Hydroinformatik II: Gerinnehydraulik

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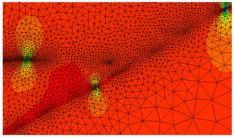
Dresden, 26. Juni 2015

Vorlesungsplan Hydroinformatik II SoSe 2015

#	Datum	Thema
01	17.04.2015	Einführung, Grundlagen: Kontinuumsmechanik
02	24.04.2015	Grundlagen: Kontinuumsmechanik/Hydromechanik
-	01.05.2015	Maifeiertag
03	08.05.2015	HW: Einführung in Qt (Installation)
04	15.05.2015	Grundlagen: Partielle Differentialgleichungen / TEX
05	22.05.2015	Grundlagen: Numerische Methoden
-	29.05.2015	Pfingsten
06	05.06.2016	Numerik: (exp) Finite Differenzen Methode
07	12.06.2015	Numerik: (imp) Finite Differenzen Methode
08	19.06.2015	Gerinnehydraulik: Theorie - Grundlagen
09	26.06.2015	Gerinnehydraulik: Programmierung, Übung 1
10	03.07.2015	Gerinnehydraulik: Programmierung, Übung 2
11	10.07.2015	Gerinnehydraulik: Programmierung, Übung 3
12	17.07.2015	Kurs-Zusammenfassung und Abschluss

Konzept

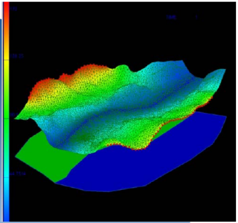
$$\frac{d\psi}{dt} = \frac{\partial\psi}{\partial t} + \mathbf{v}^E \nabla\psi$$



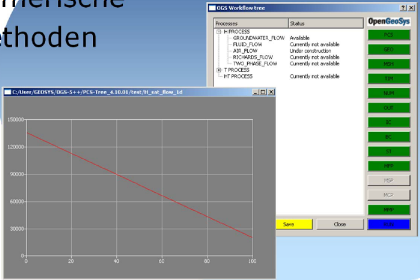
Basics

Mechanik

Anwendung



Numerische Methoden



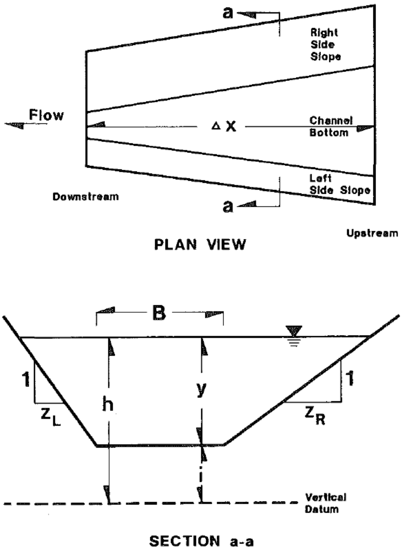
Programmierung Visual C++

Prozessverständnis

Hydroinformatik - Anwendungen

1. Abfallwirtschaft: Diffusionsprozesse
2. Hydrology: Gerinnehydraulik ($\rightarrow$ this)
3. Grundwasserwirtschaft: Grundwasserhydraulik ($\rightarrow$ next)

Energiebetrachtung #3: Bernoulli



Numerisches Verfahren #1

- Funktional: Energieerhaltung

$$f(h) = \left(h + \frac{Q^2}{2gA^2}\right)|_D - \left(h + \frac{Q^2}{2gA^2}\right)|_U + \Delta x \frac{(S_{f,U} + S_{f,D})}{2} \quad (1)$$

- Newton-Verfahren: $\mathbf{x} = h$

$$h_{k+1} = h_k + \frac{f(h_k)}{f'(h_k)} = \frac{\mathbf{R}_k}{\mathbf{J}_k} \quad (2)$$

- $f'(h) = f'(y)$

$$\frac{d}{dh}\left(h + \frac{v^2}{2g}\right) = \frac{d}{dh}\left(h + \frac{Q^2}{2gA^2}\right) = 1 - \frac{Q^2}{2gA^3}\frac{dA}{dh} \quad (3)$$

$$\frac{dA}{dh} = \frac{d}{dh}(z(B + C_4 y)) = B + C_4 y + y C_4 = B + 2C_4 y \quad (4)$$

Numerisches Verfahren #2

Bleibt noch die Differenzierung der Streckenverluste

$$\frac{dS_f}{dh} = S'_f = \frac{d}{dh}\left(\frac{Q}{AR^{2/3}}\right)^2 \tag{5}$$

$$\begin{aligned} S'_f \quad &= \quad \left[Q^2(By + C_4y^2)^{10/3}\frac{4}{3}(B + C_5y)^{1/3}C_5\right] \\ &+ \quad \left[(B + yC_5)^{4/3}\frac{-10Q^2}{3}(By + C_4y^2)^{13/3}(B + 2C_4y)\right] \end{aligned} \tag{6}$$

$$\begin{aligned} S'_f \quad &= \quad \frac{4}{3}Q^2C_5(By + C_4y^2)^{-10/3}(B + C_5y)^{1/3} \\ &- \quad \frac{10}{3}Q^2(B + 2C_4y)(B + C_5y)^{4/3}(By + C_4y^2)^{-13/3} \end{aligned} \tag{7}$$

3 ways of programming ...

- Q&D: Übung 1 (BHYWI-08-09-E1)
- OOP: Übung 2 (BHYWI-08-09-E2)
- GUI ("nicely"): Übung 3 (Qt)

Q&D #1

```
int main(int argc, char *argv[])
{
  // Geometrie
  // Anfangsbedingungen
  // Randbedingungen
  // Parameter
  // Berechnungsgrößen
  // Berechnung (1. Iteration des Newton-Verfahrens)
  // Ausgabe der Ergebnisse
    // File (Übung E10A)
    // x-y Plot (Übung E10B)
}
```

Exercises: E10_ChannelFlow_QAD(A,B)

Q&D #2

```
int main(int argc, char *argv[])
{...
  // Geometrie
  int n = 11;
  double x[n];
  for(int i=0;i<n;i++)
    x[i] = -100. + i*10.;
  double bottom_elevation[n];
  for(int i=0;i<n;i++)
    bottom_elevation[i] = 0.04 - i*0.004;
...}
```

Q&D #3

```
int main(int argc, char *argv[])
{...
  // Anfangsbedingungen
  double u_old[n];
  u_old[0]=0.244918436659073; //-100
  u_old[1]=0.243;             //-90
  u_old[2]=0.242293545352681; //-80
  u_old[3]=0.241;             //-70
  u_old[4]=0.240216955447788; //-60
  u_old[5]=0.235;             //-50
  u_old[6]=0.225684124843115; //-40
  u_old[7]=0.223;             //-30
  u_old[8]=0.220898136369048; //-20
  u_old[9]=0.201434531839821; //-10
  u_old[10]=0.1;              //0
...}
```

Warum so genau?

Q&D #4

```
int main(int argc, char *argv[])
{...
  // Randbedingungen
  u_old[10] = 0.1; // Wasserstand flußabwärts [m]
  double u_new[n];
  u_new[10] = 0.1; // Wasserstand flußabwärts [m]
...}
```

Tafelbild

Q&D #5

```
int main(int argc, char *argv[])
{...
  // Parameter
  double discharge = 0.05; // Volumenfließrate [m3/s]
  double gravity = 9.81; // [m/s2]
  double friction_law_exponent = 0.5; // Chezy, Manning-Str
  double error_tolerance = 1e-3; // [m]
  double bed_slope = 0.0004; // [m/m]
  double bottom_width = 1.; // [m]
  double m = 1.; //
  double friction_coefficient = 10.; //
...}
```

Tabelle

Q&D #6 Berechnungsgrössen

```
int main(int argc, char *argv[])
{...
  // Berechnungsgrößen
  double wetted_cross_section[n];
  double water_level_elevation[n];
  double flow_velocity[n];
  double Froude_number[n];
  double wetted_perimeter[n];
  double hydraulic_radius[n];
  double friction_slope[n];
...}
```

Q&D #7 Berechnung Parameter

```
int main(int argc, char *argv[])
{...
  for(int i=0;i<n;i++)
  {
    wetted_perimeter[i] = bottom_width + 2.*sqrt(1.+m*m)*u_old[i];
    wetted_cross_section[i] = (bottom_width + m*u_old[i])*u_old[i];
    hydraulic_radius[i] = wetted_cross_section[i] / wetted_perimeter[i]
    water_level_elevation[i] = bottom_elevation[i] + u_old[i];
    flow_velocity[i] = discharge/wetted_cross_section[i];
    Froude_number[i] = flow_velocity[i]/(sqrt(gravity*wetted_cross_sect
                       /sqrt(bottom_width*bottom_width+4.*m*wetted_cros
    friction_slope[i] = pow(flow_velocity[i]/(friction_coefficient*
                        pow(hydraulic_radius[i],friction_law_exponent))
  }
...}
```

Q&D #8 Berechnung

```
int main(int argc, char *argv[])
{...
  double N,N1,N2,N3,D,D1,D2,D21,D22;
  for(int i=0;i<n-1;i++)
  {
    N1 = pow(discharge,2)/pow(wetted_cross_section[i+1],2) + gravity*u_
    N2 = pow(discharge,2)/pow(wetted_cross_section[i],2) + gravity*u_ol
    N3 = gravity*(bed_slope - (friction_slope[i+1]+friction_slope[i])/2
    N = N1 - N2 - N3;
    D1 = pow(discharge,2)/pow(wetted_cross_section[i],3) * (bottom_widt
    D21 = friction_law_exponent*2.*(sqrt(1+m*m))/wetted_perimeter[i];
    D22 = (1.+friction_law_exponent)/wetted_cross_section[i] * (bottom_
    D2 = gravity*friction_slope[i]*(D21-D22)*(x[i+1]-x[i]);
    D = D1 + D2;
    u_new[i] = u_old[i] - N/D;
  }
...}
```

Q&D #9 Ausgabe File

```
int main(int argc, char *argv[])
{...
  ofstream out_file("out.txt");
  out_file.precision(4);
  out_file << "Water depth (old):\t";
  for(int i=0;i<n;i++)
  {
    out_file << "\t" << u_old[i] << " ";
  }
  out_file << endl;
...
  out_file << "Water depth (new):\t";
  for(int i=0;i<n;i++)
  {
    out_file << "\t" << u_new[i] << " ";
  }
  out_file << endl;
  out_file.close();
...}
```

Q&D #9 Ausgabe File

out.txt - Editor

Datei Bearbeiten Format Ansicht ?

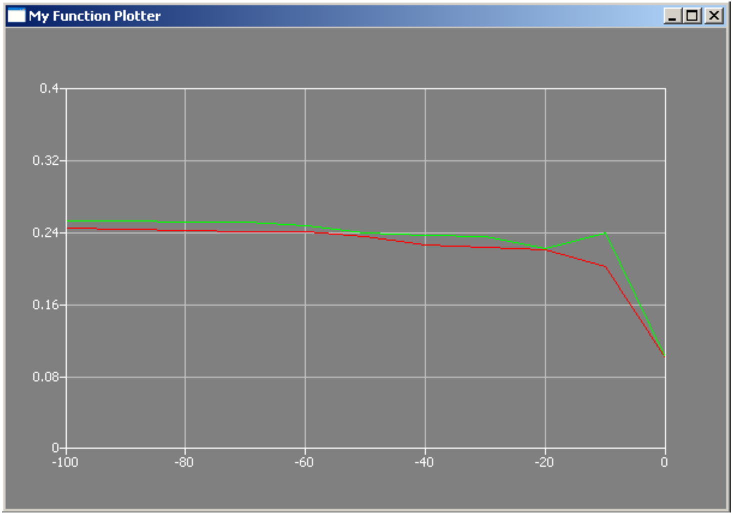
0.25
0.1
Iteration: 0

Water depth (old):		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.1
Wetted perimeter:		1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.28
Wetted cross section:	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.11	
Hydraulic radius:		0.183	0.183	0.183	0.183	0.183	0.183	0.183	0.183	0.183	0.183	0.0857
Water level elevation:	0.29	0.286	0.282	0.278	0.274	0.27	0.266	0.262	0.258	0.254	0.1	
Flow velocity:	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.455	
Froude number:	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.479	
Friction slope:	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0241	
Water depth (new):		0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.242	0.1
Iteration: 1												
Water depth (old):		0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.242	0.1
Wetted perimeter:		1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.69	1.28
Wetted cross section:	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.301	0.11	
Hydraulic radius:		0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.179	0.0857
Water level elevation:	0.299	0.295	0.291	0.287	0.283	0.279	0.275	0.271	0.267	0.246	0.1	
Flow velocity:	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.166	0.455	
Froude number:	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.118	0.479	
Friction slope:	0.00125		0.00125		0.00125		0.00125		0.00125		0.00125	
Water depth (new):		0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.253	0.242	0.1
Iteration: 2												
Water depth (old):		0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.253	0.242	0.1
Wetted perimeter:		1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.72	1.69	1.28
Wetted cross section:	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.317	0.301	0.11	
Hydraulic radius:		0.193	0.193	0.193	0.193	0.193	0.193	0.193	0.193	0.185	0.179	0.0857
Water level elevation:	0.307	0.303	0.299	0.295	0.291	0.287	0.283	0.279	0.261	0.246	0.1	
Flow velocity:	0.148	0.148	0.148	0.148	0.148	0.148	0.148	0.148	0.158	0.166	0.455	
Froude number:	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.118	0.479	
Friction slope:	0.00113		0.00113		0.00113		0.00113		0.00113		0.00113	
Water depth (new):		0.274	0.274	0.274	0.274	0.274	0.274	0.274	0.262	0.253	0.242	0.1
Iteration: 3												
Water depth (old):		0.274	0.274	0.274	0.274	0.274	0.274	0.274	0.262	0.253	0.242	0.1
Wetted perimeter:		1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.74	1.72	1.69	1.28
Wetted cross section:	0.349	0.349	0.349	0.349	0.349	0.349	0.349	0.331	0.317	0.301	0.11	
Hydraulic radius:		0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.19	0.185	0.179	0.0857
Water level elevation:	0.314	0.31	0.306	0.302	0.298	0.294	0.29	0.274	0.261	0.246	0.1	
Flow velocity:	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.151	0.158	0.166	0.455	
Froude number:	0.0962	0.0962	0.0962	0.0962	0.0962	0.0962	0.0962	0.104	0.11	0.118	0.479	
Friction slope:	0.00104		0.00104		0.00104		0.00104		0.00104		0.00104	
Water depth (new):		0.28	0.28	0.28	0.28	0.28	0.28	0.27	0.262	0.253	0.242	0.1

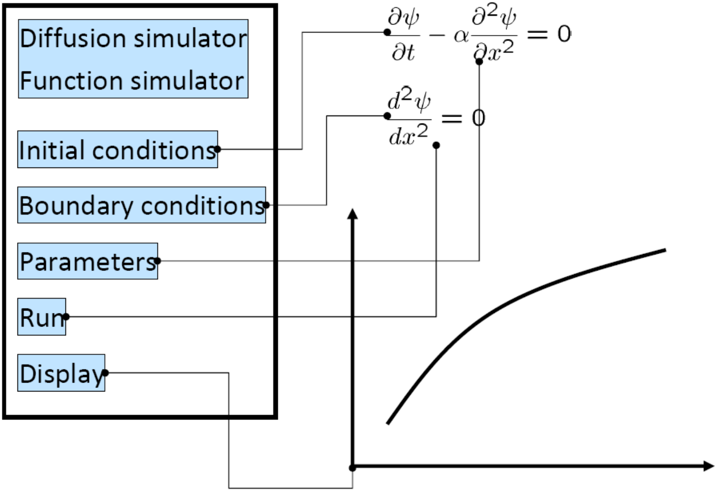
Q&D #10 Ausgabe Grafik

```
int main(int argc, char *argv[])
{...
  Plotter plotter;
  plotter.setWindowTitle(QObject::tr("My Function Plotter"));
  QVector<QPointF> points0;
  QVector<QPointF> points1;
  double l;
  for (int i=0;i<n;++i)
  {
    l = -100. + 10.*i;
    points0.append(QPointF(l,u_old[i]));
    points1.append(QPointF(l,u_new[i]));
  }
  plotter.setCurveData(0, points0);
  plotter.setCurveData(1, points1);
  PlotSettings settings;
  settings.minX = -100.0;
  settings.maxX = 0.0;
  settings.minY = 0.0;
  settings.maxY = 0.4;
```

Q&D #11 Ausgabe Grafik



OOP #1


Diffusion simulator
Function simulator
Initial conditions
Boundary conditions
Parameters
Run
Display
$\frac{\partial \psi}{\partial t} - \alpha \frac{\partial^2 \psi}{\partial x^2} = 0$
$\frac{d^2 \psi}{d x^2} = 0$

OOP #2

```
int main(int argc, char *argv[])
{
  // Geometrie
  // Anfangsbedingungen
  // Randbedingungen
  // Parameter
  // Berechnungsgrößen
  // Berechnung (1. Iteration des Newton-Verfahrens)
  // Ausgabe der Ergebnisse
    // File (Übung E10A)
    // x-y Plot (Übung E10B)
}
```

OOP #3

```
Dialog::~Dialog()
void Dialog::on_pushButtonIC_clicked()
void Dialog::on_pushButtonBC_clicked()
void Dialog::on_pushButtonMAT_clicked()
void Dialog::on_pushButtonRUN_clicked()
void Dialog::on_pushButtonSHO_clicked()
```

OOP #4

```
void Dialog::on_pushButtonIC_clicked()
{
  // 2 Anfangsbedingungen
  u_old[0]=0.244918436659073; //-100
  u_old[1]=0.243;             //-90
...
  u_old[9]=0.201434531839821; //-10
  u_old[10]=0.1;              //0
  pushButtonIC->setStyleSheet("background-color: green");
  pushButtonBC->setEnabled(true);
  out_file << lineEditIC->text().toStdString() << endl;
  double IC = lineEditIC->text().toDouble();
  for(int i=0;i<n-1;i++)
  {
      u_old[i] = IC;
  }
}
```

OOP #4

```
void Dialog::on_pushButtonBC_clicked()
{
  // 3 Randbedingungen
  double BCR = 0.05;
  BCR = lineEditBCR->text().toDouble();
  out_file << BCR << endl;
  u_old[10] = BCR; // Wasserstand flußabwärts [m]
  u_new[10] = BCR; // Wasserstand flußabwärts [m]
  pushButtonBC->setStyleSheet("background-color: green");
  pushButtonMAT->setEnabled(true);
}
```

OOP #5 MAT

```
void Dialog::on_pushButtonMAT_clicked()
{
  // Parameter
  discharge = 0.05; // Volumenfließrate [m3/s]
  gravity = 9.81; // [m/s2]
  friction_law_exponent = 0.5; // Chezy, Manning-Strickler
  error_tolerance = 1e-3; // [m]
  bed_slope = 0.0004; // [m/m]
  bottom_width = 1.; // [m]
  m = 1.; //
  friction_coefficient = 10.; //
  pushButtonMAT->setStyleSheet("background-color: green");
  pushButtonRUN->setEnabled(true);
}
```

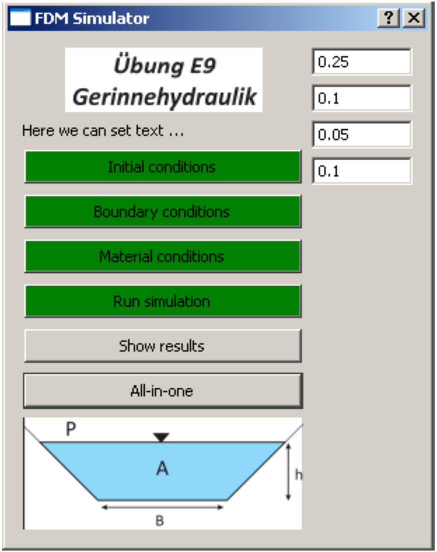
OOP #6 RUN

```
// Newton iteration loop
  for(int k=0;k<kn;k++)
  {...
    RunNewtonStep();
  ...}
```

OOP #7 AIO

```
void Dialog::on_pushButtonALL_clicked()
{
  on_pushButtonIC_clicked();
  on_pushButtonBC_clicked();
  on_pushButtonMAT_clicked();
  on_pushButtonRUN_clicked();
}
```

GUI #1


FDM Simulator
Übung E9
Gerinnehydraulik
Here we can set text ...
0.25
0.1
0.05
0.1
Initial conditions
Boundary conditions
Material conditions
Run simulation
Show results
All-in-one
P
A
h
B

GUI #2

```
int main(int argc, char *argv[])
{
  QApplication a(argc, argv);
  //...........................................................
  Dialog w;
  //splash.finish(&w); //test
  w.setWindowTitle("FDM Simulator");
  w.setFixedWidth(300);
  w.show();
  return a.exec();
}
```

GUI #3

```
int main(int argc, char *argv[])
{
  //...........................................................
  QPixmap pixmap ("../E9.jpg");
  QSplashScreen splash(pixmap);
  splash.show();
  splash.showMessage(QObject::tr("Übung E9 wird geladen..."), Qt::black
  QTime dieTime = QTime::currentTime().addSecs(3); while( QTime::curren
                  QCoreApplication::processEvents(QEventLoop::AllEvents
                  // Warte-Funktion (http://lists.trolltech.com/qt-inte
}
```

GUI #4