x) = 1 - \tanh^2(x)$  derivative generated using service from <https://www.symbolab.com/solver/derivative-calculator>.*
- template<Expression Ex>  
auto `ceras::swish` (Ex const &ex) noexcept  
*Swish activation function.*
- template<Expression Ex>  
auto `ceras::silu` (Ex const &ex) noexcept  
*An alias name of activation swish.*
- template<Expression Ex>  
auto `ceras::crelu` (Ex const &ex) noexcept  
*Concatenated Rectified Linear Units, an activation function which preserves both positive and negative phase information while enforcing non-saturated non-linearity.*

## 7.2 /data/structured\_↵ folders/workspace/github.repo/ceras/include/ceras.hpp File Reference

```
#include " ./config.hpp"
#include " ./includes.hpp"
#include " ./activation.hpp"
#include " ./ceras.hpp"
#include " ./loss.hpp"
#include " ./operation.hpp"
#include " ./complex_operator.hpp"
#include " ./optimizer.hpp"
```

```
#include "../place_holder.hpp"
#include "../session.hpp"
#include "../tensor.hpp"
#include "../variable.hpp"
#include "../constant.hpp"
#include "../layer.hpp"
#include "../model.hpp"
#include "../dataset.hpp"
```

## 7.3 /data/structured\_folders/workspace/github.repo/ceras/include/complex\_operator.hpp File Reference

```
#include "../operation.hpp"
```

### Classes

- struct [ceras::complex< Real\\_Ex, Imag\\_Ex >](#)
- struct [ceras::is\\_complex< T >](#)
- struct [ceras::is\\_complex< complex< Real\\_Ex, Imag\\_Ex > >](#)

### Namespaces

- [ceras](#)

### Functions

- template<Expression Real\_Ex, Expression Imag\_Ex>  
Real\_Ex [ceras::real](#) (complex< Real\_Ex, Imag\_Ex > const &c) noexcept
- template<Expression Real\_Ex, Expression Imag\_Ex>  
Imag\_Ex [ceras::imag](#) (complex< Real\_Ex, Imag\_Ex > const &c) noexcept
- template<Complex C>  
auto [ceras::abs](#) (C const &c) noexcept  
*Returns the magnitude of the complex expression.*
- template<Complex C>  
auto [ceras::norm](#) (C const &c) noexcept  
*Returns the squared magnitude of the complex expression.*
- template<Complex C>  
auto [ceras::conj](#) (C const &c) noexcept  
*Returns the conjugate of the complex expression.*
- template<Expression Em, Expression Ep>  
auto [ceras::polar](#) (Em const &em, Ep const &ep) noexcept  
*Returns with given magnitude and phase angle.*
- template<Complex C>  
auto [ceras::arg](#) (C const &c) noexcept  
*Calculates the phase angle (in radians) of the complex expression.*

- `template<Complex C>`  
`auto ceras::operator+ (C const &c) noexcept`  
*Returns the complex expression.*
- `template<Complex C>`  
`auto ceras::operator- (C const &c) noexcept`  
*Negatives the complex expression.*
- `template<Complex Cl, Complex Cr>`  
`auto ceras::operator+ (Cl const &cl, Cr const &cr) noexcept`  
*Sums up two complex expressions.*
- `template<Complex Cl, Complex Cr>`  
`auto ceras::operator- (Cl const &cl, Cr const &cr) noexcept`  
*Subtracts one complex expression from the other one.*
- `template<Complex Cl, Complex Cr>`  
`auto ceras::operator* (Cl const &cl, Cr const &cr) noexcept`  
*Multiplies two complex expressions. Optimization here:  $(a+ib)*(c+id) = (ac-bd) + i(ad+bc) = (ac-bd) + i((a+b)*(c+d) - ac-bd)$*
- `template<Complex C, Expression E>`  
`auto ceras::operator+ (C const &c, E const &e) noexcept`  
*Sums up a complex expression and an expression.*
- `template<Complex C, Expression E>`  
`auto ceras::operator+ (E const &e, C const &c) noexcept`  
*Sums up a complex expression and an expression.*
- `template<Complex C, Expression E>`  
`auto ceras::operator- (C const &c, E const &e) noexcept`  
*Subtracts an expression from a complex expression.*
- `template<Complex C, Expression E>`  
`auto ceras::operator- (E const &e, C const &c) noexcept`  
*Subtracts a complex expression from an expression.*
- `template<Complex C, Expression E>`  
`auto ceras::operator* (C const &c, E const &e) noexcept`  
*Multiplies a complex expression with an expression.*
- `template<Complex C, Expression E>`  
`auto ceras::operator* (E const &e, C const &c) noexcept`  
*Multiplies an expression with a complex expression.*

## Variables

- `template<typename T>`  
`constexpr bool ceras::is_complex_v = is_complex<T>::value`
- `template<typename T>`  
`concept ceras::Complex = is_complex_v<T>`  
*A type that represents a complex expression.*

## 7.4 /data/structured\_↔ folders/workspace/github.repo/ceras/include/config.hpp File Reference



## 7.5 /data/structured\_↵ folders/workspace/github.repo/ceras/include/constant.hpp File Reference

```
#include "../includes.hpp"
#include "../tensor.hpp"
#include "../utils/id.hpp"
#include "../utils/better_assert.hpp"
#include "../utils/enable_shared.hpp"
```

### Classes

- struct [ceras::constant< Tsor >](#)  
*Creates a constant expression from a tensor-like object.*
- struct [ceras::is\\_constant< T >](#)
- struct [ceras::is\\_constant< constant< Tsor > >](#)

### Namespaces

- [ceras](#)

### Variables

- template<class T >  
constexpr bool [ceras::is\\_constant\\_v](#) = is\_constant<T>::value
- template<typename T >  
concept [ceras::Constant](#) = is\_constant\_v<T>

## 7.6 /data/structured\_↵ folders/workspace/github.repo/ceras/include/dataset.hpp File Reference

```
#include "../tensor.hpp"
#include "../includes.hpp"
#include "../utils/better_assert.hpp"
#include "../utils/for_each.hpp"
```

### Namespaces

- [ceras](#)
- [ceras::dataset](#)
- [ceras::dataset::mnist](#)
- [ceras::dataset::fashion\\_mnist](#)

## Functions

- auto [ceras::dataset::mnist::load\\_data](#) (std::string const &path=std::string{"/dataset/mnist"})
- auto [ceras::dataset::fashion\\_mnist::load\\_data](#) (std::string const &path=std::string{"/dataset/fashion\_mnist"})

## 7.7 `/data/structured_↔` **folders/workspace/github.repo/ceras/include/includes.hpp File Reference**

```
#include " ./config.hpp"
#include <algorithm>
#include <any>
#include <array>
#include <cassert>
#include <chrono>
#include <cmath>
#include <compare>
#include <concepts>
#include <cstdint>
#include <ctime>
#include <filesystem>
#include <fstream>
#include <functional>
#include <initializer_list>
#include <iomanip>
#include <iostream>
#include <iterator>
#include <limits>
#include <map>
#include <memory>
#include <numeric>
#include <optional>
#include <ostream>
#include <random>
#include <ranges>
#include <regex>
#include <set>
#include <sstream>
#include <string>
#include <tuple>
#include <thread>
#include <type_traits>
#include <unordered_map>
#include <unordered_set>
#include <utility>
#include <vector>
#include " ./utils/3rd_party/stb_image.h"
#include " ./utils/3rd_party/stb_image_write.h"
#include " ./utils/3rd_party/stb_image_resize.h"
#include " ./utils/3rd_party/glob.hpp"
```

## Macros

- `#define` [STB\\_IMAGE\\_IMPLEMENTATION](#)
- `#define` [STB\\_IMAGE\\_WRITE\\_IMPLEMENTATION](#)
- `#define` [STB\\_IMAGE\\_RESIZE\\_IMPLEMENTATION](#)

### 7.7.1 Macro Definition Documentation

#### 7.7.1.1 STB\_IMAGE\_IMPLEMENTATION

```
#define STB_IMAGE_IMPLEMENTATION
```

#### 7.7.1.2 STB\_IMAGE\_RESIZE\_IMPLEMENTATION

```
#define STB_IMAGE_RESIZE_IMPLEMENTATION
```

#### 7.7.1.3 STB\_IMAGE\_WRITE\_IMPLEMENTATION

```
#define STB_IMAGE_WRITE_IMPLEMENTATION
```

## 7.8 /data/structured\_folders/workspace/github.repo/ceras/include/layer.hpp File Reference

```
#include "../operation.hpp"  
#include "../activation.hpp"  
#include "../loss.hpp"  
#include "../optimizer.hpp"  
#include "../utils/better_assert.hpp"
```

## Namespaces

- [ceras](#)

## Functions

- auto [ceras::Input](#) ()
- auto [ceras::Conv2D](#) (unsigned long output\_channels, std::vector< unsigned long > const &kernel\_size, std::vector< unsigned long > const &input\_shape, std::string const &padding="valid", std::vector< unsigned long > const &strides={1, 1}, std::vector< unsigned long > const &dilations={1, 1}, bool use\_bias=true, float kernel\_regularizer\_l1=0.0f, float kernel\_regularizer\_l2=0.0f, float bias\_regularizer\_l1=0.0f, float bias\_regularizer\_l2=0.0f)
- 2D convolution layer.*
- auto [ceras::Dense](#) (unsigned long output\_size, unsigned long input\_size, bool use\_bias=true, float kernel\_regularizer\_l1=0.0f, float kernel\_regularizer\_l2=0.0f, float bias\_regularizer\_l1=0.0f, float bias\_regularizer\_l2=0.0f)
- Densely-connected layer.*
- auto [ceras::BatchNormalization](#) (std::vector< unsigned long > const &shape, float threshold=0.95f, float kernel\_regularizer\_l1=0.0f, float kernel\_regularizer\_l2=0.0f, float bias\_regularizer\_l1=0.0f, float bias\_regularizer\_l2=0.0f)
- Applies a transformation that maintains the mean output close to 0 and the output standard deviation close to 1.*
- auto [ceras::BatchNormalization](#) (float threshold, std::vector< unsigned long > const &shape, float kernel\_regularizer\_l1=0.0f, float kernel\_regularizer\_l2=0.0f, float bias\_regularizer\_l1=0.0f, float bias\_regularizer\_l2=0.0f)
- auto [ceras::Concatenate](#) (unsigned long axis=-1) noexcept
- auto [ceras::Add](#) () noexcept
- auto [ceras::Subtract](#) () noexcept
- auto [ceras::Multiply](#) () noexcept
- template<Expression Ex>  
auto [ceras::ReLU](#) (Ex const &ex) noexcept
- auto [ceras::Softmax](#) () noexcept
- template<typename T = float>  
auto [ceras::LeakyReLU](#) (T const factor=0.2) noexcept
- template<typename T = float>  
auto [ceras::ELU](#) (T const factor=0.2) noexcept
- auto [ceras::Reshape](#) (std::vector< unsigned long > const &new\_shape, bool include\_batch\_flag=true) noexcept
- auto [ceras::Flatten](#) () noexcept
- auto [ceras::MaxPooling2D](#) (unsigned long stride) noexcept
- auto [ceras::UpSampling2D](#) (unsigned long stride) noexcept
- template<typename T >  
auto [ceras::Dropout](#) (T factor) noexcept
- auto [ceras::AveragePooling2D](#) (unsigned long stride) noexcept

## 7.9 /data/structured\_↵ folders/workspace/github.repo/ceras/include/loss.hpp File Reference

```
#include "../operation.hpp"
#include "../tensor.hpp"
#include "../utils/debug.hpp"
```

## Namespaces

- [ceras](#)

## Functions

- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto ceras::mean_squared_logarithmic_error` (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto ceras::squared_loss` (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto ceras::mean_squared_error` (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto ceras::mse` (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto ceras::abs_loss` (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto ceras::mean_absolute_error` (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto ceras::mae` (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto ceras::cross_entropy` (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto ceras::binary_cross_entropy_loss` (Lhs\_Expression const &ground\_truth, Rhs\_Expression const &prediction) noexcept
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto ceras::cross_entropy_loss` (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto ceras::hinge_loss` (Lhs\_Expression const &lhs\_ex, Rhs\_Expression const &rhs\_ex) noexcept

## Variables

- `auto ceras::MeanSquaredError`  
*Computes the mean of squares of errors between labels and predictions.*
- `auto ceras::MSE`  
*An alias name of function `MeanSquaredError`.*
- `auto ceras::MeanAbsoluteError`  
*Computes the mean of absolute errors between labels and predictions.*
- `auto ceras::MAE`  
*An alias name of function `MeanAbsoluteError`.*
- `auto ceras::Hinge`
- `auto ceras::CategoricalCrossentropy`
- `auto ceras::CategoricalCrossEntropy`
- `auto ceras::BinaryCrossentropy`
- `auto ceras::BinaryCrossEntropy`

## 7.10 /data/structured\_folders/workspace/github.repo/ceras/include/metric.hpp File Reference

```
#include "../operation.hpp"
#include "../activation.hpp"
#include "../loss.hpp"
```

## Namespaces

- [ceras](#)

## Functions

- `template<Expression Lhs_Expression, Expression Rhc_Expression, std::floating_point FP>`  
`auto ceras::binary\_accuracy (Lhs_Expression const &lhs_ex, Rhc_Expression const &rhs_ex, FP threshold=0.5) noexcept`

## 7.11 /data/structured\_↔

### folders/workspace/github.repo/ceras/include/model.hpp File Reference

```
#include "../includes.hpp"
#include "../operation.hpp"
#include "../place_holder.hpp"
#include "../tensor.hpp"
#include "../utils/better_assert.hpp"
#include "../utils/context_cast.hpp"
#include "../utils/tqdm.hpp"
```

## Classes

- `struct ceras::compiled\_model< Model, Optimizer, Loss >`
- `struct ceras::model< Ex, Ph >`

## Namespaces

- [ceras](#)

## Functions

- `template<Expression Ex>`  
`void ceras::make\_trainable (Ex &ex, bool t)`
- `template<Expression Ex, Place_Holder Ph, Expression Ey>`  
`auto ceras::replace\_placeholder\_with\_expression (Ex const &ex, Ph const &old_place_holder, Ey const &new_expression)`
- `template<typename Model, typename Optimizer, typename Loss >`  
`auto ceras::make\_compiled\_model (Model const &m, Loss const &l, Optimizer const &o)`

## 7.12 /data/structured\_folders/workspace/github.repo/ceras/include/operation.hpp File Reference

```
#include "../includes.hpp"
#include "../place_holder.hpp"
#include "../variable.hpp"
#include "../constant.hpp"
#include "../value.hpp"
#include "../utils/range.hpp"
#include "../utils/debug.hpp"
#include "../config.hpp"
#include "../utils/context_cast.hpp"
#include "../utils/for_each.hpp"
#include "../utils/id.hpp"
#include "../utils/enable_shared.hpp"
```

### Classes

- struct [ceras::unary\\_operator](#)< Operator, Forward\_Action, Backward\_Action >
- struct [ceras::binary\\_operator](#)< Lhs\_Operator, Rhc\_Operator, Forward\_Action, Backward\_Action >
- struct [ceras::is\\_unary\\_operator](#)< T >
- struct [ceras::is\\_unary\\_operator](#)< unary\_operator< Operator, Forward\_Action, Backward\_Action > >
- struct [ceras::is\\_binary\\_operator](#)< T >
- struct [ceras::is\\_binary\\_operator](#)< binary\_operator< Lhs\_Operator, Rhc\_Operator, Forward\_Action, Backward\_Action > >

### Namespaces

- [ceras](#)

### Functions

- template<Expression Ex>  
std::string [ceras::computation\\_graph](#) (Ex const &ex) noexcept
- template<Expression Lhs\_Expression, Expression Rhc\_Expression>  
constexpr auto [ceras::plus](#) (Lhs\_Expression const &lhc\_ex, Rhc\_Expression const &rhc\_ex) noexcept
- template<Expression Lhs\_Expression, Expression Rhc\_Expression>  
constexpr auto [ceras::operator+](#) (Lhs\_Expression const &lhc\_ex, Rhc\_Expression const &rhc\_ex) noexcept
- template<Expression Ex>  
constexpr auto [ceras::operator+](#) (Ex const &ex) noexcept
- template<Expression Lhs\_Expression, Expression Rhc\_Expression>  
auto [ceras::operator\\*](#) (Lhs\_Expression const &lhc\_ex, Rhc\_Expression const &rhc\_ex) noexcept
- template<Expression Ex>  
constexpr auto [ceras::negative](#) (Ex const &ex) noexcept
- template<Expression Ex>  
constexpr auto [ceras::operator-](#) (Ex const &ex) noexcept
- template<Expression Lhs\_Expression, Expression Rhc\_Expression>  
constexpr auto [ceras::elementwise\\_product](#) (Lhs\_Expression const &lhc\_ex, Rhc\_Expression const &rhc\_ex) noexcept

- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto ceras::elementwise_multiply (Lhs_Expression const &lhs_ex, Rhs_Expression const &rhs_ex)`  
`noexcept`
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto ceras::hadamard_product (Lhs_Expression const &lhs_ex, Rhs_Expression const &rhs_ex)`  
`noexcept`
- `template<Expression Ex>`  
`constexpr auto ceras::sum_reduce (Ex const &ex) noexcept`
- `template<Expression Ex>`  
`constexpr auto ceras::reduce_sum (Ex const &ex) noexcept`
- `template<Expression Ex>`  
`constexpr auto ceras::mean_reduce (Ex const &ex) noexcept`  
*Computes the mean of elements across all dimensions of an expression.*
- `template<Expression Ex>`  
`constexpr auto ceras::reduce_mean (Ex const &ex) noexcept`  
*An alias name of mean\_reduce.*
- `template<Expression Ex>`  
`constexpr auto ceras::mean (Ex const &ex) noexcept`  
*An alias name of mean\_reduce.*
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto ceras::minus (Lhs_Expression const &lhs_ex, Rhs_Expression const &rhs_ex) noexcept`
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto ceras::operator- (Lhs_Expression const &lhs_ex, Rhs_Expression const &rhs_ex) noexcept`
- `template<Expression Ex>`  
`constexpr auto ceras::square (Ex const &ex) noexcept`
- `template<Expression Ex, Expression Ey>`  
`*endcode **constexpr auto hypot (Ex const &ex, Ey const &ey) noexcept`
- `template<typename Float >`  
`requires std::floating_point< Float > constexpr auto clip (Float lower, Float upper=std::numeric_limits< Float >::max()) noexcept`
- `auto reshape (std::vector< unsigned long > const &new_shape, bool include_batch_flag=true) noexcept`
- `template<Expression Ex>`  
`constexpr auto flatten (Ex const &ex) noexcept`
- `template<Expression Ex>`  
`constexpr auto identity (Ex const &ex) noexcept`
- `template<Expression Ex>`  
`auto transpose (Ex const &ex) noexcept`
- `auto img2col (unsigned long const row_kernel, unsigned long col_kernel=-1, unsigned long const row_↵  
padding=0, unsigned long col_padding=0, unsigned long const row_stride=1, unsigned long const col_↵  
stride=1, unsigned long const row_dilation=1, unsigned long const col_dilation=1) noexcept`
- `auto conv2d (unsigned long row_input, unsigned long col_input, unsigned long const row_stride=1, unsigned  
long const col_stride=1, unsigned long const row_dilation=1, unsigned long const col_dilation=1, std::string  
const &padding="valid") noexcept`
- `template<typename T >`  
`requires std::floating_point< T > auto drop_out (T const factor) noexcept`
- `auto max_pooling_2d (unsigned long stride) noexcept`
- `auto average_pooling_2d (unsigned long stride) noexcept`
- `auto up_sampling_2d (unsigned long stride) noexcept`
- `template<typename T = double>`  
`requires std::floating_point< T > auto normalization_batch (T const momentum=0.98) noexcept`
- `template<typename T >`  
`requires std::floating_point< T > auto batch_normalization (T const momentum=0.98) noexcept`
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto concatenate (Lhs_Expression const &lhs_ex, Rhs_Expression const &rhs_ex) noexcept`
- `auto concatenate (unsigned long axe=-1)`



- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto concat (Lhs_Expression const &lhs_ex, Rhs_Expression const &rhs_ex) noexcept`
- `auto concat (unsigned long axis=-1)`
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto maximum (Lhs_Expression const &lhs_ex, Rhs_Expression const &rhs_ex) noexcept`
- `template<Expression Lhs_Expression, Expression Rhs_Expression>`  
`constexpr auto atan2 (Lhs_Expression const &lhs_ex, Rhs_Expression const &rhs_ex) noexcept`  
*Computes the arc tangent of y/x using the signs of arguments to determine the correct quadrant.*
- `template<typename T = float>`  
`requires std::floating_point< T > auto random_normal_like (T mean=0.0, T stddev=1.0) noexcept`
- `template<Expression Ex>`  
`auto ones_like (Ex const &ex) noexcept`
- `template<Expression Ex>`  
`auto zeros_like (Ex const &ex) noexcept`
- `template<Expression Lhs_Expression, Expression Rhs_Expression, std::floating_point FP>`  
`constexpr auto equal (Lhs_Expression const &lhs_ex, Rhs_Expression const &rhs_ex, FP threshold=0.5) noexcept`
- `template<Expression Ex>`  
`constexpr auto sign (Ex const &ex) noexcept`
- `auto zero_padding_2d (std::vector< unsigned long > const &padding) noexcept`  
*Zero-padding layer for 2D input. The input should have 4-dimensions: (batch\_size, row, col, channel). The output has 4-dimensions: (batch\_size, new\_row, new\_col, channel).*
- `auto repeat (unsigned long repeats, unsigned long axis=-1) noexcept`  
*Repeats elements along an axis.*
- `auto reduce_min (unsigned long axis=-1) noexcept`  
*Reduce minimal elements along an axis.*
- `auto reduce_max (unsigned long axis=-1) noexcept`  
*Reduce maximum elements along an axis.*
- `auto reduce_sum (unsigned long axis) noexcept`  
*Reduce sum elements along an axis.*
- `template<Expression Ex>`  
`constexpr auto abs (Ex const &ex) noexcept`  
*Computes Abs of the given expression.*
- `template<Expression Ex>`  
`constexpr auto acos (Ex const &ex) noexcept`  
*Computes Acos of the given expression.*
- `template<Expression Ex>`  
`constexpr auto acosh (Ex const &ex) noexcept`  
*Computes Acosh of the given expression.*
- `template<Expression Ex>`  
`constexpr auto asin (Ex const &ex) noexcept`  
*Computes Asin of the given expression.*
- `template<Expression Ex>`  
`constexpr auto asinh (Ex const &ex) noexcept`  
*Computes Asinh of the given expression.*
- `template<Expression Ex>`  
`constexpr auto atan (Ex const &ex) noexcept`  
*Computes Atan of the given expression.*
- `template<Expression Ex>`  
`constexpr auto atanh (Ex const &ex) noexcept`  
*Computes Atanh of the given expression.*
- `template<Expression Ex>`  
`constexpr auto cbrt (Ex const &ex) noexcept`  
*Computes Cbrt of the given expression.*

- `template<Expression Ex>`  
`constexpr auto ceil (Ex const &ex) noexcept`  
*Computes Ceil of the given expression.*
- `template<Expression Ex>`  
`constexpr auto cos (Ex const &ex) noexcept`  
*Computes Cos of the given expression.*
- `template<Expression Ex>`  
`constexpr auto cosh (Ex const &ex) noexcept`  
*Computes Cosh of the given expression.*
- `template<Expression Ex>`  
`constexpr auto erf (Ex const &ex) noexcept`  
*Computes Erf of the given expression.*
- `template<Expression Ex>`  
`constexpr auto erfc (Ex const &ex) noexcept`  
*Computes Erfc of the given expression.*
- `template<Expression Ex>`  
`constexpr auto exp (Ex const &ex) noexcept`  
*Computes Exp of the given expression.*
- `template<Expression Ex>`  
`constexpr auto exp2 (Ex const &ex) noexcept`  
*Computes Exp2 of the given expression.*
- `template<Expression Ex>`  
`constexpr auto expm1 (Ex const &ex) noexcept`  
*Computes Expm1 of the given expression.*
- `template<Expression Ex>`  
`constexpr auto fabs (Ex const &ex) noexcept`  
*Computes Fabs of the given expression.*
- `template<Expression Ex>`  
`constexpr auto floor (Ex const &ex) noexcept`  
*Computes Floor of the given expression.*
- `template<Expression Ex>`  
`constexpr auto llrint (Ex const &ex) noexcept`  
*Computes Llrint of the given expression.*
- `template<Expression Ex>`  
`constexpr auto llround (Ex const &ex) noexcept`  
*Computes Llround of the given expression.*
- `template<Expression Ex>`  
`constexpr auto log (Ex const &ex) noexcept`  
*Computes Log of the given expression.*
- `template<Expression Ex>`  
`constexpr auto log10 (Ex const &ex) noexcept`  
*Computes Log10 of the given expression.*
- `template<Expression Ex>`  
`constexpr auto log1p (Ex const &ex) noexcept`  
*Computes Log1p of the given expression.*
- `template<Expression Ex>`  
`constexpr auto log2 (Ex const &ex) noexcept`  
*Computes Log2 of the given expression.*
- `template<Expression Ex>`  
`constexpr auto lrint (Ex const &ex) noexcept`  
*Computes Lrint of the given expression.*
- `template<Expression Ex>`  
`constexpr auto lround (Ex const &ex) noexcept`

- Computes Lround of the given expression.*

• template<Expression Ex>  
constexpr auto [nearbyint](#) (Ex const &ex) noexcept
- Computes Nearbyint of the given expression.*

• template<Expression Ex>  
constexpr auto [rint](#) (Ex const &ex) noexcept
- Computes Rint of the given expression.*

• template<Expression Ex>  
constexpr auto [round](#) (Ex const &ex) noexcept
- Computes Round of the given expression.*

• template<Expression Ex>  
constexpr auto [sin](#) (Ex const &ex) noexcept
- Computes Sin of the given expression.*

• template<Expression Ex>  
constexpr auto [sinh](#) (Ex const &ex) noexcept
- Computes Sinh of the given expression.*

• template<Expression Ex>  
constexpr auto [sqrt](#) (Ex const &ex) noexcept
- Computes Sqrt of the given expression.*

• template<Expression Ex>  
constexpr auto [tan](#) (Ex const &ex) noexcept
- Computes Tan of the given expression.*

• template<Expression Ex>  
constexpr auto [tanh](#) (Ex const &ex) noexcept
- Computes Tanh of the given expression.*

• template<Expression Ex>  
constexpr auto [trunc](#) (Ex const &ex) noexcept
- Computes Trunc of the given expression.*

## Variables

- static constexpr auto [ceras::make\\_unary\\_operator](#)
- static constexpr auto [ceras::make\\_binary\\_operator](#)
- template<class T >  
constexpr bool [ceras::is\\_unary\\_operator\\_v](#) = is\_unary\_operator<T>::value
- template<typename T >  
concept [ceras::Unary\\_Operator](#) = is\_unary\_operator\_v<T>

*A type that represents an unary operator.*
- template<class T >  
constexpr bool [ceras::is\\_binary\\_operator\\_v](#) = is\_binary\_operator<T>::value
- template<typename T >  
concept [ceras::Binary\\_Operator](#) = is\_binary\_operator\_v<T>

*A type that represents a binary operator.*
- template<typename T >  
concept [ceras::Operator](#) = Unary\_Operator<T> || Binary\_Operator<T>

*A type that represents an unary or a binary operator.*
- template<typename T >  
concept [ceras::Expression](#) = Operator<T> || Variable<T> || Place\_Holder<T> || Constant<T> || Value<T>

*A type that represents a unary operator, a binary operator, a variable, a [place\\_holder](#), a constant or a value.*
- \*auto [y](#) = variable<tensor<float>>>{ }
- \*auto [sqr](#) = [hypot](#)( x, y )

## 7.12.1 Function Documentation

### 7.12.1.1 abs()

```
template<Expression Ex>
constexpr auto abs (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Abs of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = abs( a );
```

### 7.12.1.2 acos()

```
template<Expression Ex>
constexpr auto acos (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Acos of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = acos( a );
```

### 7.12.1.3 acosh()

```
template<Expression Ex>
constexpr auto acosh (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Acosh of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = acosh( a );
```

### 7.12.1.4 asin()

```
template<Expression Ex>
constexpr auto asin (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Asin of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = asin( a );
```

### 7.12.1.5 asinh()

```
template<Expression Ex>
constexpr auto asinh (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Asinh of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = asinh( a );
```

### 7.12.1.6 atan()

```
template<Expression Ex>
constexpr auto atan (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Atan of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = atan( a );
```

### 7.12.1.7 atan2()

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto atan2 (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]
```

Computes the arc tangent of y/x using the signs of arguments to determine the correct quadrant.

### 7.12.1.8 atanh()

```
template<Expression Ex>
constexpr auto atanh (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Atanh of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = atanh( a );
```

### 7.12.1.9 average\_pooling\_2d()

```
auto average_pooling_2d (
    unsigned long stride ) [inline], [noexcept]
```

### 7.12.1.10 batch\_normalization()

```
template<typename T >
requires std::floating_point<T> auto batch_normalization (
    T const momentum = 0.98 ) [inline], [noexcept]
```

### 7.12.1.11 cbrt()

```
template<Expression Ex>
constexpr auto cbrt (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Cbert of the given expression.

Example code:

```
auto a = variable{ random<float>({ 2, 3, 5 } ) };
auto b = cbrt( a );
```

### 7.12.1.12 ceil()

```
template<Expression Ex>
constexpr auto ceil (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Ceil of the given expression.

Example code:

```
auto a = variable{ random<float>({ 2, 3, 5 } ) };
auto b = ceil( a );
```

### 7.12.1.13 clip()

```
template<typename Float >
requires std::floating_point<Float> constexpr auto clip (
    Float lower,
    Float upper = std::numeric_limits<Float>::max() ) [constexpr], [noexcept]
```

**7.12.1.14 concat()** [1/2]

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto concat (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]
```

**7.12.1.15 concat()** [2/2]

```
auto concat (
    unsigned long axe = -1 ) [inline]
```

**7.12.1.16 concatenate()** [1/2]

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto concatenate (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]
```

**7.12.1.17 concatenate()** [2/2]

```
auto concatenate (
    unsigned long axe = -1 ) [inline]
```

**7.12.1.18 conv2d()**

```
auto conv2d (
    unsigned long row_input,
    unsigned long col_input,
    unsigned long const row_stride = 1,
    unsigned long const col_stride = 1,
    unsigned long const row_dilation = 1,
    unsigned long const col_dilation = 1,
    std::string const & padding = "valid" ) [inline], [noexcept]
```

### 7.12.1.19 cos()

```
template<Expression Ex>
constexpr auto cos (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Cos of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = cos( a );
```

### 7.12.1.20 cosh()

```
template<Expression Ex>
constexpr auto cosh (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Cosh of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = cosh( a );
```

### 7.12.1.21 drop\_out()

```
template<typename T >
requires std::floating_point<T> auto drop_out (
    T const factor ) [inline], [noexcept]
```

### 7.12.1.22 equal()

```
template<Expression Lhs_Expression, Expression Rhs_Expression, std::floating_point FP>
constexpr auto equal (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex,
    FP threshold = 0.5 ) [constexpr], [noexcept]
```

Returns the truth value of (lhs == rhs) element-wise. [+1 for true, 0 for false]

Parameters

<i>lhs_ex</i>	The first operator.
<i>rhs_ex</i>	The second operator.



### Returns

An instance of a binary operator that evaluate the element-wise equality of two input operators.

#### Example code:

```

auto l = variable<tensor<float>>{ /*...*/ };
auto r = place_holder<tensor<float>>{};
auto eq = equal(l, r);

```

### 7.12.1.23 erf()

```

template<Expression Ex>
constexpr auto erf (
    Ex const & ex ) [constexpr], [noexcept]

```

Computes Erf of the given expression.

#### Example code:

```

auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = erf( a );

```

### 7.12.1.24 erfc()

```

template<Expression Ex>
constexpr auto erfc (
    Ex const & ex ) [constexpr], [noexcept]

```

Computes Erfc of the given expression.

#### Example code:

```

auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = erfc( a );

```

### 7.12.1.25 exp()

```

template<Expression Ex>
constexpr auto exp (
    Ex const & ex ) [constexpr], [noexcept]

```

Computes Exp of the given expression.

#### Example code:

```

auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = exp( a );

```

### 7.12.1.26 exp2()

```
template<Expression Ex>
constexpr auto exp2 (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Exp2 of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = exp2( a );
```

### 7.12.1.27 expm1()

```
template<Expression Ex>
constexpr auto expm1 (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Expm1 of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = expm1( a );
```

### 7.12.1.28 fabs()

```
template<Expression Ex>
constexpr auto fabs (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Fabs of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = fabs( a );
```

### 7.12.1.29 flatten()

```
template<Expression Ex>
constexpr auto flatten (
    Ex const & ex ) [constexpr], [noexcept]
```

### 7.12.1.30 floor()

```
template<Expression Ex>
constexpr auto floor (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Floor of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = floor( a );
```

### 7.12.1.31 hypot()

```
template<Expression Ex, Expression Ey>
* endcode* * constexpr auto hypot (
    Ex const & ex,
    Ey const & ey ) [constexpr], [noexcept]
```

### 7.12.1.32 identity()

```
template<Expression Ex>
constexpr auto identity (
    Ex const & ex ) [constexpr], [noexcept]
```

### 7.12.1.33 img2col()

```
auto img2col (
    unsigned long const row_kernel,
    unsigned long col_kernel = -1,
    unsigned long const row_padding = 0,
    unsigned long col_padding = 0,
    unsigned long const row_stride = 1,
    unsigned long const col_stride = 1,
    unsigned long const row_dilation = 1,
    unsigned long const col_dilation = 1 ) [inline], [noexcept]
```

### 7.12.1.34 llrint()

```
template<Expression Ex>
constexpr auto llrint (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Llrint of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = llrint( a );
```

### 7.12.1.35 llround()

```
template<Expression Ex>
constexpr auto llround (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Llround of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = llround( a );
```

### 7.12.1.36 log()

```
template<Expression Ex>
constexpr auto log (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Log of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = log( a );
```

### 7.12.1.37 log10()

```
template<Expression Ex>
constexpr auto log10 (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Log10 of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = log10( a );
```

### 7.12.1.38 log1p()

```
template<Expression Ex>
constexpr auto log1p (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Log1p of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = log1p( a );
```

### 7.12.1.39 log2()

```
template<Expression Ex>
constexpr auto log2 (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Log2 of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = log2( a );
```

### 7.12.1.40 lrint()

```
template<Expression Ex>
constexpr auto lrint (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Lrint of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = lrint( a );
```

### 7.12.1.41 lround()

```
template<Expression Ex>
constexpr auto lround (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Lround of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = lround( a );
```

### 7.12.1.42 max\_pooling\_2d()

```
auto max_pooling_2d (
    unsigned long stride ) [inline], [noexcept]
```

### 7.12.1.43 maximum()

```
template<Expression Lhs_Expression, Expression Rhs_Expression>
constexpr auto maximum (
    Lhs_Expression const & lhs_ex,
    Rhs_Expression const & rhs_ex ) [constexpr], [noexcept]
```

### 7.12.1.44 nearbyint()

```
template<Expression Ex>
constexpr auto nearbyint (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Nearbyint of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = nearbyint( a );
```

### 7.12.1.45 normalization\_batch()

```
template<typename T = double>
requires std::floating_point<T> auto normalization_batch (
    T const momentum = 0.98 ) [inline], [noexcept]
```

### 7.12.1.46 ones\_like()

```
template<Expression Ex>
auto ones_like (
    Ex const & ex ) [noexcept]
```

ones\_like produces a tensor of the same shape as the input expression, but with every element to be 1.

#### Returns

An unary operator that takes an unary operator, and producing an output tensor Example Code:

```
auto va = variable{ ones<float>({3, 3, 3}) };
auto v_rand = ones_like( va ); // this expression will produces a tensor of shape (3, 3, 3), with every
    element to be 1.
```

### 7.12.1.47 random\_normal\_like()

```
template<typename T = float>
requires std::floating_point<T> auto random_normal_like (
    T mean = 0.0,
    T stddev = 1.0 ) [inline], [noexcept]
```

random\_normal\_like produces random tensor from a normal distribution

#### Parameters

<i>mean</i>	Mean of the normal distribution, a scalar.
<i>stddev</i>	Standard deviation of the normal distribution, a scalar.

## Returns

An unary operator that takes an unary operator, and producing output tensor from a normal distribution. The shape of the output tensor has the same shape corresponding to the input unary operator.

## Example Code

```
auto va = variable{ ones<float>({3, 3, 3}) };
auto v_rand = random_normal_like( 1.0, 4.0 )( va ); // this expression will produces a tensor of shape (3,
3, 3) from a normal distribution with parameters (1.0, 4.0)
```

### 7.12.1.48 reduce\_max()

```
auto reduce_max (
    unsigned long axis = -1 ) [inline], [noexcept]
```

Reduce maximum elements along an axis.

#### Parameters

<i>axis</i>	The axis along which to reduce maximum values. Defaults to the last axis.
-------------	---------------------------------------------------------------------------

#### Example code:

```
auto a = variable{ random<float>({2, 3, 5}) };
auto b = reduce_max( 0 )( a ); // <- output shape is ( 3, 5 )
auto b = reduce_max( 1 )( a ); // <- output shape is ( 2, 5 )
auto b = reduce_max( 2 )( a ); // <- output shape is ( 2, 3 )
auto b = reduce_max( ) ( a ); // <- output shape is ( 2, 3 )
```

### 7.12.1.49 reduce\_min()

```
auto reduce_min (
    unsigned long axis = -1 ) [inline], [noexcept]
```

Reduce minimal elements along an axis.

#### Parameters

<i>axis</i>	The axis along which to reduce minimal values. Defaults to the last axis.
-------------	---------------------------------------------------------------------------

#### Example code:

```
auto a = variable{ random<float>({2, 3, 5}) };
auto b = reduce_min( 0 )( a ); // <- output shape is ( 3, 5 )
auto b = reduce_min( 1 )( a ); // <- output shape is ( 2, 5 )
auto b = reduce_min( 2 )( a ); // <- output shape is ( 2, 3 )
auto b = reduce_min( ) ( a ); // <- output shape is ( 2, 3 )
```

### 7.12.1.50 reduce\_sum()

```
auto reduce_sum (
    unsigned long axis ) [inline], [noexcept]
```

Reduce sum elements along an axis.

#### Parameters

<i>axis</i>	The axis along which to reduce sum.
-------------	-------------------------------------

#### Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = reduce_sum( 0 )( a ); // <- output shape is ( 3, 5 )
auto b = reduce_sum( 1 )( a ); // <- output shape is ( 2, 5 )
auto b = reduce_sum( 2 )( a ); // <- output shape is ( 2, 3 )
auto b = reduce_sum( -1 )( a ); // <- output shape is ( 2, 3 )
```

### 7.12.1.51 repeat()

```
auto repeat (
    unsigned long repeats,
    unsigned long axis = -1 ) [inline], [noexcept]
```

Repeats elements along an axis.

#### Parameters

<i>repeats</i>	The number of repetitions for each element.
<i>axis</i>	The axis along which to repeat values. Defaults to the last axis.

#### Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b0 = repeat( 2, 0 )( a ); // <- output shape is ( 4, 3, 5 )
auto b1 = repeat( 2, 1 )( a ); // <- output shape is ( 2, 6, 5 )
auto b2 = repeat( 2, 2 )( a ); // <- output shape is ( 2, 3, 10 )
auto bx = repeat( 2 )( a ); // <- output shape is ( 2, 3, 10 )
```

### 7.12.1.52 reshape()

```
auto reshape (
    std::vector< unsigned long > const & new_shape,
    bool include_batch_flag = true ) [inline], [noexcept]
```

### 7.12.1.53 rint()

```
template<Expression Ex>
constexpr auto rint (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Rint of the given expression.

#### Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = rint( a );
```



### 7.12.1.54 round()

```
template<Expression Ex>
constexpr auto round (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Round of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = round( a );
```

### 7.12.1.55 sign()

```
template<Expression Ex>
constexpr auto sign (
    Ex const & ex ) [constexpr], [noexcept]
```

Returns the sign. [1 for positive, 0 for 0 and -1 for negative]

Parameters

ex	The input operator.
----	---------------------

Returns

An instance of a unary\_operator that evaluate the sign of the input operator.

Example code:

```
auto e = variable<tensor<float>>( /*...*/ );
auto si = sign(e);
```

### 7.12.1.56 sin()

```
template<Expression Ex>
constexpr auto sin (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Sin of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = sin( a );
```

### 7.12.1.57 sinh()

```
template<Expression Ex>
constexpr auto sinh (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Sinh of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = sinh( a );
```

### 7.12.1.58 sqrt()

```
template<Expression Ex>
constexpr auto sqrt (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Sqrt of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = sqrt( a );
```

### 7.12.1.59 tan()

```
template<Expression Ex>
constexpr auto tan (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Tan of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = tan( a );
```

### 7.12.1.60 tanh()

```
template<Expression Ex>
constexpr auto tanh (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Tanh of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = tanh( a );
```

### 7.12.1.61 transpose()

```
template<Expression Ex>
auto transpose (
    Ex const & ex ) [noexcept]
```

### 7.12.1.62 trunc()

```
template<Expression Ex>
constexpr auto trunc (
    Ex const & ex ) [constexpr], [noexcept]
```

Computes Trunc of the given expression.

Example code:

```
auto a = variable{ random<float>( {2, 3, 5} ) };
auto b = trunc( a );
```

### 7.12.1.63 up\_sampling\_2d()

```
auto up_sampling_2d (
    unsigned long stride ) [inline], [noexcept]
```

### 7.12.1.64 zero\_padding\_2d()

```
auto zero_padding_2d (
    std::vector< unsigned long > const & padding ) [inline], [noexcept]
```

Zero-padding layer for 2D input. The input should have 4-dimensions: (batch\_size, row, col, channel). The output has 4-dimensions: (batch\_size, new\_row, new\_col, channel).

Parameters

<i>padding</i>	If a single integer, then apply symmetric padding to height and width. If two integers, then first is for height and the second is for width. If four integers, then is interpreted as<tt>(top_pad, bottom_pad, left_pad, right_pad)</tt>.
----------------	--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Example code:

```
auto a = variable{ random<float>( {16, 16, 3} ) };
auto b = zero_padding_2d( {8,} )( a ); // shape for b is (8+16+8, 8+16+8, 3)
auto c = zero_padding_2d( {8, 4} )( a ); // shape for c is (8+16+8, 4+16+4, 3)
auto d = zero_padding_2d( {8, 4, 2, 1} )( a ); // shape for d is (8+16+4, 2+16+1, 3)
```

### 7.12.1.65 zeros\_like()

```
template<Expression Ex>
auto zeros_like (
    Ex const & ex ) [noexcept]
```

`zeros_like` produces a tensor of the same shape as the input expression, but with every element to be 0.

#### Returns

An unary operator that takes an unary operator, and producing an output tensor Example Code:

```
auto va = variable{ ones<float>({3, 3, 3}) };
auto v_rand = zeros_like( va ); // this expression will produces a tensor of shape (3, 3, 3), with
    every element to be 0.
```

## 7.12.2 Variable Documentation

### 7.12.2.1 sqr

```
* auto sqr = hypot( x, y )
```

### 7.12.2.2 y

```
* auto y = variable<tensor<float>>{ }
```

## 7.13 /data/structured\_↵ folders/workspace/github.repo/ceras/include/optimizer.hpp File Reference

```
#include "../config.hpp"
#include "../operation.hpp"
#include "../place_holder.hpp"
#include "../variable.hpp"
#include "../session.hpp"
#include "../utils/color.hpp"
#include "../utils/debug.hpp"
#include "../utils/id.hpp"
#include "../utils/enable_shared.hpp"
```

### Classes

- struct `ceras::sgd< Loss, T >`
- struct `ceras::adagrad< Loss, T >`
- struct `ceras::rmsprop< Loss, T >`
- struct `ceras::adadelta< Loss, T >`
- struct `ceras::adam< Loss, T >`
- struct `ceras::gradient_descent< Loss, T >`

## Namespaces

- [ceras](#)

## Typedefs

- `template<typename Loss , typename T >`  
using [ceras::ada\\_grad](#) = `adagrad< Loss, T >`
- `template<typename Loss , typename T >`  
using [ceras::rms\\_prop](#) = `rmsprop< Loss, T >`
- `template<typename Loss , typename T >`  
using [ceras::ada\\_delta](#) = `adadelat< Loss, T >`

## Variables

- `auto` [ceras::Adam](#)
- `auto` [ceras::SGD](#)
- `auto` [ceras::Adagrad](#)
- `auto` [ceras::RMSprop](#)
- `auto` [ceras::Adadelta](#)

## 7.14 /data/structured\_folders/workspace/github.repo/ceras/include/place\_holder.hpp File Reference

```
#include "../includes.hpp"
#include "../tensor.hpp"
#include "../utils/better_assert.hpp"
#include "../utils/debug.hpp"
#include "../utils/id.hpp"
#include "../utils/enable_shared.hpp"
#include "../utils/state.hpp"
```

## Classes

- `struct` [ceras::place\\_holder\\_state< Tsor >](#)
- `struct` [ceras::place\\_holder< Tsor >](#)
- `struct` [ceras::is\\_place\\_holder< T >](#)
- `struct` [ceras::is\\_place\\_holder< place\\_holder< Tsor > >](#)

## Namespaces

- [ceras](#)

## Functions

- `template<Place_Holder Ph>`  
`bool ceras::operator== (Ph const &lhs, Ph const &rhs)`
- `template<Place_Holder Ph>`  
`bool ceras::operator!= (Ph const &lhs, Ph const &rhs)`
- `template<Place_Holder Ph>`  
`bool ceras::operator< (Ph const &lhs, Ph const &rhs)`
- `template<Place_Holder Ph>`  
`bool ceras::operator> (Ph const &lhs, Ph const &rhs)`
- `template<Place_Holder Ph>`  
`bool ceras::operator<= (Ph const &lhs, Ph const &rhs)`
- `template<Place_Holder Ph>`  
`bool ceras::operator>= (Ph const &lhs, Ph const &rhs)`

## Variables

- `template<class T >`  
`constexpr bool ceras::is_place_holder_v = is_place_holder<T>::value`
- `template<typename T >`  
`concept ceras::Place_Holder = is_place_holder_v<T>`

## 7.15 /data/structured\_↔ folders/workspace/github.repo/ceras/include/recurrent.hpp File Reference

```
#include "../constant.hpp"
#include "../session.hpp"
#include "../operation.hpp"
#include "../activation.hpp"
#include "../layer.hpp"
```

## Namespaces

- `ceras`

## Functions

- `auto ceras::lstm (std::unsigned long units) noexcept`

### 7.15.1 Variable Documentation

#### 7.15.1.1 units\_

```
unsigned long units_
```

## 7.16 /data/structured\_folders/workspace/github.repo/ceras/include/session.hpp File Reference

```
#include "../includes.hpp"
#include "../tensor.hpp"
#include "../place_holder.hpp"
#include "../variable.hpp"
#include "../utils/singleton.hpp"
#include "../utils/debug.hpp"
```

### Classes

- struct [ceras::ceras\\_private::session< Tsor >](#)

### Namespaces

- [ceras](#)
- [ceras::ceras\\_private](#)

### Functions

- [template<Tensor Tsor>](#)  
[ceras\\_private::session< Tsor > & ceras::get\\_default\\_session \(\)](#)

## 7.17 /data/structured\_folders/workspace/github.repo/ceras/include/tensor.hpp File Reference

```
#include "../includes.hpp"
#include "../utils/better_assert.hpp"
#include "../utils/range.hpp"
#include "../utils/stride_iterator.hpp"
#include "../utils/for_each.hpp"
#include "../utils/buffered_allocator.hpp"
#include "../utils/debug.hpp"
#include "../utils/id.hpp"
#include "../utils/list.hpp"
#include "../backend/cuda.hpp"
```

### Classes

- struct [ceras::tensor< T, Allocator >](#)
- struct [ceras::is\\_tensor< T >](#)
- struct [ceras::is\\_tensor< tensor< T, A > >](#)
- struct [ceras::view\\_1d< T >](#)
- struct [ceras::view\\_2d< T >](#)
- struct [ceras::view\\_3d< T >](#)
- struct [ceras::view\\_4d< T >](#)
- struct [ceras::view< T, N >](#)

## Namespaces

- [ceras](#)

## Typedefs

- `template<typename T >`  
using [ceras::default\\_allocator](#) = `std::allocator< T >`
- `template<typename T >`  
using [ceras::array](#) = `view_1d< T >`
- `template<typename T >`  
using [ceras::matrix](#) = `view_2d< T >`
- `template<typename T >`  
using [ceras::cube](#) = `view_3d< T >`
- `template<typename T >`  
using [ceras::tesseract](#) = `view_4d< T >`

## Functions

- `template<typename T , typename A = default_allocator<T>>`  
`constexpr tensor< T, A > ceras::as\_tensor (T val) noexcept`
- `template<Tensor Tsr, typename CharT , typename Traits >`  
`std::basic_ostream< CharT, Traits > & ceras::operator<< (std::basic_ostream< CharT, Traits > &os_, Tsr const &tsr)`
- `template<typename T >`  
`requires std::floating_point< T > void ceras::gemm\_cpu (T const *A, bool a_transposed, T const *B, bool b_transposed, unsigned long m, unsigned long n, unsigned long k, T *C)`
- `void ceras::update\_cuda\_gemm\_threshold ()`
- `template<typename T >`  
`requires std::floating_point< T > void ceras::gemm (T const *A, bool a_transposed, T const *B, bool b_↔ transposed, unsigned long m, unsigned long n, unsigned long k, T *C)`
- `template<typename T >`  
`requires std::floating_point< T > void ceras::gemm (view_2d< T > const &x, view_2d< T > const &y, view_2d< T > &ans)`
- `template<Tensor Tsr>`  
`Tsr ceras::add (Tsr const &lhs, Tsr const &rhs) noexcept`
- `template<Tensor Tsr>`  
`Tsr ceras::operator+ (Tsr const &lhs, Tsr const &rhs) noexcept`
- `template<Tensor Tsr>`  
`Tsr ceras::operator+ (typename Tsr::value_type const &lhs, Tsr const &rhs) noexcept`
- `template<Tensor Tsr>`  
`Tsr ceras::operator+ (Tsr const &lhs, typename Tsr::value_type const &rhs) noexcept`
- `template<Tensor Tsr>`  
`Tsr ceras::minus (Tsr const &lhs, Tsr const &rhs) noexcept`
- `template<Tensor Tsr>`  
`Tsr ceras::operator- (Tsr const &lhs, Tsr const &rhs) noexcept`
- `template<Tensor Tsr>`  
`Tsr ceras::operator- (typename Tsr::value_type const &lhs, Tsr const &rhs) noexcept`
- `template<Tensor Tsr>`  
`Tsr ceras::operator- (Tsr const &lhs, typename Tsr::value_type const &rhs) noexcept`
- `template<Tensor Tsr>`  
`Tsr ceras::operator\* (typename Tsr::value_type const &lhs, Tsr const &rhs) noexcept`
- `template<Tensor Tsr>`  
`Tsr ceras::operator\* (Tsr const &lhs, typename Tsr::value_type const &rhs) noexcept`



- `template<Tensor Tsor>`  
`Tsor ceras::operator/ (Tsor const &lhs, typename Tsor::value_type const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor ceras::reshape (Tsor const &ts, std::vector< unsigned long > const &new_shape)`
- `template<Tensor Tsor>`  
`void ceras::multiply (Tsor const &lhs, Tsor const &rhs, Tsor &ans) noexcept`
- `template<Tensor Tsor>`  
`Tsor ceras::multiply (Tsor const &lhs, Tsor const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor ceras::operator* (Tsor const &lhs, Tsor const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor ceras::elementwise_product (Tsor const &lhs, Tsor const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor ceras::hadamard_product (Tsor const &lhs, Tsor const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor ceras::elementwise_divide (Tsor const &lhs, Tsor const &rhs) noexcept`
- `template<Tensor Tsor>`  
`Tsor ceras::repeat (Tsor const &tsor, unsigned long n)`
- `template<Tensor Tsor>`  
`Tsor ceras::reduce_sum (Tsor const &tsor)`
- `template<Tensor Tsor>`  
`Tsor ceras::reduce_mean (Tsor const &tsor)`
- `template<Tensor Tsor>`  
`Tsor ceras::clip (Tsor &tsor, typename Tsor::value_type lower=0, typename Tsor::value_type upper=1)`
- `template<Tensor Tsor>`  
`Tsor ceras::squeeze (Tsor const &tsor)`
- `template<typename T , typename A = default_allocator<T>>`  
`tensor< T, A > ceras::randn (std::vector< unsigned long > const &shape, T mean=T{0}, T stddev=T{1})`
- `template<typename T , typename A = default_allocator<T>>`  
`tensor< T, A > ceras::truncated_normal (std::vector< unsigned long > const &shape, T mean=T{0}, T stddev=T{1}, T lower=T{0}, T upper=T{1})`
- `template<typename T , typename A = default_allocator<T>>`  
`tensor< T, A > ceras::random (std::vector< unsigned long > const &shape, T min=T{0}, T max=T{1})`
- `template<Tensor Tsor>`  
`Tsor ceras::random_like (Tsor const &tsor, typename Tsor::value_type min=0, typename Tsor::value_type max=1)`
- `template<Tensor Tsor>`  
`Tsor ceras::randn_like (Tsor const &tsor, typename Tsor::value_type mean=0, typename Tsor::value_type stddev=1)`
- `template<typename T , typename A = default_allocator<T>>`  
`tensor< T, A > ceras::glorot_uniform (std::initializer_list< unsigned long > shape)`
- `template<Tensor Tsor>`  
`Tsor ceras::deep_copy (Tsor const &tsor)`
- `template<Tensor Tsor>`  
`Tsor ceras::copy (Tsor const &tsor)`
- `template<Tensor Tsor>`  
`Tsor ceras::concatenate (Tsor const &lhs, Tsor const &rhs, unsigned long axis=0) noexcept`
- `template<Tensor Tsor>`  
`Tsor ceras::repmat (Tsor const &tsor, unsigned long row_rep, unsigned long col_rep)`
- `template<Tensor Tsor>`  
`constexpr bool ceras::empty (Tsor const &tsor) noexcept`
- `template<typename T , typename A = default_allocator<T>>`  
`constexpr tensor< T, A > ceras::zeros (std::vector< unsigned long > const &shape)`
- `template<Tensor Tsor>`  
`constexpr Tsor ceras::zeros_like (Tsor const &tsor)`
- `template<typename T , typename A = default_allocator<T>>`  
`constexpr tensor< T, A > ceras::ones (std::vector< unsigned long > const &shape)`

- `template<Tensor Tsr>`  
`constexpr Tsr ceras::ones\_like (Tsr const &tsr)`
- `template<Tensor Tsr>`  
`auto ceras::max (Tsr const &tsr)`
- `template<Tensor Tsr>`  
`auto ceras::amax (Tsr const &tsr)`
- `template<Tensor Tsr>`  
`auto ceras::min (Tsr const &tsr)`
- `template<Tensor Tsr>`  
`auto ceras::amin (Tsr const &tsr)`
- `template<Tensor Tsr>`  
`auto ceras::sum (Tsr const &tsr)`
- `template<Tensor Tsr>`  
`auto ceras::mean (Tsr const &tsr)`
- `template<Tensor Tsr>`  
`auto ceras::norm (Tsr const &tsr)`
- `template<Tensor Tsr>`  
`Tsr ceras::abs (Tsr const &tsr)`
- `template<Tensor Tsr>`  
`Tsr ceras::softmax (Tsr const &tsr)`
- `template<Tensor Tsr>`  
`bool ceras::has\_nan (Tsr const &tsr)`
- `template<Tensor Tsr>`  
`bool ceras::has\_inf (Tsr const &tsr)`
- `template<Tensor Tsr>`  
`bool ceras::is\_valid (Tsr const &tsr)`
- `template<Tensor Tsr, typename Function >`  
`Tsr ceras::reduce (Tsr const &ts, unsigned long axis, typename Tsr::value_type const &init, Function const &func, bool keepdims=false) noexcept`
- `template<Tensor Tsr>`  
`Tsr ceras::sum (Tsr const &ts, unsigned long axis, bool keepdims=false) noexcept`
- `template<Tensor Tsr>`  
`requires std::floating_point< typename Tsr::value_type > Tsr ceras::mean (Tsr const &ts, unsigned long axis, bool keepdims=false) noexcept`
- `template<Tensor Tsr>`  
`requires std::floating_point< typename Tsr::value_type > Tsr ceras::variance (Tsr const &ts, unsigned long axis, bool keepdims=false) noexcept`
- `template<Tensor Tsr>`  
`requires std::floating_point< typename Tsr::value_type > Tsr ceras::standard\_deviation (Tsr const &ts, unsigned long axis, bool keepdims=false) noexcept`
- `template<Tensor Tsr>`  
`requires std::floating_point< typename Tsr::value_type > Tsr::value_type ceras::var (Tsr const &ts) noexcept`
- `template<Tensor Tsr>`  
`requires std::floating_point< typename Tsr::value_type > Tsr::value_type ceras::std (Tsr const &ts) noexcept`
- `template<Tensor Tsr>`  
`Tsr ceras::max (Tsr const &ts, unsigned long axis, bool keepdims=false) noexcept`
- `template<Tensor Tsr>`  
`Tsr ceras::min (Tsr const &ts, unsigned long axis, bool keepdims=false) noexcept`
- `template<typename T, typename A = default_allocator<T>>`  
`requires std::floating_point< T > tensor< T, A > ceras::linspace (T start, T stop, unsigned long num, bool endpoint=true) noexcept`
- `template<class _Tp, class _CharT, class _Traits, class _Alloc >`  
`std::basic_istream< _CharT, _Traits > & ceras::read\_tensor (std::basic_istream< _CharT, _Traits > &__is, tensor< _Tp, _Alloc > &__x)`

- `template<class _Tp, class _CharT, class _Traits, class _Alloc >`  
`std::basic_ostream< _CharT, _Traits > & ceras::write\_tensor (std::basic_ostream< _CharT, _Traits > & __os,`  
`tensor< _Tp, _Alloc > const & __x)`
- `template<typename T, typename A = default_allocator<T>>`  
`tensor< T, A > ceras::load\_tensor (std::string const &file_name)`
- `template<Tensor Tsor>`  
`void ceras::save\_tensor (std::string const &file_name, Tsor const &tsor)`

## Variables

- static unsigned long [ceras::random\\_seed](#) = std::chrono::system\_clock::now().time\_since\_epoch().count()
- static std::mt19937 [ceras::random\\_generator](#) {random\_seed}
- `template<class T >`  
`constexpr bool ceras::is\_tensor\_v = is_tensor<T>::value`
- `template<typename T >`  
`concept ceras::Tensor = is_tensor_v<T>`

## 7.18 /data/structured\_folders/workspace/github.repo/ceras/include/value.hpp File Reference

```
#include "../includes.hpp"
#include "../tensor.hpp"
#include "../utils/id.hpp"
#include "../utils/better_assert.hpp"
#include "../utils/enable_shared.hpp"
```

## Classes

- struct [ceras::value< T >](#)
- struct [ceras::is\\_value< T >](#)
- struct [ceras::is\\_value< value< T > >](#)
- struct [ceras::tensor\\_deduction< L, R >](#)

## Namespaces

- [ceras](#)

## Variables

- `template<class T >`  
`constexpr bool ceras::is\_value\_v = is_value<T>::value`
- `template<typename T >`  
`concept ceras::Value = is_value_v<T>`

## 7.19 /data/structured\_↵ folders/workspace/github.repo/ceras/include/variable.hpp File Reference

```
#include "../includes.hpp"
#include "../tensor.hpp"
#include "../utils/id.hpp"
#include "../utils/debug.hpp"
#include "../config.hpp"
#include "../utils/enable_shared.hpp"
#include "../utils/state.hpp"
```

### Classes

- struct [ceras::variable\\_state< Tsor >](#)
- struct [ceras::regularizer< Float >](#)
- struct [ceras::variable< Tsor >](#)
- struct [ceras::is\\_variable< T >](#)
- struct [ceras::is\\_variable< variable< Tsor > >](#)

### Namespaces

- [ceras](#)
- [ceras::ceras\\_private](#)

### Functions

- template<Tensor Tsor>  
ceras\_private::session< Tsor > & [ceras::get\\_default\\_session](#) ()
- template<Variable Var>  
bool [ceras::operator==](#) (Var const &lhs, Var const &rhs) noexcept

### Variables

- template<class T >  
constexpr bool [ceras::is\\_variable\\_v](#) = is\_variable<T>::value
- template<typename T >  
concept [ceras::Variable](#) = is\_variable\_v<T>

## 7.20 /data/structured\_folders/workspace/github.repo/ceras/include/xmodel.hpp File Reference

```
#include "../includes.hpp"
#include "../operation.hpp"
#include "../place_holder.hpp"
#include "../session.hpp"
#include "../tensor.hpp"
#include "../utils/better_assert.hpp"
#include "../utils/context_cast.hpp"
#include "../utils/tqdm.hpp"
#include "../utils/list.hpp"
#include "../utils/debug.hpp"
```

### Classes

- struct [ceras::model< Ex, Ph >](#)

### Namespaces

- [ceras](#)



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