Intermediate Programming

Day 32

Outline

- Exercise 31
- Inheritance
- Review questions
- Homework 7

Exercise 31: `int_node.h` → `my_node.h`

int_node.h

```
#ifndef INT_NODE_H
#define INT_NODE_H


class int_node
{
private:
      int      data;  //the payload stored in this node
      int_node* next;  //the pointer to node after this one

public:
      //constructors
      int_node(int value): data(value), next(nullptr) { }
      int_node(int value, int_node* ptr): data(value), next(ptr

      //getters
      int get_data() const        { return data; }
      int_node* get_next() const   { return next; }

      //setters
      void set_data(int value)     { data = value; }
      void set_next(int_node* ptr) { next = ptr; }
};
#endif
```

my_node.h

```
#ifndef MY_NODE_H
#define MY_NODE_H

template< typename T >
class my_node
{
private:
      T       data;  //the payload stored in this node
      my_node* next;  //the pointer to node after this one

public:
      //constructors
      my_node(T value): data(value), next(nullptr) { }
      my_node(T value, my_node* ptr) : data(value), next(ptr) { }

      //getters
      T get_data() const        { return data; }
      my_node* get_next() const  { return next; }

      //setters
      void set_data(T value)      { data = value; }
      void set_next(my_node* ptr) { next = ptr; }
};
#endif
```

Exercise 31: `int_set.h` → `my_set.h`

int_set.h

```
#ifndef INT_SET_H
#define INT_SET_H

#include <iostream>
#include "int_node.h"


class int_set
{
private:
	int_node* head;
	int	  size;

public:
	...
	bool add(int new_value);
	...

	friend std::ostream& operator <<
		(std::ostream& os, const int_set& s);
};

#endif
```

my_set.h

```
#ifndef MY_SET_H
#define MY_SET_H

#include <iostream>
#include "my_node.h"

template< typename T >
class my_set
{
private:
	my_node< T >* head;
	int	  size;

public:
	...
	bool add(T new_value);
	...
	template< typename _T >
	friend std::ostream& operator <<
		(std::ostream& os, const my_set< _T >& s);
};
#include “my_set.inc”
#endif
```

Exercise 31: `int_set.cpp` → `my_set.inc`

Exercise 31: int_set.cpp → my_set.inc

int_set.cpp

```
int_set::int_set( const int_set& orig ) : head(nullptr)
{
      for( const int_node *n=orig.head ; n ; n=n->get_next() )
        add( n->get_data() );
}


int_set::~int_set( void )
{
      clear();
}
...
```

my_set.inc

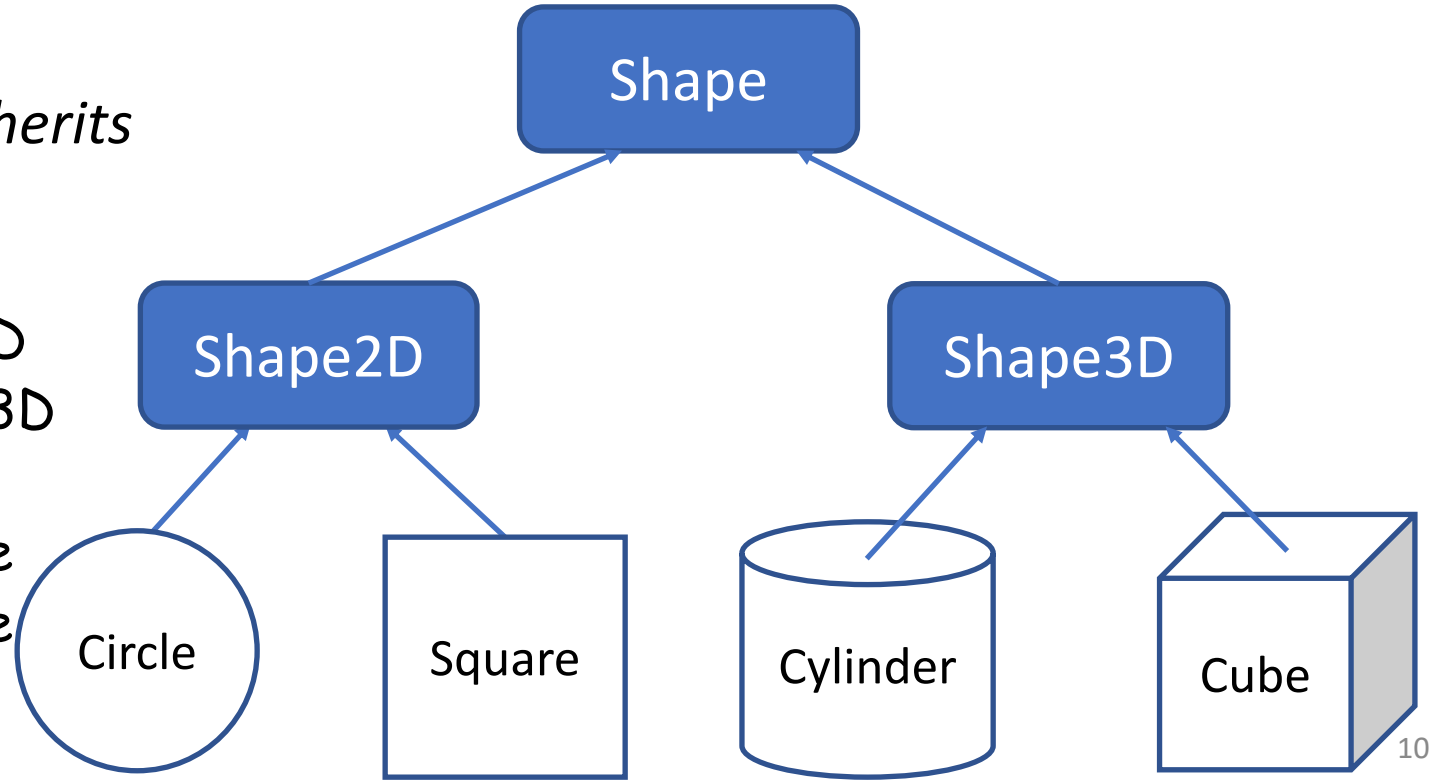
```
template< typename T >
my_set< T >::my_set(const my_set& o) : head(nullptr)
{
      for( const my_node< T > *n=o.head ; n ; n=n ->get_next() )
            add( n->get_data() );
}

template< typename T >
my_set< T >::~my_set( void )
{
      clear();
}
...
```

Outline

- Exercise 31
- Inheritance
- Review questions
- Homework 7

Inheritance

- A class can describe a particular type of a more general class
  - Cylinders and cubes are types of 3D shape
  - Circles and squares are types of 2D shapes
  - The relationships can nest
  - We say that *a derived class inherits from a base class*:
    - `Circle` inherits from `Shape2D`
    - `Square` inherits from `Shape2D`
    - `Cylinder` inherits from `Shape3D`
    - `Cube` inherits from `Shape3D`
    - `Shape2D` inherits from `Shape`
    - `Shape3D` inherits from `Shape`



Inheritance

- We specify that a derived class inherits from a base class when we declare the derived class

  class <derived class> : <inherit how> <base class>

```
class Account
{
public:
      double balance( void ) const { return _balance; }
private:
      double _balance;
};
```

```
class CheckingAccount : public Account
{
public:
      ...
};
```

Inheritance

Q: What is inherited?

A: Everything

- All members, whether **public**, **protected**, or **private** (constructors, destructors, and assignment operators are not inherited, but they are invoked)

```
class Account
{
public:
        double balance( void ) const { return _balance; }
private:
        double _balance;
};
```

```
class CheckingAccount : public Account
{
public:
        ...
};
```

Inheritance

Q: What can be accessed?

A: All base-class members marked **public** or **protected** can be accessed from the derived class

- **private** members are there and can be accessed by the base class, but not by the derived class

```
class Account
{
public:
        double balance( void ) const { return _balance; }
private:
        double _balance;
};
```

```
class CheckingAccount : public Account
{
public:
        void printBalance( void ) const
        {
                cout << balance() << endl;
        }
        ...
};
```

Inheritance

- **protected** is an access level between **public** and **private**:
  - Derived classes have access to protected members in the base class but nobody else does

```
class Account
{
public:
	double balance( void ) const { return _balance; }
private:
	double _balance;
};
```

```
class CheckingAccount : public Account
{
public:
	void printBalance( void ) const
	{
		cout << balance() << endl;
	}
	...
};
```

Inheritance

account.h

```
class Account
{
public:
      Account( void ) : _balance(0.0) { }
      Account( double b ) : _balance( b ) { }
      void credit( double amt ) { _balance += amt; }
      void debit( double amt ) { _balance -= amt; }
      double balance( void ) const { return _balance; }
private:
      double _balance;
};
```

- Constructors:
  - Default constructor sets `Account::_balance` member data to 0
  - Non-default constructor sets `Account::_balance` member data according to the argument
- `Account::_balance` is private:
  - users modify it via the `Account::credit` / `Account::debit` member functions
  - users get a copy of its value via the `Account::balance` member functions

Inheritance

account.h

```
class Account
{
public:
	Account( void ) : _balance(0.0) { }
	Account( double b ) : _balance( b ) { }
	void credit( double amt ) { _balance += amt; }
	void debit( double amt ) { _balance -= amt; }
	double balance( void ) const { return _balance; }
private:
	double _balance;
};
```

main.cpp

```
#include <iostream>
#include "account.h"
using namespace std;

int main( void )
{
	Account acct( 1000.0 );
	acct.credit( 1000.0 );
	acct.debit( 100.0 );
	cout << "Balance is: $ " << acct.balance() << endl;
	return 0;
}
```

```
>> ./a.out
Balance is $1900
>>
```

- Constructors:
  - Default constructor sets `Account::_balance` member data to 0
  - Non-default constructor sets `Account::_balance` member data according to the argument
- `Account::_balance` is private:
  - users modify it via the `Account::credit` / `Account::debit` member functions
  - users get a copy of its value via the `Account::balance` member functions

Inheritance

account.h

```
class Account
{
public:
        Account( void ) : _balance(0.0) { }
        Account( double b ) : _balance( b )
        void credit( double amt ) { _balanc
        void debit( double amt ) { _balance
        double balance( void ) const { retu
private:
        double _balance;
};
…
```

account.h

```
…
class CheckingAccount : public Account
{
public:
        CheckingAccount( void ) : _totalFees( 0.0 ) { }
        CheckingAccount( double b ) : Account( b ) , _totalFees( 0.0 ) { }
        void cashWithdrawal( double amt )
        {
                _totalFees += _ATMFee;
                debit( amt + _ATMFee);
        }
        double totalFees( void ) const { return _totalFees; }
private:
        static const double _ATMFee = 2.00;
        double _totalFees;
};
```

- **CheckingAccount** inherits from **Account**
  - The **CheckingAccount** constructor calls the **Account** constructor (and initializes its own data)

Inheritance

account.h

```
class Account
{
public:
        Account( void ) : _balance(0.0) { }
        Account( double b ) : _balance( b )
        void credit( double amt ) { _balanc
        void debit( double amt ) { _balance
        double balance( void ) const { retu
private:
        double _balance;
};
…
```

account.h

```
…
class CheckingAccount : public Account
{
public:
        CheckingAccount( void ) : _totalFees( 0.0 ) { }
        CheckingAccount( double b ) : Account( b ) , _totalFees( 0.0 ) { }
        void cashWithdrawal( double amt )
        {
                _totalFees += _ATMFee;
                debit( amt + _ATMFee);
        }
        double totalFees( void ) const { return _totalFees; }
private:
        static const double _ATMFee = 2.00;
        double _totalFees;
};
```

- CheckingAccount inherits from Account
  - The CheckingAccount constructor calls the Account constructor (and initializes its own data)
  - CheckingAccount::cashWithrdawl calls the Account::debit (which modifies the private member data Account::_balance)

Inheritance

account.h

```
class Account
{
public:
        Account( void ) : _balance(0.0) { }
        Account( double b ) : _balance( b )
        void credit( double amt ) { _balanc
        void debit( double amt ) { _balance
        double balance( void ) const { retu
private:
        double _balance;
};
...
```

account.h

```
...
class CheckingAccount : public Account
{
public:
        CheckingAccount( void ) : _totalFees( 0.0 ) { }
        CheckingAccount( double b ) : Account( b ) , _totalFees( 0.0 ) { }
        void cashWithdrawal( double amt )
        {
priv
};
```

main.cpp

```
#include <iostream>
#include "account.h"
using namespace std;

int main(void)
{
        Account acct( 1000.0 );
        acct.credit( 1000.0 );
        acct.debit( 100.0 );
        cout << "Balance is: $" << acct. balance() << endl;
        return 0;
}
```

- CheckingAccount inherits f
  - The CheckingAccount constr (and initializes its own data)
  - CheckingAccount::cashWit (which modifies the private member data Accou

```
>> ./a.out
Balance is $1900
>>
```

Inheritance

account.h

```
class Account
{
public:
        Account( void ) : _balance(0.0) { }
        Account( double b ) : _balance( b )
        void credit( double amt ) { _balanc
        void debit( double amt ) { _balance
        double balance( void ) const { retu
private:
        double _balance;
};
...
```

account.h

```
...
class CheckingAccount : public Account
{
public:
        CheckingAccount( void ) : _totalFees( 0.0 ) { }
        CheckingAccount( double b ) : Account( b ) , _totalFees( 0.0 ) { }
        void cashWithdrawal( double amt )
        {
priv
};
```

main.cpp

```
#include <iostream>
#include "account.h"
using namespace std;

int main(void)
{
        CheckingAccount acct( 1000.0 );
        acct.credit( 1000.0 );
        acct.cashWithrdawl( 100.0 );
        cout << "Balance is: $" << acct. balance() << endl;
        return 0;
}
```

```
>> ./a.out
Balance is $1898
>>
```

- **CheckingAccount** inherits f
  - The **CheckingAccount** constr
    (and initializes its own data)
  - **CheckingAccount::cashWit**
    (which modifies the private member data **Accou**

Inheritance

- We specify that a derived class inherits from a base class when we declare the derived class

  class <derived class> : <inherit how> <base class>

  <inherit how>: Describes the public / private / protected status of inherited members
  - public: members stay as is
  - protected: public members become protected, everything else stays as is
  - private: everything becomes private

Inheritance (casting)

- We can convert from a derived class back to its base
  - The compiler casts to the derived class

account.h

```
#include <string>
class Account
{
public:
      …
      double balance( void ) const { return _balance; }
private:
      double _balance;
};
class CheckingAccount : public Account
{
public:
      …
};
```

main.cpp

```
#include <iostream>
#include "account.h"
using namespace std;
void PrintBalance( Account acct )
{
      cout << "Balance: " << acct.balance() << endl;
}
int main( void )
{
      Account acct( 1000 );
      CheckingAccount cAcct( 5000 );
      PrintBalance( acct );
      PrintBalance( cAcct );
      return 0;
}
```

```
>> ./a.out
Balance: 1000
Balance: 5000
>>
```

Inheritance (slicing)

- We can convert from a derived class back to its base
  - The compiler "slices out" the derived class

account.h

```
#include <string>
class Account
{
public:
      …
      double balance( void ) const { return _balance; }
private:
      double _balance;
};
class CheckingAccount : public Account
{
public:
      …
};
```

main.cpp

```
#include <iostream>
#include "account.h"
using namespace std;
void PrintBalance( const Account &acct )
{
      cout << "Balance: " << acct.balance() << endl;
}
int main( void )
{
      Account acct( 1000 );
      CheckingAccount cAcct( 5000 );
      PrintBalance( acct );
      PrintBalance( cAcct );
      return 0;
}
```

```
>> ./a.out
Balance: 1000
Balance: 5000
>>
```

Inheritance (slicing)

- We can convert from a derived class back to its base
  - The compiler "slices out" the derived class

account.h

```
#include <string>
class Account
{
public:
        …
        double balance( void ) const { return _balance; }
private:
        double _balance;
};
class CheckingAccount : public Account
{
public:
        …
};
```

main.cpp

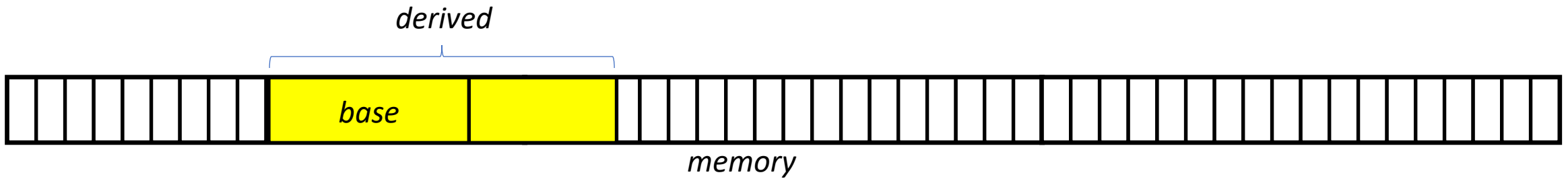
```
#include <iostream>
#include "account.h"
using namespace std;
void PrintBalance( const Account *acct )
{
        cout << "Balance: " << acct->balance() << endl;
}
int main( void )
{
        Account acct( 1000 );
        CheckingAccount cAcct( 5000 );
        PrintBalance( &acct );
        PrintBalance( &cAcct );
        return 0;
}
```

```
>> ./a.out
Balance: 1000
Balance: 5000
>>
```

Inheritance

<u>Under the hood</u>:

When the compiler lays out a derived object in memory, it puts the data of the base class first

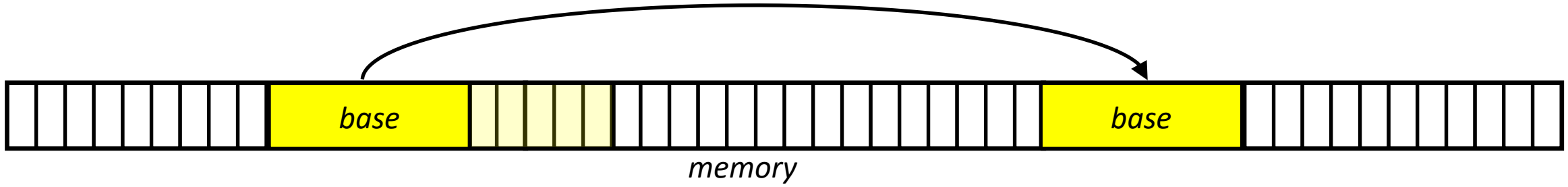


Inheritance (casting)

Under the hood:

When the compiler lays out a derived object in memory, it puts the data of the base class first

- To **cast** to the derived class, the compiler copies the contents of the base and ignores the contents of memory past the base data



Inheritance (slicing)

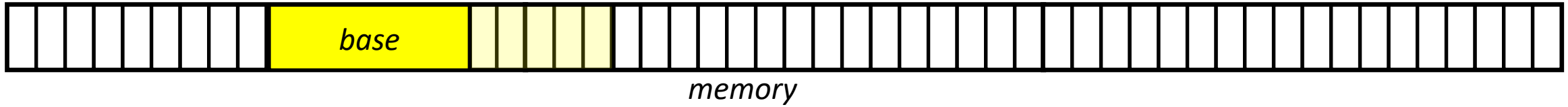
Under the hood:

When the compiler lays out a derived object in memory, it puts the data of the base class first

- To **cast** to the derived class, the compiler copies the contents of the base and ignores the contents of memory past the base data
- To **slice** out the derived class, the compiler ignores the contents of memory past the base data

⇒ The address of the derived object is the same as the address of the base

⇒ A reference to the derived object is a reference to the base



Inheritance (overriding)

- A derived class can override inherited methods by declaring its own version of the method

account.h

```
#include <string>
class Account
{
public:
        …
        std::string type( void ) const { return "generic"; }
};
class CheckingAccount : public Account
{
public:
        …
        std::string type( void ) const { return "checking"; }
};
```

main.cpp

```
#include <iostream>
#include "account.h"
using namespace std;

int main( void )
{
        Account acct();
        CheckingAccount cAcct();
        cout << "Type: " << acct.type() << endl;
        cout << "Type: " << cAcct.type() << endl;
        return 0;
}
```

```
>> ./a.out
Type: generic
Type: checking
>>
```

Inheritance (overriding)

Q: What happens if we slice and override?
(Whose method is called?)

account.h

```
#include <string>
class Account
{
public:
	…
	std::string type( void ) const { return "generic"; }
};
class CheckingAccount : public Account
{
public:
	…
	std::string type( void ) const { return "checking"; }
};
```

main.cpp

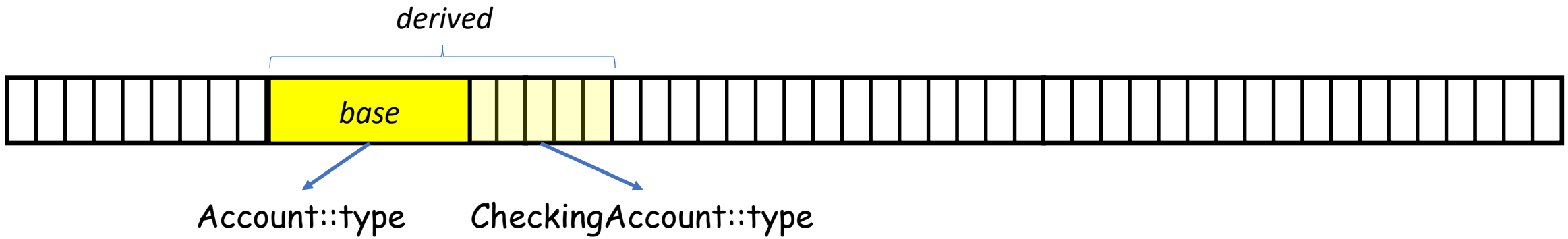
```
#include <iostream>
#include "account.h"
using namespace std;
void PrintType( const Account &acct )
{
	cout << "Type: " << acct.type() << endl;
}
int main( void )
{
	Account acct( 1000 );
	CheckingAccount cAcct( 5000 );
	PrintType( acct );
	PrintType( cAcct );
	return 0;
}
```

Inheritance (overriding)

Under the hood:

When the compiler lays out a derived object in memory, it puts the data of the base class first

- To **cast** to the derived class, the compiler copies the contents of the base and ignores the contents of memory past the base data
- To **slice** out the derived class, the compiler ignores the contents of memory past the base data



Inheritance (overriding)

Q: What happens if we cast/slice and override? (Whose method is called?)

A: The method of the base class

- When `PrintType` is called, the `CheckingAccount` part of `cAcct` is sliced out and only the `Account` part remains

main.cpp

```
#include <iostream>
#include "account.h"
using namespace std;
void PrintType( const Account &acct )
{
      cout << "Type: " << acct.type() << endl;
}
int main( void )
{
      Account acct( 1000 );
      CheckingAccount cAcct( 5000 );
      PrintType( acct );
      PrintType( cAcct );
      return 0;
}
```

```
>> ./a.out
Type: generic
Type: generic
>>
```

Inheritance (polymorphism)

- We can tell the compiler to determine the “true” type of a class **at invocation time**, and use the implementation for that class
  - Use the keyword `virtual` to indicate that a method *may* be overridden by a derived class and that the derived class's method should be used

Inheritance (polymorphism)

- We can tell the compiler to determine the "true" type of a class **at invocation time**, and use the implementation for that class
  - Use the keyword virtual to indicate that a

account.h

```
#include <string>
class Account
{
public:
    …
    virtual std::string type( void ) const { return "generic"; }
};
class CheckingAccount : public Account
{
public:
    …
    std::string type( void ) const { return "checking"; }
};
```

main.cpp

```
#include <iostream>
#include "account.h"
void PrintType( const Account& a )
{
    std::cout << "Type: " << a.type() << std::endl;
}
int main( void )
{
    Account acct( 1000 );
    CheckingAccount cAcct( 5000 );
    PrintType( acct );
    PrintType( cAcct );
    return 0;
}
```

```
>> ./a.out
Type: generic
Type: checking
>>
```

Inheritance (polymorphism)

- Note:
  This only works when you pass the values by reference or by pointer.
  If you pass by value, the implementation of base class is used.

foo.h

```
#include <iostream>
class Base
{
public:
	virtual void print( void ) const
	{ std::cout << "base" << std::endl; }
};
class Derived : public Base
{
public:
	void print( void ) const
	{ std::cout << "derived" << std::endl; }
};
```

main.cpp

```
#include "foo.h"
void Print1( const Base& b ){ b.print(); }
void Print2( const Base* b ){ b->print(); }
void Print3(          Base  b ){ b.print(); }
int main( void )
{
	Derived d;
	Print1( d );
	Print2( &d );
	Print3( d );
	return 0;
}
```

```
>> ./a.out
derived
derived
base
>>
```

Inheritance (polymorphism)

Q: When is polymorphism useful?

A: When we only know the object type at run-time

shape.h

```
#include <iostream>
using namespace std;
class Shape
{
public:
        virtual void readParameters( void );
        virtual void draw( void );
};
...
```

Inheritance (polymorphism)

Q: When is polymorphism useful?

A: When we only knov

shape.h

```
#include <iostream>
using namespace std;
class Shape
{
public:
	virtual void readParameters( void );
	virtual void draw( void );
};
...
```

shape.h

```
...
class Circle : public Shape
{
	double x , y , r; // center and radius
	void readParameters( void )
	{
		cout << "Center and radius: ";
		cin >> x >> y >> r;
	}
	void draw( void )
	{
		cout << "Drawing circle: ";
		cout << "( " << x << " , " << y << " ) " << r << endl;
		...
	}
};
...
```

Inheritance (polymorphism)

Q: When is polymorphism useful?

A: When we only knov

shape.h

```
#include <iostream>
using namespace std;
class Shape
{
public:
	virtual void readParameters( void );
	virtual void draw( void );
};
...
```

shape.h

```
...
class Rectangle : class Shape
{
	double x1 , y1 , x2 ,  y2; // corners
	void readParameters( void )
	{
		cout << "Bottom left / Top right: ";
		cin >> x1 >> y1 >> x2 >> y2;
	}
	void draw( void )
	{
		cout << "Drawing rectangle: ";
		cout << "( " << x1 << " , " << y1 << " ) : " << "( " << x2 << " , " << y2 << " )" << endl;
		...
	}
};
```

Inheritance (polymorphism)

Q: When is polymorph

A: When we only knov

shape.h

```
#include <iostream>
using namespace std;
class Shape
{
public:
	virtual void readParameters( void );
	virtual void draw( void );
};
...
```

main.cpp

```
#include <iostream>
#include <vector>
#include <string>
#include "shape.h"
int main( void )
{
	std::string type;
	std::vector< Shape* > shapes;
	std:: cout << "Shape type [circle/rectangle]: ";
	while( std::cin >> type )
	{
		if	( type=="circle"	) shapes.push_back( new Circle() );
		else if( type=="rectangle" ) shapes.push_back( new Rectangle() );
		else break;
		shapes.back()->readParameters();
		std::cout << "Shape type [circle/rectangle]: ";
	}
	for( size_t i=0 ; i<shapes.size() ; i++ ){ shapes[i]->draw() ; delete shapes[i]; }
	return 0;
}
```

Inheritance (polymorphism)

Q: When is polymorph

A: When we only knov

```
>> ./a.out
Shape type [circle/rectangle]: circle
Center and radius: 5 6 7
```

main.cpp

```
#include <iostream>
#include <vector>
#include <string>
#include "shape.h"
int main( void )
{
	std::string type;
	std::vector< Shape* > shapes;
	std:: cout << "Shape type [circle/rectangle]: ";
	while( std::cin >> type )
	{
		if	( type=="circle"	) shapes.push_back( new Circle() );
		else if( type=="rectangle" ) shapes.push_back( new Rectangle() );
		else break;
		shapes.back()->readParameters();
		std::cout << "Shape type [circle/rectangle]: ";
	}
	for( size_t i=0 ; i<shapes.size() ; i++ ){ shapes[i]->draw() ; delete shapes[i]; }
	return 0;
}
```

shape.h

```
#include <iostream>
using namespace std;
class Shape
{
public:
	virtual void readParameters( void );
	virtual void draw( void );
};
...
```

Inheritance (polymorphism)

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>> ./a.out
Shape type [circle/rectangle]: circle
Center and radius: 5 6 7
Shape type [circle/rectangle]: rectangle
Bottom left / Top right: 1 3 2 5
```

shape.h

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```

```
>> ./a.out
Shape type [circle/rectangle]: circle
Center and radius: 5 6 7
Shape type [circle/rectangle]: rectangle
Bottom left / Top right: 1 3 2 5
Shape type [circle/rectangle]: rectangle
Bottom left / Top right: -1 -5 90 399
```

Inheritance (polymorphism)

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Shape type [circle/rectangle]: circle
Center and radius: 5 6 7
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Bottom left / Top right: -1 -5 90 399
Shape type [circle/rectangle]: done
```

Inheritance (polymorphism)

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	return 0;
}
```

```
>> ./a.out
Shape type [circle/rectangle]: circle
Center and radius: 5 6 7
Shape type [circle/rectangle]: rectangle
Bottom left / Top right: 1 3 2 5
Shape type [circle/rectangle]: rectangle
Bottom left / Top right: -1 -5 90 399
Shape type [circle/rectangle]: done
Drawing circle: ( 5 , 6 ) 7
Drawing rectangle: ( 1 , 3 ) : ( 2 , 5 )
Drawing rectangle: ( -1 , -5 ) : ( 90 , 399 )
>>
```

Inheritance (multiple)

- C++ allows a derived class to inherit from multiple base classes

main.cpp

```
#include <iostream>
class Base1 { public: size_t b; };
class Base2 { public: size_t b; };
class Derived: public Base1, public Base2 { public: size_t d; };

using namespace std;

int main( void )
{
	cout << sizeof(Base1) << " : " << sizeof(Base2) << " : ";
	cout << sizeof(Derived) << endl;
	return 0;
}
```

```
>>  ./a.out
8 : 8 : 24
>>
```

Inheritance (multiple)

- C++ allows a derived class to inherit from multiple base classes
  - Slicing is trickier because we can't put both base classes at the beginning of the derived class

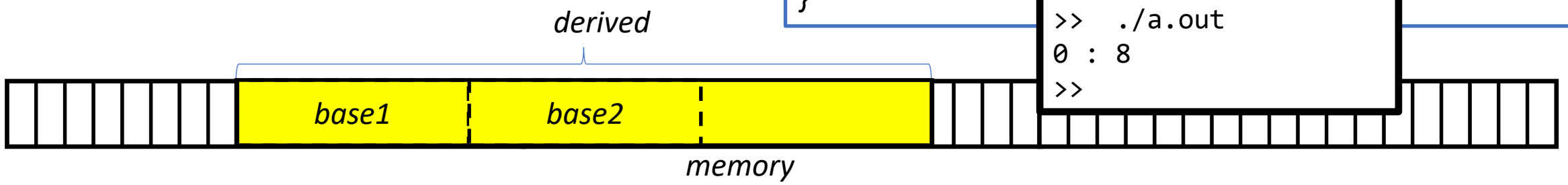
main.cpp

```
#include <iostream>
class Base1 { public: size_t b; };
class Base2 { public: size_t b; };
class Derived: public Base1, public Base2 { public: size_t d; };

using namespace std;

int main( void )
{
        Derived d;
        size_t dAddr = (size_t)&d;
        size_t b1Addr = (size_t)(Base1*)&d;
        size_t b2Addr = (size_t)(Base2*)&d;
        cout << b1Addr-dAddr << " : " b2Addr-dAddr << endl;
        return 0;
}
```

```
>>  ./a.out
0 : 8
>>
```



Inheritance (multiple)

Note:

Watch out for ambiguity when accessing a base class's member!

main.cpp

```
#include <iostream>
class Base1 { public: size_t b; };
class Base2 { public: size_t b; };
class Derived: public Base1, public Base2 { public: size_t d; };

using namespace std;

int main( void )
{
	Derived d;
	cout << d.b << endl;
	return 0;
}
```

Inheritance (multiple)

Note:

Watch out for ambiguity when accessing a base class's member!

main.cpp

```
#include <iostream>
class Base1 { public: size_t b; };
class Base2 { public: size_t b; };
class Derived: public Base1, public Base2 { public: size_t d; };

using namespace std;

int main( void )

 d;
d.b << endl;
0;
```

```
>>  g++ -std=c++11 -Wall -Wextra main.cpp
main.cpp: In function 'int main()':
main.cpp:11:12: error: request for member 'b' is ambiguous
   11 |  cout << d.b << endl;
      |            ^
main.cpp:3:30: note: candidates are: 'size_t Base2::b'
    3 | class Base2 { public: size_t b; };
      |                              ^
main.cpp:2:30: note:                 'size_t Base1::b'
    2 | class Base1 { public: size_t b; };
      |                              ^
>>
```

Inheritance (multiple)

Note:

Watch out for ambiguity when accessing a base class's member!

This can be resolved by slicing to the appropriate base class.

main.cpp

```
#include <iostream>
class Base1 { public: size_t b; };
class Base2 { public: size_t b; };
class Derived: public Base1, public Base2 { public: size_t d; };

using namespace std;

int main( void )
{
	Derived d;
	cout << ( (Base1&)d ).b << endl;
	return 0;
}
```

Outline

- Exercise 31
- Inheritance
- Review questions
- Homework 7

Review questions

1. Do derived classes inherit constructors?

No

Review questions

2. What does `protected` imply for a class field?

Only member functions of the class and member functions of derived class have access to the field.

Review questions

3. What is polymorphism?

When a call to a member function will cause a different function to be executed depending on the type of object that invokes the function.

Review questions

4. What is the purpose of the `virtual` keyword?

To indicate that the behavior of a function can be overriden by a derived class.

Review questions

5. Can a derived class have multiple bases?

Yes

Outline

- Exercise 31
- Inheritance
- Review questions
- Homework 7

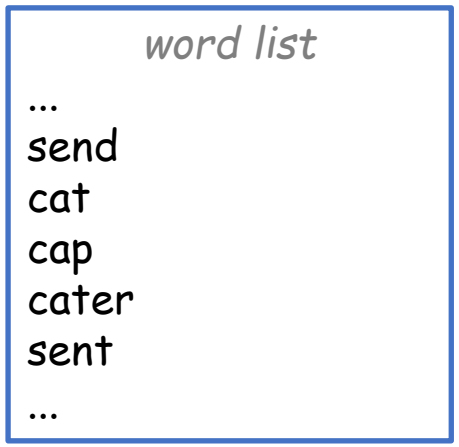
Homework 7

Data:

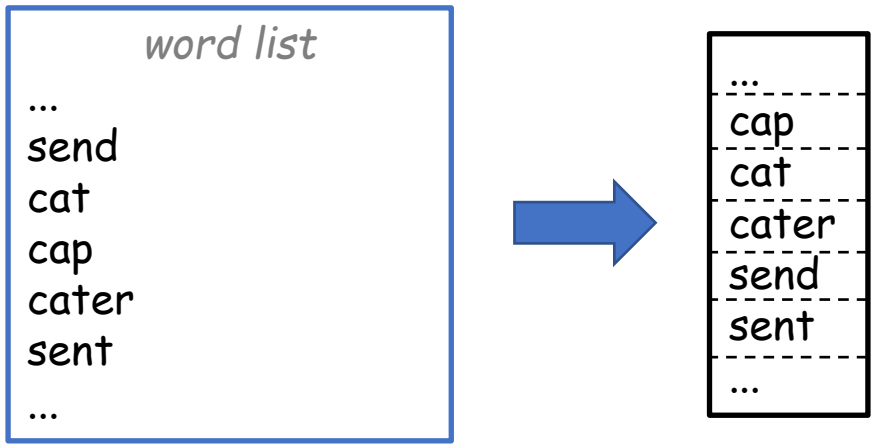
- A collection of words

Processing:

- Find if a word is in the list
- Add a word to the list



Homework 7



Data:

- A collection of words

Processing:

- Find if a word is in the list
- Add a word to the list

You can represent the data in a sorted array:

- ✓ You can quickly determine if a word is in the list
- ✗ It's inefficient to add a word to the list
- ✗ The number of characters stored (memory used) equals the sum of the number of characters in the words

Homework 7

<u>Data</u>:

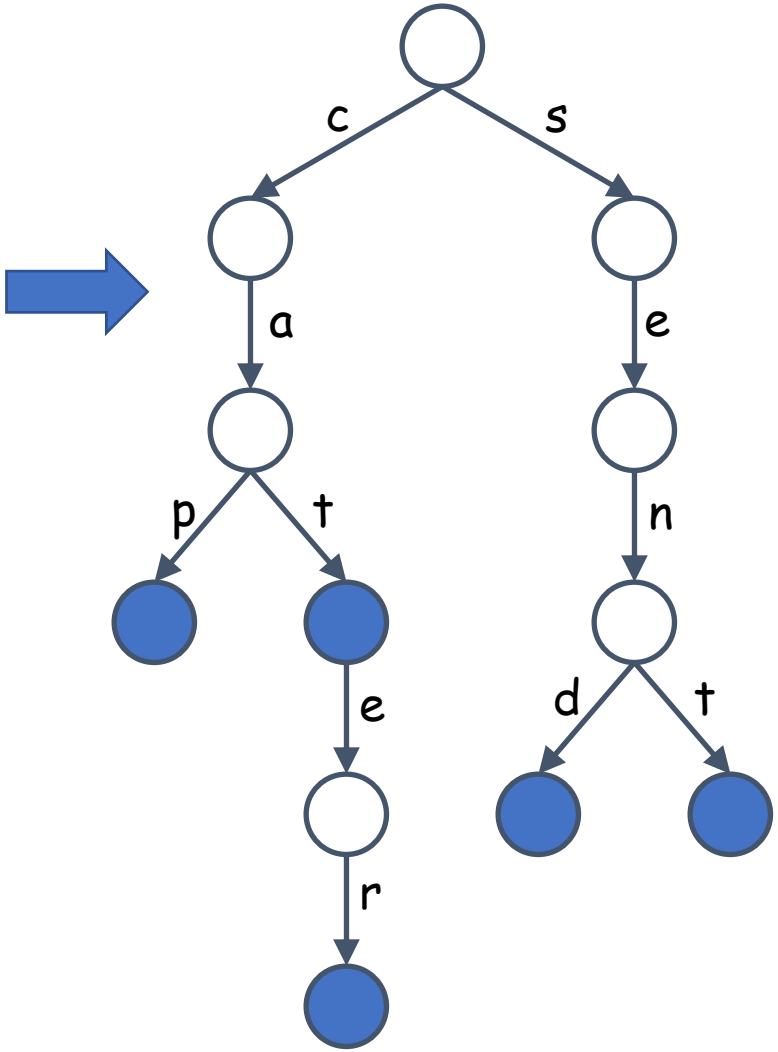
- A collection of words

<u>Processing</u>:

- Find if a word is in the list
- Add a word to the list

word list

…
send
cat
cap
cater
sent
…



A trie data-structure stores the words as a tree:

- Each node has multiple (possibly zero) child nodes
- Edges between nodes are marked with a single character
- Nodes are marked as terminal if the sequence from the root comprises a word

Homework 7 (**trie**)

word list

…
send
cat
cap
cater
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…

Construction:

Initialize with a root node.

For every word:

Thread the characters through the tree, constructing (in sorted order) and labeling new nodes/edges as needed

Homework 7 (**trie**)

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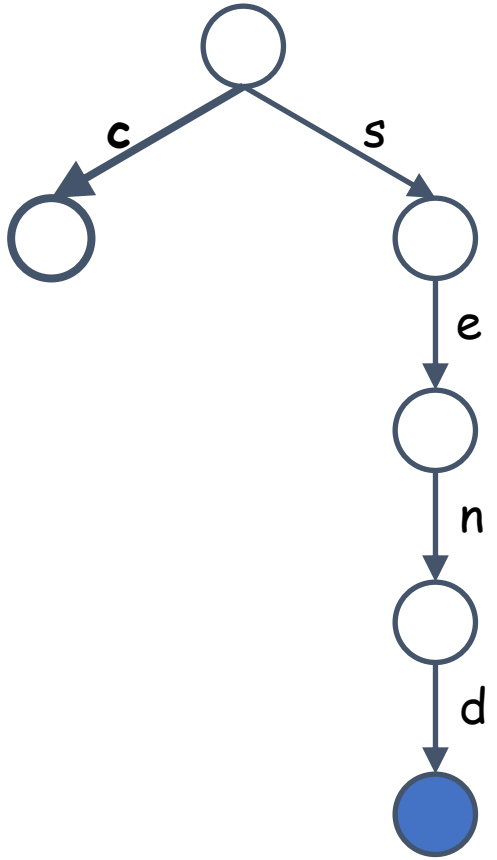

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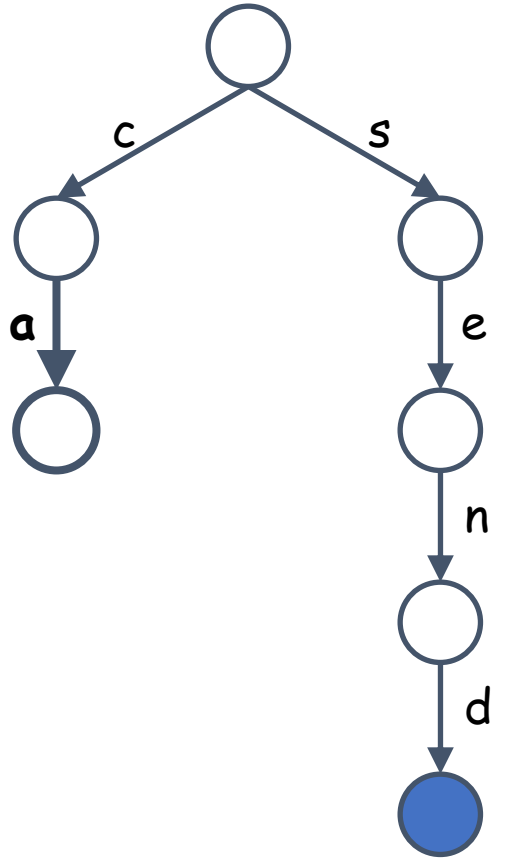

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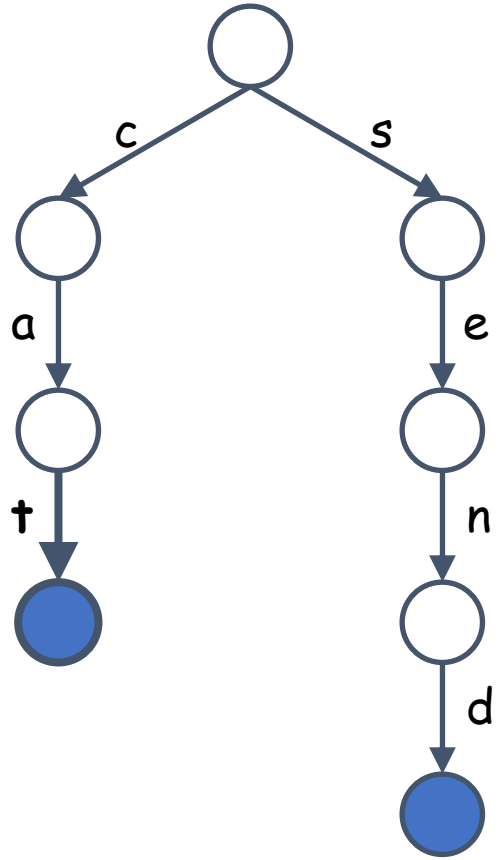

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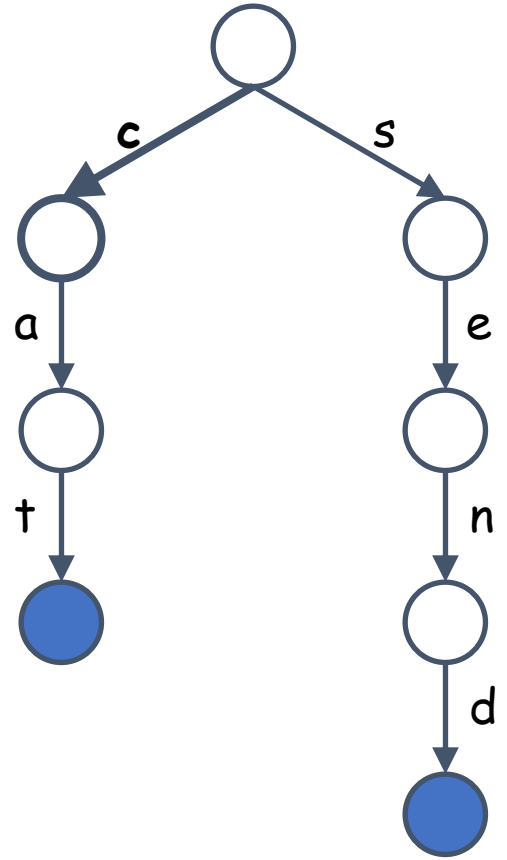

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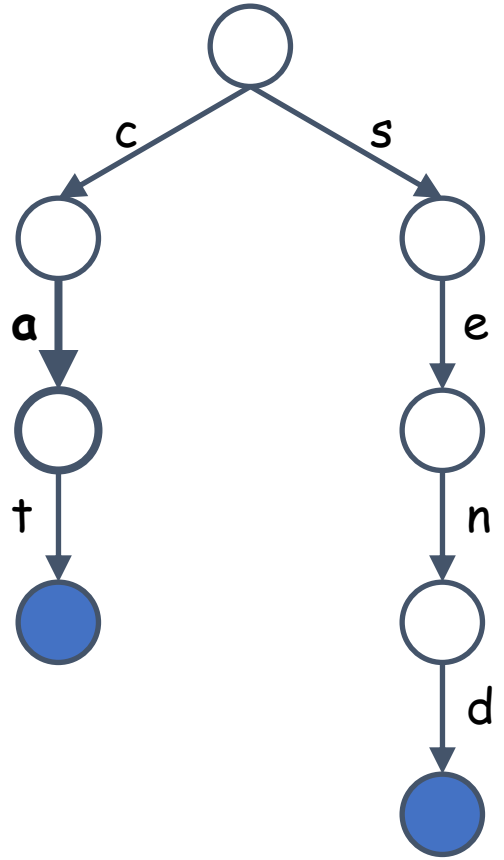

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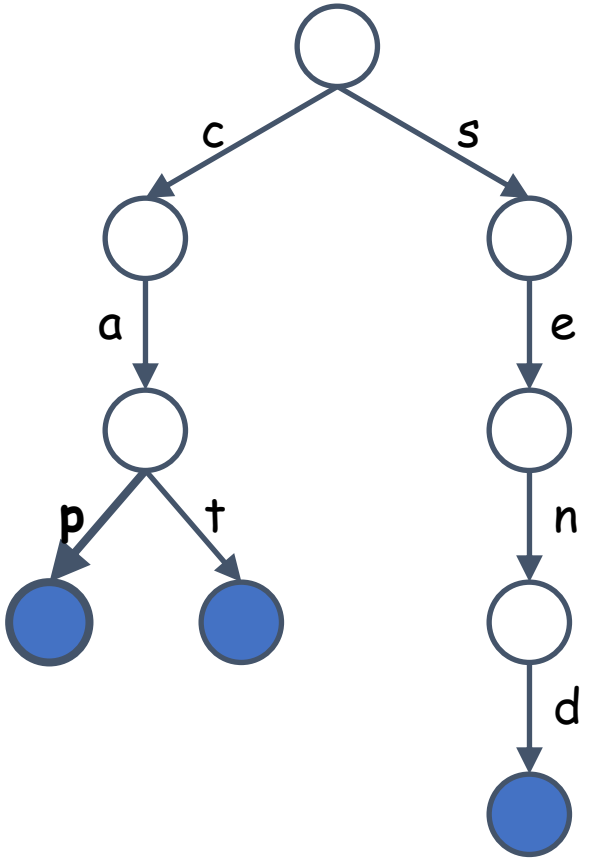

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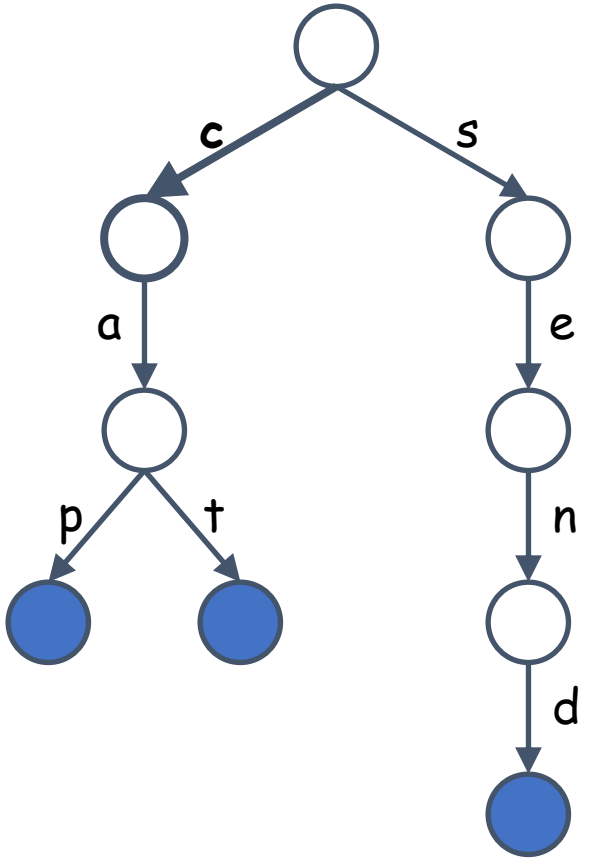

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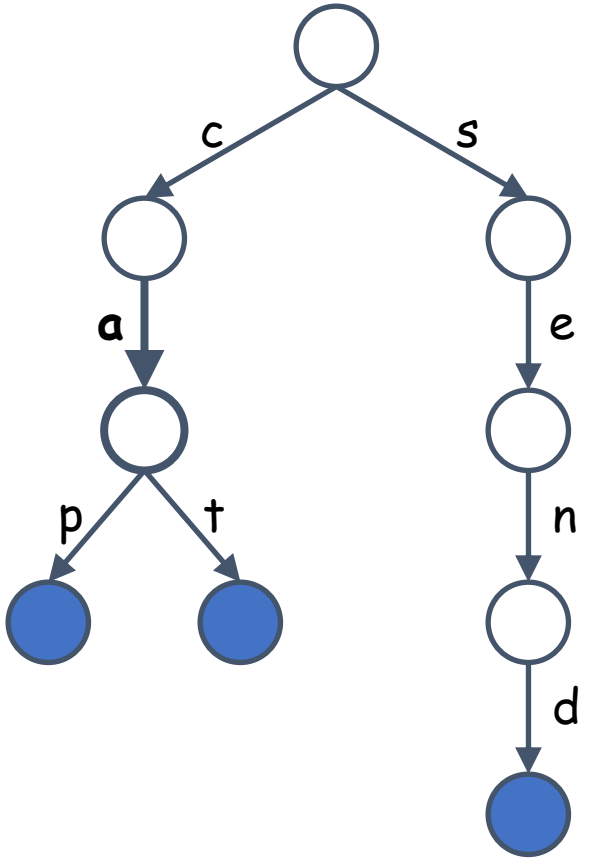

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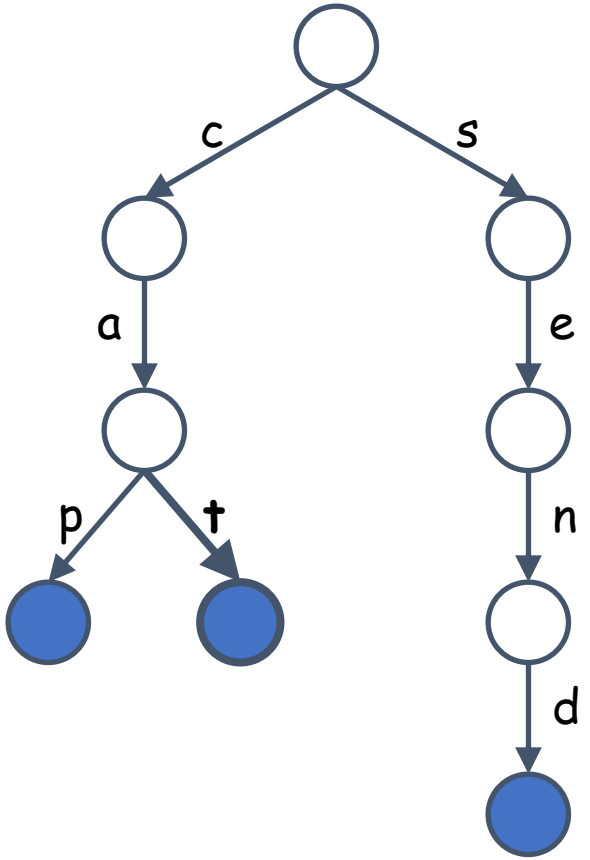

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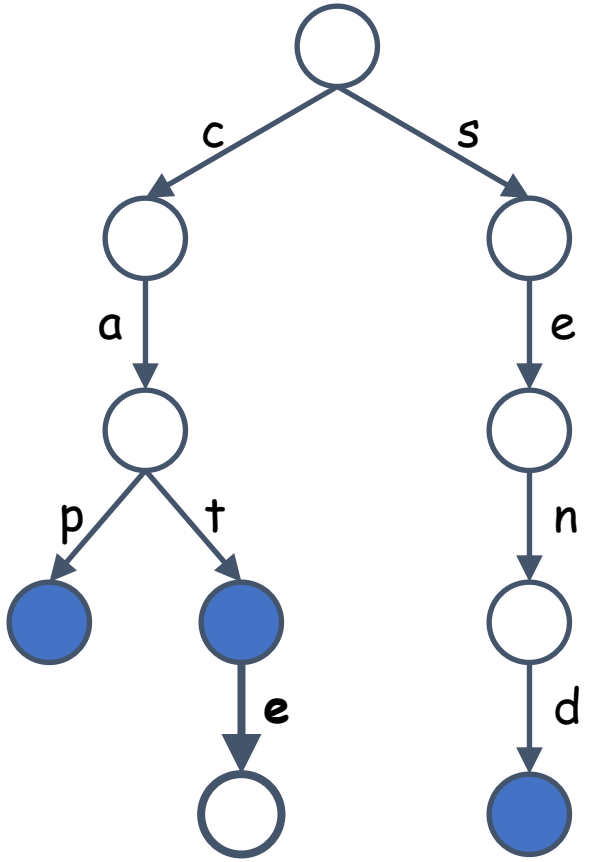

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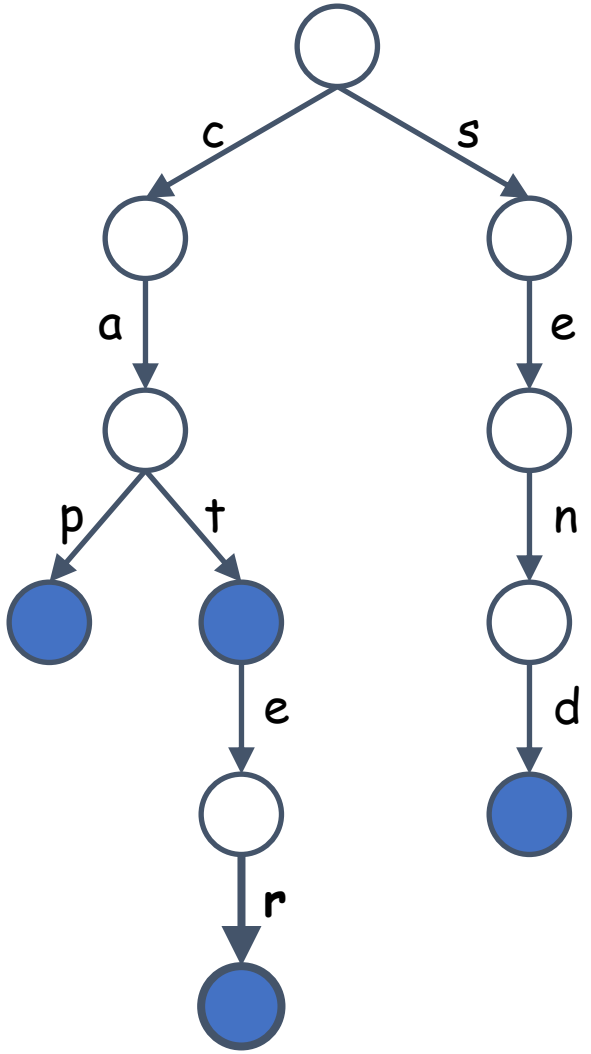

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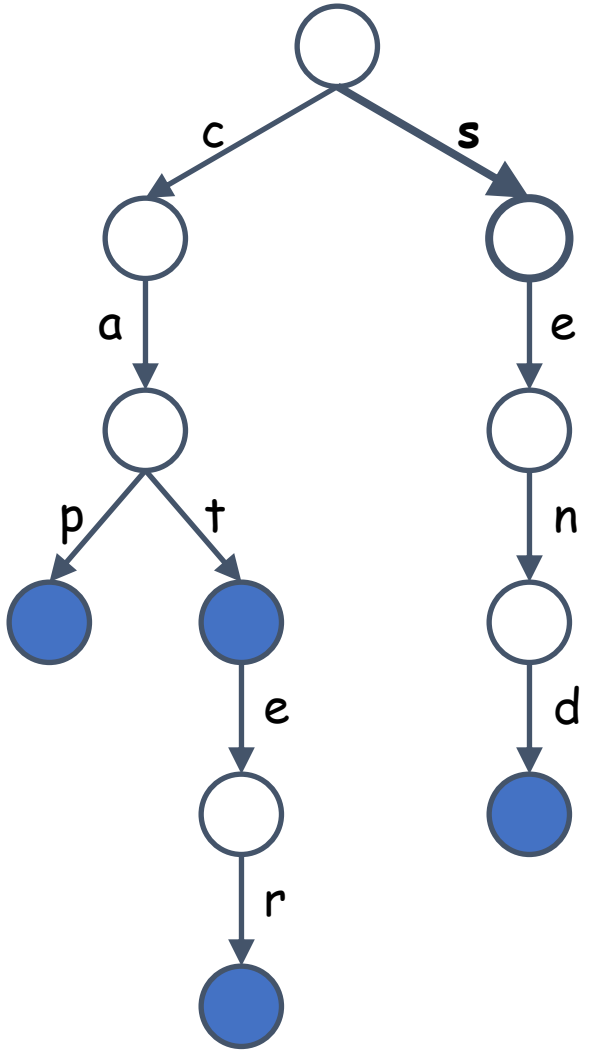

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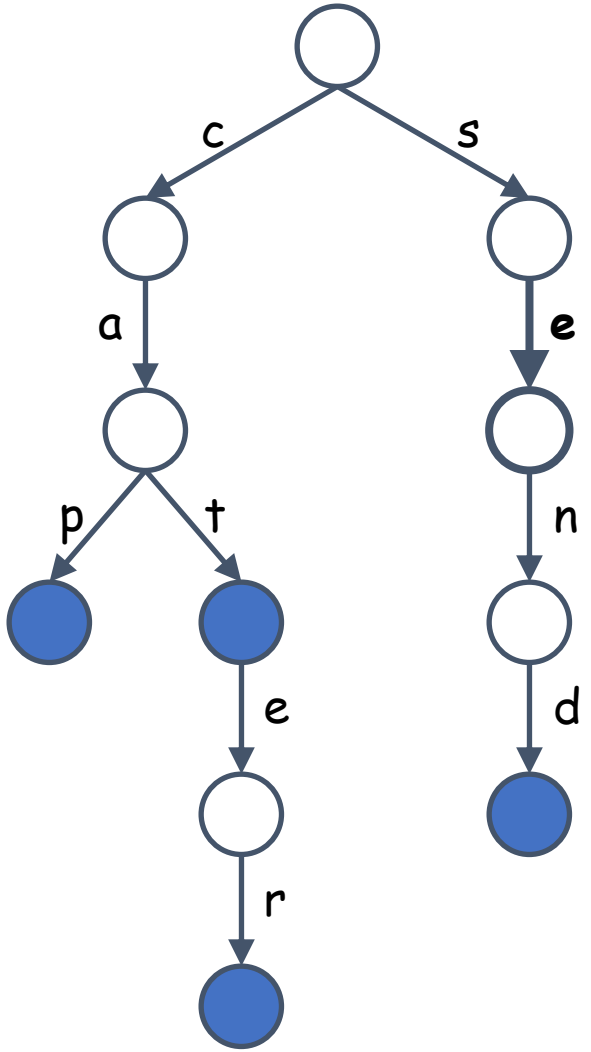

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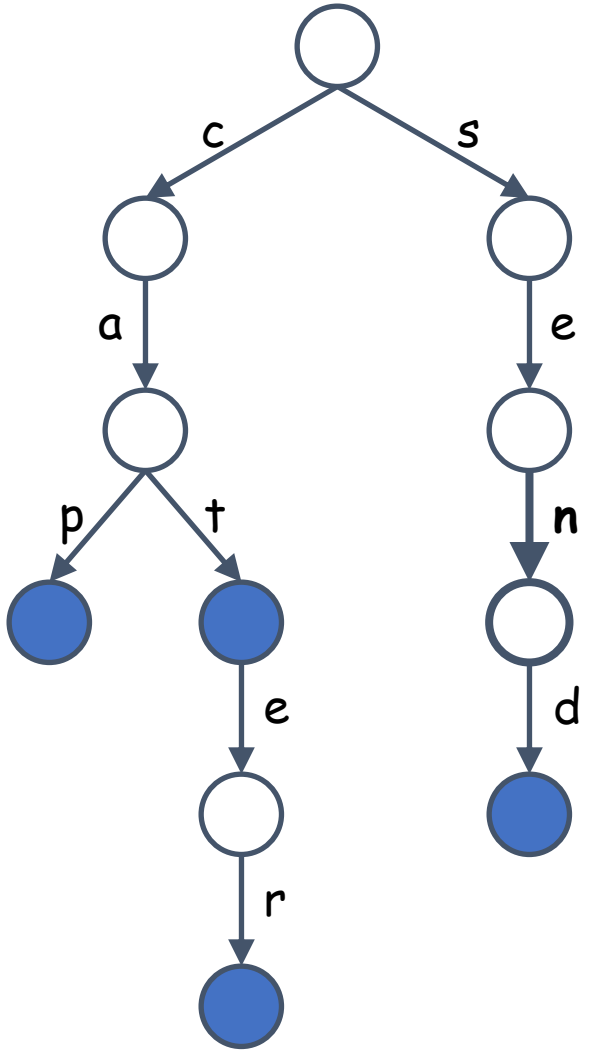

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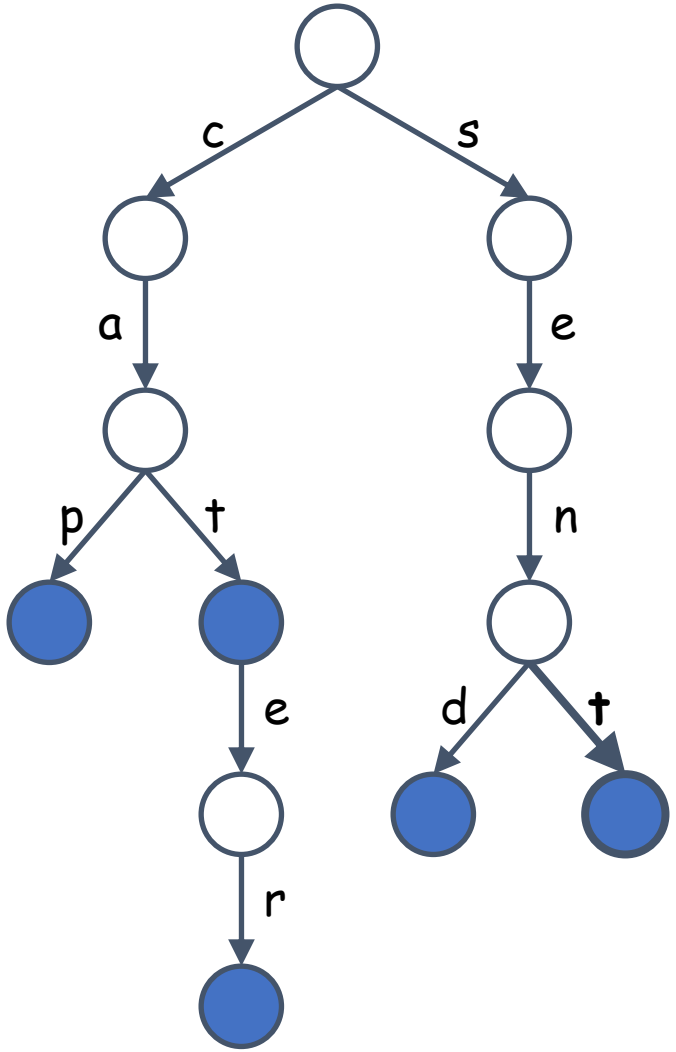

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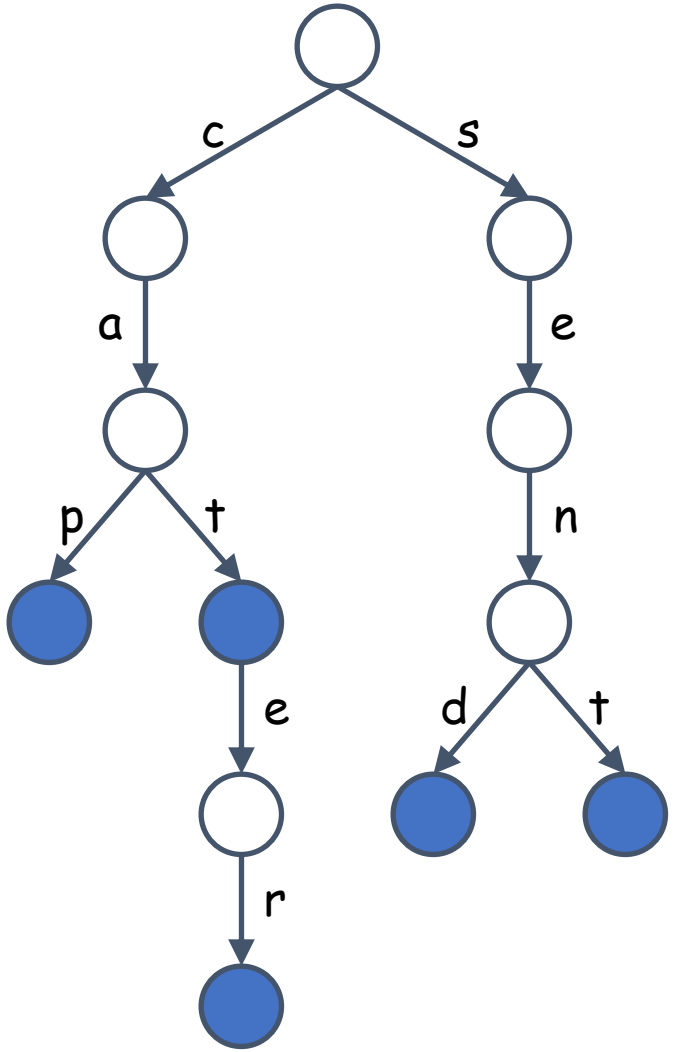

Properties:

- ✓You can quickly determine if a word is in the list
- ✓It's efficient to add a word to the list
- ✓The number of characters stored (memory used) is less than the number of characters in the words

Exercise 32

- Website -> Course Materials -> ex32